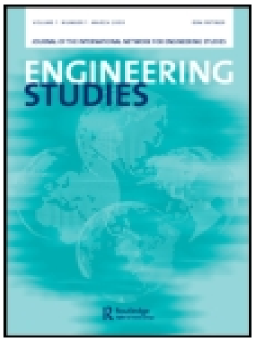

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Engineering Risk and Disaster: Disaster-STS and the American History of Technology

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For a long time the historiographies of engineering and technology focused on technological intensification and progress across society, the economy, and government. Little specific attention was reserved in these narratives for risk, disaster, failure, and blame. However, more recently a vibrant, interdisciplinary synthesis of science and technology-focused disaster research has emerged in the form of a definable Disaster-STS, a subfield with close connections to engineering studies. This revisionist project inserts the contingencies of risk and the prevalence of disaster into the more traditional episodes of modern American technology history, such as urban industrialization and systems development, the rise of technical professions, postwar nuclear and other high-risk systems, and the history of postwar metropolitan growth. By expanding our view to include risk and disaster we explain the emergence of key engineering tools such as risk and cost–benefit analysis – and we chart the rise and elaboration of previously obscured technical artifacts like standards, codes, and techniques of risk management fostered by engineers working in risky environments. We come to a fuller understanding of failure as a “designed in” aspect of systems building. We note the push and pull of societal expectations of technological safety. Disasters have also created unique spaces of technical inquiry – post-disaster studies, investigations, and hearings–which have also strongly influenced codes of ethics, liability calculations, engineering education, and professionalization more generally.

Keywords: American; Disaster; Engineering; Risk; Technology

Engineering Studies and Disaster: “We Will Recover and This Will Happen Again”

In the months following Hurricane Katrina, with much of New Orleans a ruin, Washington was abuzz with investigative hearings. There were political scalps to collect, first and foremost that of Federal Emergency Management Agency (FEMA) chief Michael Brown, whose preening and pouting as the disaster unfolded were almost as universally derided as President Bush’s assessment of “Brownie” as doing a “heck of a job.” And with the failure of the nation’s largest flood protection system replaying over and over on cable television engineers were anxiously busy as well. A major post-disaster investigation conducted by the American Society of Civil Engineers (ASCE) ultimately concluded that a

> large portion of the destruction from Hurricane Katrina was caused not only by the storm itself . . . but also by the storm’s exposure of engineering and engineering-related policy failures . . . a combination of unfortunate choices and decisions, made over many years, at almost all levels of responsibility.[1]

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[1]American Society of Civil Engineers Hurricane Katrina External Review Panel, *The New Orleans Hurricane Protection System*, 2007, p. v.

The U.S. Army Corps of Engineers – the federal agency ultimately responsible for the design, construction, and maintenance of the lower Mississippi flood control system – concluded in its own investigation that the

> system in place before Katrina was compromised by a long series of decisions driven by competing priorities, incremental decision making and funding, inadequate consideration of change and de-facto standards far too low to deal with the realities of modern natural hazards.[2]

In the midst of these investigations a dark absurdity was revealed. Despite repeated claims by government officials that Katrina's unique variables created an unthinkable (therefore unplanned) disaster, FEMA *itself* had in fact crafted a hypothetical hurricane scenario for New Orleans, *only just the year before*. The Hurricane Pam exercise, as it was known, placed in front of Congress and the nation all of the evidence necessary to see that Katrina's horrors were anything but unexpected. Pam had not been imagined as the "worst case," but as an entirely plausible (and easily predicted) real case, a slow-moving category three storm causing the failure of levee and "dewatering" systems and necessitating a mass evacuation. The similarities between the fictional and the real storm were eerie. In Pam the disaster experts imagined New Orleans under 10–20 feet of water (20 feet were recorded), 55,000 people in shelters (the actual number reached 60,000), 1.1 million residents displaced (1 million displaced, 100,000 yet to return), and 234,000 buildings destroyed (250,000 homes destroyed).[3] Practically the only detail in which Hurricane Pam was not brought to life in Hurricane Katrina was the death toll, projected in Pam at a horrific 61,000 – no comfort for the families of the 1,833 killed in the disaster.

In a dramatic 2006 hearing, Senators drove questions toward the broken link from Pam's lessons to poor preparations for Katrina. In his turn before the committee Plaquemines Parish emergency management director Jesse St. Amant offered a broader context for Pam, for Katrina, and for American disasters more generally.

> One of the documents I wanted to show you today was this one, dated 1994. It gives you the exact scenario of the worst case . . . that could happen. It was never a case of if, it was a case of when. . . . I hear this diatribe about 50-foot levees or what they call Category 5 levees that are being planned or being cried for . . . My experience in emergency management tells me this. You build a 20-foot levee, Mother Nature will give you a 25-foot storm surge. . . . we can blame everything and his brother for what has happened, but the fact of the matter is, due to the soil subsidence, due to the loss of our wetlands, we knew in this business that this was coming. We tried to say the words, this is coming, time and again. We will recover and this will happen again.[4]

Even before Jesse St. Amant offered his testimony his vision was proving true. A $51.8 billion relief package for Gulf Coast economic recovery was passed quickly after Katrina. Reconstruction began before the "engineering policy failures" and the "realities of modern natural hazards" could be assessed – before even all of the victims had been identified. The Corps of Engineers set to work at once, repairing the New Orleans protective levee and "dewatering" system, facing the ever-present 1 June opening of hurricane season, and ultimately spending $14.5 billion on the nation's most elaborate urban flood control system.

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[2]US Army Corps of Engineers, *Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System*, 2009, p. 18.
[3]Beriwal, *Preparing for a Catastrophe*, 2006, p. 67.
[4]Beriwal, *Preparing for a Catastrophe*, 2006, pp. 14–15.

Today "fortress New Orleans" displays the cutting-edge of technique in the ongoing battle against land subsidence, wetlands depletion, and life-below-sea-level defiance.[5]

"We will recover and this will happen again," is an almost poetically concise description of the process creating modern American disasters. Sociologist Ulrich Beck termed this process "reflexive modernization" in his landmark study, *Risk Society* (1986), but the meaning is the same: we have entered a time when industrialized nations are spending as much time and effort managing risks and disasters as they used to spend managing the creation of cities and factories. For Beck the relationship is causal, risks today "are risks *of modernization*. They are a *wholesale product* of industrialization, and are systematically intensified as it becomes global." In risk society the production of wealth in industrial society entails the production of risk – there is no escape from disaster, there is only debate over how best to allocate risk, how to determine the winners and losers, and how (or if) to relieve the suffering.[6]

Risk calculations are rooted in supposedly objective and neutral science and engineering practices, but Beck and STS scholarship more generally shows us consistently that the technical "objectivity" of risk science is firmly embedded in a political world. And almost thirty years on since Beck proposed the risk society concept we have even more evidence – climate change and sea-level rise, nuclear accidents, industrial accidents, and increasing losses from natural disasters – that the construction of technological society invariably entails destruction, sometimes abruptly but often chronically, slowly, over time in the aggregate impacts of land development and pollution. In short, anyone surprised by the impacts of Hurricane Katrina or Deepwater Horizon at this point has simply not been paying attention to the investments Americans have made to risky technological systems over the past 150 years.

"We will recover," because disaster recovery and reconstruction in hazardous terrains is today an expected function of the state, of emergency management, and of the professions connected to the technology-development complex. Recovery opens the door to a limited critique of risk-taking – usually in the form of blue ribbon technical investigations – but such critique has historically been drowned out by the sound of bulldozers and hammers in the service of reconstruction. "It will happen again," because the USA has since the Civil War aggressively developed entrenched patterns of land use in hazardous terrains, high-risk technological systems, and a technical knowledge production apparatus focused on supporting and maintaining the economic achievements that technologically intense risk-taking provides.

If Ulrich Beck's is an accurate vision for modern America – and there is an emerging synthesis in "Disaster Science, Technology, and Society" studies (Disaster-STS) to show that it is – then Jesse St. Amant was describing in his Senate testimony merely one more instance in perhaps the signal historical process defining the modern USA. This essay serves as an attempt to chart modern American disasters, but more specifically to serve as a historiographical primer for an increasingly coherent body of American-disaster-centric work in STS and the history of technology.

American risk society is the culmination of the long evolution of knowledge in technical realms giving rise to the full range of engineering specializations. Disaster experts know more than ever before about the science of hazardous environments, human behavior in disaster, and the techniques of safer development. But this knowledge has not rendered significant disaster reductions, just the opposite. Americans make recurrent pledges to learn

[5]Schleifstein, *Upgraded Metro New Orleans Levees Will Greatly Reduce Flooding*, 2013.
[6]Beck, *Risk Society*, 1986, p. 21. See also Beck, Giddens, and Lash, *Reflexive Modernization*, 1994.

from disasters – but what would such learning entail, what would be the results? More regulation, stronger levees, retrofitted buildings? Would we be willing to unbuild the coastlines and pour hundreds of billions into infrastructure? Postwar American history points to these as unlikely outcomes. The fact is that disasters are today common, and are more expensive than they were a century ago. Risk-taking (sometimes calculated, sometimes not) is central to land development, manufacturing, urbanization, and large-scale systems. The fact is that Hurricane Katrina revealed a continuation of, not a break, with American history.[7]

Through all of this we see the rise of the American engineering professions, with all of the specialization and sub-specialization charted by historians of engineering and technology. For a long time the historiographies of engineering and technology focused on technological intensification and progress across society, the economy, and government. Little specific attention was reserved in these narratives for risk, disaster, failure, and blame. However, more recently a vibrant, interdisciplinary synthesis of science and technology-focused disaster research has emerged in the form of a definable Disaster-STS, a subfield with close connections to engineering studies. This revisionist project inserts the contingencies of risk and the prevalence of disaster into the more traditional episodes of modern American technology history, such as urban industrialization and systems development, the rise of technical professions, postwar nuclear and other high-risk systems, and the history of postwar metropolitan growth. Risk has been a constant, disaster a humbling force – but never a force that has for long moved engineers away from their chosen areas of work.

By expanding our view to include risk and disaster we explain the emergence of key engineering tools such as risk and cost–benefit analysis – and we chart the rise and elaboration of previously obscured technical artifacts like standards, codes, and techniques of risk management fostered by engineers working in risky environments. We come to a fuller understanding of failure as a "designed in" aspect of systems building. We note the push and pull of societal expectations of technological safety. Disasters have also created unique spaces of technical inquiry – post-disaster studies, investigations, and hearings – which have also strongly influenced codes of ethics, liability calculations, engineering education, and professionalization more generally.

Cities and Disaster

Lewis Mumford conceptualized a sort of golden mean for cities, as a planner who also wrote history he applied his judgments on the degree to which the city was in balance (the early Medieval European city) or out of balance. To Mumford the English industrial city of the eighteenth century ("Coketown") was a preview of the excesses in urban misery later visited on American cities such as Chicago. "It was a period of vast urban improvisation: makeshift hastily piled upon makeshift," according to Mumford. It was even worse than that, as Mumford saw it: "Every man was for himself; and the Devil, if he did not take the hindmost, at least reserved for himself the privilege of building the cities."[8] In other words, the industrial city was hell on earth. Upton Sinclair described it through the eyes of immigrants arriving in Chicago for the first time by train:

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[7]For an outline of Disaster-STS, including its key analytical questions and goals, see Fortun and Frickel, "Making a Case for Disaster Science and Technology Studies," 2012.

[8]Mumford, *City in History*, 1961, pp. 447–449.

> A full hour before the party reached the city they had begun to note the perplexing changes in the atmosphere. It grew darker all the time, and upon the earth the grass seemed to grow less green. Every minute, as the train sped on, the colors of things became dingier; the fields were grown parched and yellow, the landscape hideous and bare.[9]

It was a time of nature transformed, and it has given rise to some of the most critical works in American urban, environmental, and technology history. It is also the first period in American history treated in depth by disaster historians. William Cronon's *Nature's Metropolis: Chicago and the Great West* (1992) describes the "productive" side of the story, laying out the transformation of Chicago from a trading post to the nation's greatest industrial power. Cronon's Chicago stands in for all American cities of the industrial age – wonderful systems for creating profit via the scaled up and sped up modification of nature (cattle, wheat, wood, land) into products (beef, bread, reapers, real estate). In Chicago factory buildings grew into factory neighborhoods and complexes, and they connected to an expanding river, canal, and rail network that by 1900 found Chicago at the heart of the world's fastest growing economy.[10] The rapid transformations of prairie into factory, river into highway, made Chicago a holy site for American technological enthusiasts of the nineteenth century. The 1893 World's Columbian Exposition presented architect and planner Daniel H. Burnham's vision of a technological metropolis, a fantasy city where neoclassical architecture could harmonize easily with the forces of mass production and the exciting new technological systems that represented an emerging modernity. Water, sewerage, electricity, transportation, machines for all manner of manufacturing, convenience, and entertainment were on display.

But the technological joy of the fair also had an expectant edge to it, it was an enthusiasm tempered by the palpable fear of disaster. The cities were magnificent producers of risk, and were frequently brought to a halt by disasters: floods, epidemics, earthquakes, and boiler explosions (in factories, locomotives, and steamboats). Steamboat explosions and fires, alongside railway accidents, were indeed constant sources of risk (and headlines) in antebellum America.[11] But, urban conflagrations were the gravest threat – evidenced by major blazes in Portsmouth, New Hampshire (1813), New York City (1835), and Pittsburgh (1845). Between the end of the Civil War and World War II, American cities experienced fires at very high rates compared to decades before or afterwards, rates that increased rapidly and stayed high for half a century despite the best efforts of scientists, engineers, insurance companies, public health reformers, and (eventually) public officials to address the problem. Eighteen of the twenty deadliest fires in American history happened in these years. Portland, Maine (1866), Chicago (1871), Boston (1872), Baltimore (1904), San Francisco (1913), and Salem (1914) experienced fires that ran out of control for hours, or sometimes days, destroying huge swaths of urban space and causing death, unemployment, and homelessness.[12]

Christine Meisner Rosen was the first to connect the individual conflagrations of this era in one analysis – in her case the synthesis is accomplished in order to draw lessons about the emerging struggles of governance in technologically intense urban centers. Her closely detailed studies of Chicago (1871) and Boston (1872) show urban elites guiding a process of reconstruction that mostly replicated previous patterns of ownership and urban form (and risk). Rebuilding efforts in Baltimore (1904), though, helped consolidate the

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[9] Sinclair, *Jungle*, 1906.
[10] Cronon, *Nature's Metropolis*, 1992.
[11] See Burke, "Bursting Boilers and the Federal Power," 1966; Aldrich, *Death Rode the Rails*, 2006.
[12] Knowles, *Disaster Experts*, 2011.

power of the local business and technical elites as they worked to undo the messiness of industrial growth and replace it with an orderly commercial downtown.[13] High-profile fires that claimed lives in schools, hospitals, and theaters such as the Iroquois Theatre Fire (1903), at times forced local officials to evaluate safety conditions in public facilities. Carl Smith's masterful *Urban Disorder and the Shape of Belief: The Great Chicago Fire, the Haymarket Bomb, and the Model Town of Pullman* (1996) strings together three episodes in Chicago's wildest period of industrialization. His reading of the Chicago Fire literature shows us how the national relief effort served as a tool of Reconstruction-era reconciliation. Americans north and south contributed to the effort. Boosters looked at their destroyed city and cried that at last an American city was destined for greatness (!), for only great cities in the mold of Rome and London burn to the ground. Ultimately, Smith shows how "disorder" and disaster fit into broader political narratives that mostly despaired of the unplanned city, with its radical, immigrant working class. In this, Smith connects disaster history to the tradition of Robert Wiebe's classic study of the Progressive Era, *The Search for Order, 1877–1920* (1966).[14]

The Triangle Shirtwaist Factory Fire was only the most famous of a series of fires that demonstrated the new level of risk workers were accepting in the industrial metropolis. Sinclair's *The Jungle* still remains perhaps the most insightful treatment of risk on the turn-of-the-century factory floor, and certainly the most influential. Concern over the bodies, and the rights of workers, were beginning to surface in these years, mostly by way of union agitation. Factory disasters epitomized by Triangle could give rise to mass movements, and in the case of Triangle the movement fed into the river of Progressive factory reform taking shape in New York state. Still no factory or theater owner of the era went to jail for negligence. The law was not geared toward finding the agents of production, construction, or commerce liable for the risks of the metropolis.[15]

For engineers and scientists of the era disasters threw into question their technical capabilities and threatened their rising professional status. This tension was especially frustrating to disaster experts when it was obvious that more research and more rigorous public policy could create growing mastery over problems, for example, the effects of earthquakes on buildings, or the application of fireproofing to materials. Disasters were object lessons in the limits of industrial modernity itself. In the face of threat, engineers aligned themselves with the branch of political Progressivism that found sanity in science and engineering amid the political corruption and immigrant jostle of urban life, offering technical solutions to the thorniest problems facing the industrializing nation.[16] It was a high wire act – engineering expertise enabled technological risk-taking while simultaneously providing the remedies to risk. The rising skylines and sheer productive capacity of the nation gave hope to the promise of technical mastery. Conflagrations, polluted cities, and the professional gloom that came when a system such as a dam failed (witness the downfall of an engineer as powerful as William Mulholland) were constant reminders that system expansion entailed risk to lives, property, and reputation.

[13] Rosen, *Limits of Power*, 1986.

[14] Smith, *Urban Disorder and the Shape of Belief*, 1995. See also Greenberg, *Cause for Alarm*, 1998; Hazen and Hazen, *Keepers of the Flame*, 1992; Pyne, *Fire in America*, 1982; Sawislak, *Smoldering City*, 1995.

[15] See Stein, *Triangle Fire*, 1962; Drehle, *Triangle*, 2003; Hoffer, *Seven Fires*, 2006; Aldrich, *Safety First*, 1997.

[16] Layton, *Revolt of the Engineers*, 1986.

Overall, it was a remarkably creative time for interdisciplinary risk research, and for the creation of new disciplines focused on understanding risk in its myriad forms. From actuarial science to public health, earthquake engineering to fire protection engineering, experts were hard at work trying to understand the relationships among nature and the new material realities of cities and their environments.[17] The disaster experts of this era sometimes worked for the federal government, but they were also situated in insurance companies, in hospitals and medical schools, industrial research labs, or in university science departments.

As I argue in *The Disaster Experts: Mastering Risk in Modern America* (2011), fire insurance companies were the first major institutions to connect the rapidity and "makeshift" qualities of industrial urbanism to the rising specter of fire's dangers and take concrete action. Fire was good for business on the one hand – it sold policies. But conflagrations could wipe out dozens of insurance companies in a day. Attempts to lobby states and cities for more stringent building and safety codes often proved futile in the face of the powerful banking–real estate-construction complex. The Supreme Court's decision in *Paul v. Virginia* (1866) found insurance not to be a form of interstate commerce, thus rendering it immune to congressional oversight, a precedent that held until 1944. The insurers wished it otherwise, as they fought through a tangle of regulatory policies developed piecemeal, state by state.

Over time the fire insurers, often working in opposition to local and state political forces, initiated a system of private regulation and standards. Closely scrutinized by antitrust reformers, the insurance industry established non-profit standard setting institutions, namely the National Fire Protection Association (NFPA) and Underwriters Laboratories (UL). Steeped in claims to scientific neutrality, and plugged into the worlds of architecture, engineering, and construction, UL and NFPA were received as honest brokers in the creation and promulgation of standards that could bring down losses from fire, save lives, and still promote sensible development. These standards were visible by the 1920s in "model" building codes and in safety/performance standards for specific products (electrical products especially) that for many states and cities became their de facto building codes. This was the development of a private fire risk regulation system that persists to the present day in the USA.[18] The existing engineering disciplines of architectural and electrical engineering were necessarily forced to address themselves to the emergence of fire regulation, and the entirely new specialization of fire protection engineering was born.[19] While fires certainly continued, the era of great conflagrations was at an end by the 1930s.

Fire could strike any time in the industrial metropolis, but many, many other "slow" disasters were taking shape as well. Joel Tarr expertly documents the "destructive" side of technological systems in his many articles and essential collection *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (1996). Tarr charts the history of technological networks and systems across time and urban sites, finding overall that through "technology, urbanites reshaped and scarred the landscape, constructed a built environment above and underground, and contaminated air, land, surface water, and

[17] On the earthquakes, see Geschwind, *California Earthquakes*, 2001; Reitherman, *Earthquakes and Engineers*, 2012; on building materials and testing, see Slaton, *Reinforced Concrete and the Modernization of American Building*, 2001.

[18] Tebeau, *Eating Smoke*, 2003; Baranoff, "Shaped by Risk," 2004; Baranoff, "Policy of Cooperation," 2003; Wermiel, *Fireproof Building*, 2000; Maines, *Asbestos & Fire*, 2005. For risk and disaster science, see Porter, *Trust in Numbers*, 1995; Mohun, "On the Frontier of the Empire of Chance," 2005; and Mohun, *Risk*, 2013.

[19] Kargon and Knowles, "Knowledge for Use," 2002, pp. 1–20.

groundwater as their ecological footprint expanded."[20] Elaborating on sanitary engineer Abel Wolman's concept of the "metabolism of the city," Tarr shows in a representative case how engineers in Pittsburgh solving one problem, the need for clean water, could create another, the drowning of the city in fetid wastewater. The answer was a sewer system, the same answer that towns upriver had arrived at as well. "By 1900," Tarr explains:

> most of the Pittsburgh population received its water from either the Allegheny or the Monongahela River, and over the years the watersheds of these streams had become increasingly populated. . . . The resulting pollution gave Pittsburgh the highest typhoid fever death rate of the nation's large cities from 1882 to 1907 . . . Typhoid fever death rates were highest in working-class immigrant and African American living areas.[21]

Infrastructure and Disaster

The most readily observable and certainly the most crucial markers of technological success over the past two centuries are seen in the engineered systems that sustain human life on earth. Water delivery and sewerage; wires for power, light, and communication; roads, ports, rails, and airports; satellites, towers, servers, and Wi-Fi networks – each of these is a system of technology rooted in the nineteenth century and continuously updated to the present. Historians have documented in minute detail the "systems heroes," geniuses in the tradition of Edison and Ford who brought forward not single inventions, but linked technologies into systems – systems that then grew into enormous, capital-intensive corporations and public utilities. It was in the industrializing American metropolis that systems of technology enabled rapid profits and population growth. The development of systems of technology since the nineteenth century also teaches us a great deal about the centrality of risk (and risk management techniques) and the persistence of disaster amid the sweep of urban industrialization.

Safety-minded engineers of the era found perhaps their greatest influence in the creation of protective infrastructures, water control serving as the paradigmatic case. This was especially true in commercial ports along the lines of Galveston, TX and New Orleans. Galveston was leveled by a hurricane in 1900; it was subsequently raised 8 feet and provided a 17-foot high seawall by the U.S. Army Corps of Engineers.[22] New Orleans had a long history of floodwaters coming down the Mississippi and storm surge coming from the Gulf. In fact, the entire history of New Orleans going back to the French colonial period was one extended tale of a city barely above, and often below water. It was also the story of a city of geographical necessity, located in a spot so crucial that it crafted its own culture of defiant flood fatalism.[23]

Martin Reuss has contributed greatly to our understanding of the role the U.S. Army Corps of Engineers played in the nineteenth and early twentieth centuries in the protection of these cities and other coastal port and key river cities. The methods of analysis and planning developed by the Corps – including cost–benefit analysis, and "project design flood" models – set historical precedents that continue today. The Corps was ahead of its time in modeling likely disaster scenarios and working backwards into plans for protective

[20]Tarr, "City as an Artifact of Technology and the Environment," 2010, p. 145.

[21]Tarr, "Metabolism of the Industrial City," 2002, pp. 516–517; see also Tarr, *Search for the Ultimate Sink*, 1996; and Melosi, *Sanitary City*, 2000.

[22]Larson, *Isaac's Storm*, 1999.

[23]See Colten, *Transforming New Orleans and Its Environs*, 2002; Colten, *Unnatural Metropolis*, 2005; also Kelman, *River and Its City*, 2003.

infrastructures. Such techniques of risk and failure modeling are used across high-risk engineering specializations today, though they are not without limits, and certainly not without critics. On the Mississippi, the demand for technological control over the nation's waterways ran well ahead of a complete (or even partial) understanding of rivers as natural systems. Reuss notes that:

> River engineers faced an astounding array of questions. Why do alluvial rivers like the Mississippi weave back and forth like drunks in an alley? Do meanders result from terrain characteristics or from alluvial processes? . . . Do bed-load particles leap along the bottom like ballet dancers across a stage? Do they slide along in a layer like maple syrup across a stack of pancakes or roll along like bowling balls? . . . Science desired answers; politics demanded them. Three decades into the twentieth century, engineers still knew far more about the structures they placed in the streams than about the streams themselves.[24]

The Corps provides an example of a government agency (the first in the USA) to take on both the engineering of systems, and also the pursuit of deeper scientific understanding that would come to inform the evolution of risk engineering practice over time. As Hurricane Katrina would show a century later, the political demand for "the control of nature" placed engineers in constant positions of compromise, and normalized the acceptance of "acceptable levels" of risk as central to their work.[25]

The activities of the Corps (i.e. the federal government) also introduced difficulties politically – was it the state's role to protect private development and industry? If so, was this fair to those left unprotected or poorly protected? The issue was not hypothetical to African-Americans living in the poorly protected neighborhoods of New Orleans, or experiencing segregation in the miserable relief camps during the 1927 Mississippi River flood.[26] Starting with the catastrophic 1927 Mississippi River floods, the Executive Branch took a more active stance. In fact, it was Secretary of Commerce Herbert Hoover's assignment to organize disaster relief in the aftermath of the 1927 flood, and he did so in such a prominent (and media savvy) way that he built name recognition sufficient to win his party's nomination, and the presidency in 1928. Recent research by historian Michele Landis Dauber traces a history of federal disaster relief showing that focused relief legislation was the purview of congress since the founding of the republic. In fact congress was frequently willing to offer relief in the form of tax and duty refunds, and even direct financial aid. Dauber shows how this type of relief, construed as constitutional under the "general welfare" clause, laid the groundwork for New Deal claims of the Depression as a form of disaster, and the attendant programs of relief that this logic enabled.[27] Dauber breaks new ground by arguing that federal involvement with disaster relief figured very prominently in broader conceptions of the welfare state developing in the 1930s. This link between the welfare state, Executive power, and disaster is one that would develop rapidly in the postwar USA.

Recently, a new theorization about risk, disaster, and technological systems has emerged in work by Sara B. Pritchard and Thomas Zeller. Their revision of industrialization is one that explicitly blurs the boundaries between natural, technological, and human realms of action. Thinking about the quintessentially (unnatural) industrial space of a coal mine,

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[24] Reuss, "Art of Scientific Precision," 1999, p. 297.
[25] McPhee, *Control of Nature*, 1989.
[26] Barry, *Rising Tide*, 1997; and Rozario, *Culture of Calamity*, 2007. On disaster relief and the Red Cross, see Irwin, *Making the World Safe*, 2013.
[27] Dauber, *Sympathetic State*, 2013.

Prichard and Zeller point out that "[w]ater, trees, air, animals, and human bodies themselves are thus all organic components of a mine's complex technological system, what scholars working at the intersection of technology studies and environmental history increasingly see, in fact, as *envirotechnical systems*."[28] The concept of the envirotechnical system usefully revises the work of historians of technology led by Thomas P. Hughes who documented the development of large-scale technological systems and networks. In the envirotechnical system, expert management of tools, technique, or finance do not necessarily guarantee success. This insight helps historians make sense of the long catalog of "system failures" in the history of technology, and it corrects a history of engineering that focuses solely on internal discussions among experts. The envirotechnical systems model helps explain the success of system builders who think and work across traditional disciplinary boundaries, a key explanation (as I have argued elsewhere) in understanding the ultimate solution to the fire problem in industrializing American cities. Strict divides between technical expertise and natural science, or between technical experts and environmental activists in a later generation, have in fact been highly counterproductive to the formation of effective risk reduction policy.[29]

Nuclear, Chemical, and Environmental Disaster

Writing just a few months before the September 11 attacks, psychologist Robert J. Lifton observed that the persistence of a global nuclear threat, while very real, had seemingly subsided from consciousness. "In the absence of the sort of threatening nuclear rhetoric the USA and Russia indulged in during the 1980s," Lifton said, "we can all too readily numb ourselves to everything nuclear, and thereby live as though the weapons pose no danger, or as though they don't exist." Lifton has spent a celebrated career studying the effects of trauma and the atrocities of war on survivors, and he first created the widely used concept of "psychic numbing" in the 1960s, to explain the means by which Hiroshima survivors carried on with their lives after the war ended. The concept was also applicable toward understanding the ways that Americans coped with the conflicting messages they received from the government and from technical experts throughout the cold war on concerns related to nuclear weapons, or nuclear power, pesticides, the ozone layer, global warming, and a hundred other concerns for that matter.

At one and the same time Americans of that era were experiencing the benefits of postwar peace and prosperity – better living through chemistry (and superpower status) – tempered by the constant awareness that they could be vaporized and their cities turned to ash at any time. Lifton explained that this condition of numbness and detachment, induced by the constant threat of high-risk technology, was a broadly shared experience of postwar life.

> To be sure, we have never quite been able to muster an appropriate level of fear with respect to these weapons – one that would spur us to take constructive steps to remove the threat. We have always been able to numb ourselves in this regard, which must be seen as a basic human response to a threat that is apocalyptic in scope and so technologically distanced as to be unreal.[30]

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[28] Pritchard and Zeller, "Nature of Industrialization," 2010, p. 76.

[29] Pritchard and Zeller, "Nature of Industrialization," 2010, p. 96; also Hughes, *Networks of Power*, 1983; see also an extension of the envirotechnical concept directly into recent disaster history (Fukushima) in Pritchard, "Envirotechnical Disaster," 2012.

[30] Lifton, "Illusions of the Second Nuclear Age," 2001, p. 27; see also Lifton, *Death in Life*, 1967.

At the same time interest groups – including engineers across disciplines – often broke faith with technological confidence and offered sustained critique of high-risk technology and its threats. A signal analytical challenge for scholars of this era involves tracing the back-and-forth between technological confidence and doubt, set against the backdrop of the growing military–industrial complex, but also the environmental movement and the development of the environmental regulatory state.

How do we explain the "technological distance" of nuclear weapons, or for that matter of nuclear power, toxic chemicals, power grids and the many, many other technological systems that have done so much to secure the political and economic dominance of the postwar USA? Lifton approaches it from the perspective of psychology, and points us to a sort of practiced incuriosity that leads Americans away from critique in the face of risk. To Lifton it is a product of the imponderability of failure, the simple fact that modern technological society cannot function optimistically and realistically at the same time.

The historiography of cold war civil defense emerged in two waves. The first came forward in the 1980s, in reaction to the availability of documents and to the rising fears of nuclear confrontation in the Reagan presidency. The second wave arrived in the 2000s, a revisionist moment stoked at least in part by the resurgence of civil defense concepts propagated by September 11 and the policies of the Department of Homeland Security.[31] Immediately upon the Soviet detonation of an atomic bomb in 1949, the USA adopted a bureaucratic structure of nuclear civil defense. By the time troops were on the ground in Korea, President Truman had signed a package of laws that crafted a far-reaching civil defense system aimed at keeping the nation at a high and continual state of war readiness. The Civil Defense Act of 1950 and related Disaster Relief Act of 1950 were both revised and elaborated through legislation that gave more and more disaster management power to the Executive Branch throughout the cold war. A civil defense planning bureaucracy took hold in the Pentagon, producing everything from the "Duck and Cover" films we laugh at today to the chilling "Hypothetical Test" exercises that city and state officials across the land used to imagine and plan for atomic attack.

Scholars have looked through every unclassified nook and cranny of the civil defense era, and have returned with the conclusion that, in general, (as Lifton explained) American citizens had little involvement with civil defense – they did not build fall-out shelters and they did not volunteer for the apocalypse as block wardens or ambulance drivers. By operating mostly in secret, and taking no heed of the public's apathy, the civil defenders keenly carried on preparations for nuclear attack over a span of decades. Of particular interest in this historiographical tradition is Lynn Eden's essential *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* (2004). Eden traces the history of a flawed assumption about nuclear weapons among the civil defense technical elite, resulting in an emphasis on blast effects over mass fire. The result according to Eden was a larger nuclear stockpile than necessary to achieve the Pentagon's aims – a finding with dire implications for both the cold war and post-cold war worlds. The engineers of nuclear preparedness could make mistakes, and yet they remained powerful throughout the cold war. In fact, their plans begat more and more elaborate plans – "fantasy documents", as noted by Lee Clarke,

[31] See Blanchard, "American Civil Defense 1945–1975," 1980; Davis, *Stages of Emergency*, 2007; Garrison, *Bracing for Armageddon*, 2006; Grossman, *Neither Red Nor Dead*, 2001; Kerr, *Civil Defense in the U.S.*, 1983; Krugler, *This Is Only a Test*, 2006; Leaning and Keyes, *Counterfeit Ark*, 1984; McEnaney, *Civil Defense Begins at Home*, 2000; Rose, *One Nation Underground*, 2001; and Eden, *Whole World on Fire*, 2004, p. 303.

> likely to be produced to defend very large systems, or systems that are newly scaled up. . . . The fantasies can lead people working within high-risk organizations to be overconfident that their procedures are strong enough to prevent system breakdown; and they can lead people outside organizations to believe promises that their interests are protected.[32]

Clarke's assessment squares with the historical record of the interactions between the American public and civil defense officials. Poll after poll in the cold war indicated that Americans believed a nuclear attack was quite likely, that their city would be attacked, and that the government was doing something to prepare. A 1966 civil defense study found that Americans in the Cold War did "not think that civil defense systems will make war more probable. Nor do they believe that war will become less likely."[33] It was an apocalyptic status quo.

Other scholars have looked at the political nature of the technologies themselves, citing a distance less psychological than political in nature – documenting the ways that high-risk technologies are manufactured and deployed either in secret, or hidden in plain sight but shrouded in mystery. It is an era of technological development quite different from that which created the industrial metropolis, a time when factories sat in the middle of neighborhoods, employed unskilled and semi-skilled laborers, and made things (textiles, furniture, tools) that were not so distant from pre-industrial manufactures except in the speed and scale of the operations. Nuclear technology is different. It is a "political technology," as Langdon Winner puts it in describing his visit to the Diablo Canyon nuclear reactor in California.

> From the point of view of civil liberties and political freedom, Diablo Canyon is a prime example of an inherently political technology. Its workings require authoritarian management and extremely tight security. It is one of those structures, increasingly common in modern society, whose hazards and vulnerability require them to be well policed. What that means, of course, is that insofar as we have to live with nuclear power, we ourselves become increasingly well policed.[34]

Of course, the locked doors and faulty fire escapes of the Triangle Shirtwaist Factory had betrayed a politics as well, a machine politics of industrializing risk, with the odds of disaster stacked against the working class in firetrap cities. High-risk sites such as Diablo Canyon (using technology pioneered at Hanford and Los Alamos) were to Winner an unwelcome and authoritarian phony-peaceful exponent of the postwar military–industrial complex. Winner's connection of high-risk technology to a distinctive cold war political philosophy echoes the anti-war and anti-corporate critiques of technology coming from the political left, and even audible among some sectors of the engineering profession itself. Indeed as Matthew Wisnioski details in *Engineers for Change: Competing Visions of Technology in 1960s America* (2013), the era was alive with opportunities for protest and reform for engineers who wanted to remake the system from the inside out, and who often attempted to forge common cause with the environmental and civil rights movements.[35]

Nuclear weapons and nuclear power represent an extended technological system embedded in secrecy. It is also a system with significant indeterminacy, not just an "accident waiting to happen," but already happening if one considers (as Winner does) that "it will produce routine releases of low level radiation and thermal pollution of the surrounding

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[32] Clarke, *Mission Improbable*, 1999, pp. 41–42.
[33] Knowles, *Disaster Experts*, 2011, p. 206.
[34] Winner, *Whale and the Reactor*, 1986, p. 175.
[35] Wisnioski, *Engineers for Change*, 2012.

ocean water," and that "No one has developed a coherent plan for storing the long-lived radioactive wastes that this plant and others like it will generate."[36] These are dangers different enough from the past that we might even consider them a "new species," according to Kai Eriskon. Erikson notes that these "new troubles involve toxins: They contaminate rather than merely damage; they pollute, befoul and taint rather than just create wreckage; they penetrate human tissue indirectly rather than wound the surfaces by assaults of a more straightforward kind."[37] Erikson also notes that, unlike the dramatic arc of a natural disaster, the risks of pollution, and of outright technological disaster do not have a beginning, middle, and end.

> Toxic disasters . . . violate all of the rules of plot. Some of them have clearly defined beginnings, such as the explosion that signaled the emergency at Chernobyl . . . others begin long years before anyone senses that something is wrong, as was the case at Love Canal. But they never end. Invisible contaminants remain a part of the surroundings . . . An all clear is never sounded.[38]

Are we in the midst of a disaster if it is unfolding over days, months, years – longer? These are the questions provoked by the persistent threat (and reality) not only of radioactivity, but also of pollution more generally. And they are questions central to a modern economy so highly evolved toward producing complicated and toxic wastes: the effluvia of power, petrochemical, and synthetic material manufacture. As Rachel Carson explained in *Silent Spring* (1962), "Today we are concerned with a different kind of hazard – a hazard we ourselves have introduced into our world as our modern way of life has evolved."[39] Carson was writing in the hottest moments of the cold war, and extending the analysis of technological risk outside the boundaries of the nuclear and into the more mundane world of agriculture. But just as with the threat of radiation, and the stockpile of nuclear weapons, DDT (dichlorodiphenyltrichloroethane) presented again the problem of limited citizen awareness and the rule of technical experts. In Carson's case she managed to awaken the country (with the nod of the Kennedy administration) to pollution as both a political and a moral dilemma. The politics of secrecy around DDT were obvious – manufacturers knew it was dangerous to animals (including humans), and they did not have to share that information with the public. So, they did not. Not that the public was much interested at first, considering the protean abilities of DDT to kill mosquitoes and thus reduce disease outbreaks. But, there were other ways to prevent mosquito-borne illness. The moral dilemma as Carson framed it was, quite simply, the choice of instant gratification and profit versus the long-term poisoning of our children and their world. This dilemma became the central argument at the heart of both the rising environmental consciousness of the 1960s, and ultimately the development of a new regulatory state around environmental protection in the 1970s.

A final form of postwar technological uncertainty has to do with the nature of expertise and the steadiness of the hands at the controls. In his *Normal Accidents: Living with High-Risk Technologies* (1984), Charles Perrow takes us inside the unfolding crisis at the Three Mile Island nuclear plant in 1979. The media at the time (and more recently

[36]Winner, *Whale and the Reactor*, 1986, p. 175; see also Beck, *Risk Society*, pp. 51–57.
[37]Eriskon, *New Species of Trouble*, 1994, p. 144.
[38]Eriskon, *New Species of Trouble*, 1994, p. 148. For an overview of debates over nuclear power, see also Weart, *Rise of Nuclear Fear*, 2012.
[39]Carson, *Silent Spring*, 2002, p. 187.

with the nuclear accident at Japan's Daiichi complex) has trouble explaining the causality of technological disasters. As Erikson tells us, good copy needs heroes, villains, and a straightforward flow of events from problem to resolution. Three Mile Island did not cooperate, in large part as Perrow explains, because a nuclear power plant is so complex that straightforward cause and effect is difficult to ascertain. Looking for operator error, or a single flawed part, we would be unable to explain (as was the Kemeny Commission, charged with doing so) what happened at Three Mile Island. Perrow describes it in terms of what he calls "normal accidents," the kind of technological failures that result in massive system disruptions such as blackouts or nuclear power plant accidents. Perrow explains:

> Nothing is perfect, neither designs, equipment, procedures, operators, supplies, or the environment. Because we know this, we load our complex systems with safety devices . . . Small failures go on continuously . . . but the safety devices and the cunning of designers, and the wit and experience of the operating personnel, cope with them. Occasionally, however, two or more failures, none of them devastating in themselves in isolation, come together in unexpected ways and defeat the safety devices – the definition of a "normal accident" . . . If the accident brings down a significant part of the system, and the system has catastrophic potential, we will have a catastrophe.[40]

Perrow's work is profound in that it calls into serious questions the central logic of high-risk technology, namely, that the experts know the risks and have designed the system accordingly, and with plenty of protective redundancies. If Perrow is right, then it throws into question the competencies of some pretty critical institutions of modern American life: the engineering professions, industrial corporations, and regulatory agencies. Looking at the nuclear power industry, Perrow concludes that "a long list of construction failures, cover-ups, threats, and sheer ineptitude plagues the industry." The aforementioned Diablo Canyon plant, for one example, was sited in a supposedly earthquake-free zone on the California coastline. While under construction the plant was steadily monitored by the U.S. Nuclear Regulatory Commission. And then, in 1980, an engineer noticed that "required earthquake reinforcements of key equipment had been incorrectly installed . . . and then 111 other violations were found."[41] Eventually new seismic research showed that Diablo Canyon sat on a fault line, too.

Disaster and Governance

The ups and downs of postwar government's attempts to effectively monitor and regulate high-risk technology are also well documented in books such as Brian Balogh's *Chain Reaction* (1991). The Nuclear Regulatory Commission, just as with the Office of Civil Defense, was always in a difficult position. These were agencies created not to say no to the dominant trends in national defense or high-risk technological development – they did not have the kill switch. Postwar technological regulation was instead an attempt by regulators to map out the contingencies and keep the public mostly in the dark, but confident in the judgment of risk and disaster experts.

In time, heavily industrialized corridors became trouble spots for regulators – and for workers – as evidence built over decades that industry was systematically poisoning the environment, workers, and residents nearby. The rise of environmental health, occupational safety and health, environmental engineering (a continuation of an earlier era's sanitary engineering), and environmental justice movements brought media attention and

[40] Perrow, *Normal Accidents*, 1984, pp. 356–357.
[41] Perrow, *Normal Accidents*, 1984, pp. 59–60.

increased government oversight through new agencies (Occupational Safety and Health Administration, Environmental Protection Agency (EPA), Centers for Disease Control). This oversight sometimes built toward successful class action lawsuits and medical relief for the people in the way of industrial toxicity. Most frequently, though, the record reveals profound limits in government's ability to successfully monitor and track toxins, and the unwillingness of regulators to stop the wheels of production.

When disaster strikes in an area already struggling under the weight of industrial pollution the results can be doubly toxic. Scott Frickel makes this case in his studies of the post-Katrina environmental politics of New Orleans.[42] He follows the trail as fears of a "toxic gumbo" swamping New Orleans were raised in the immediate past-disaster period. EPA and LDEQ (Louisiana Department of Environmental Quality) officials dutifully tested and declared the "gumbo" to be not as harmful as people had worried, after all. Frickel takes issue with the conclusion, and in doing so introduces a provocative new concept: "organized ignorance":

> The tests the EPA and LDEQ have conducted are based on the compartmentalization of ecosystems into discrete media (e.g. air, soil, and water). These testing regimes, in turn, correspond to media-specific disciplines (e.g. aquatic toxicology), regulatory bureaucracies (e.g. LDEQ's Water Quality Assessment Division), and federal regulatory frameworks (e.g. Clean Water Act), each of which develops understandings of environmental contamination in ways that stand at some odds to ecological reality. In short, we have organized knowledge in ways that ensure we will not really know what is happening in the ecosystems we study. This is [a] . . . form of organized ignorance.[43]

Another challenge to governance in the age of "technological distance" has come in the public expectation, again, that facts and justice will be swiftly delivered in the aftermath of technological disasters. This expectation is rooted in a history of disaster investigations going back in the USA to the nineteenth century. Disaster investigations were at different times conducted by coroners, elected officials, even newspapers; and, of course engineers conducted high-profile investigations of most of the major disasters of the industrialization era.[44] Civil defense oversight hearings were held from time to time, invariably revealing the strange world inhabited by the civil defenders and their distance from the lived world of ordinary Americans. Investigations of DDT, Strontium-90, Love Canal, Three Mile Island, the Challenger explosion, the MGM Grand fire, the Exxon Valdez, the World Trade Center collapse, and Hurricane Katrina's levee failures have one thing in common: they place technical experts in the unenviable situation of discerning discrete cause and effect relationships between risk-taking and disaster.

In high-profile disaster investigations this has repeatedly exposed the uncomfortable fact that no technology is risk-free, and no engineer works in a realm of pure certainty. Describing the nuances of the 1986 Challenger explosion investigation, Harry Collins and Trevor

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[42]For overviews of social science research into Hurricane Katrina, see "Understanding Katrina: Perspectives from the Social Sciences," Social Science Research Council (online), http://understandingkatrina.ssrc.org/ and Social Science Research Council Katrina Research Hub (online), http://katrinaresearchhub.ssrc.org/rdb/katrina-hub . See also Birch and Wachter, *Rebuilding Urban Places after Disaster*, 2006; and Daniels, Kettl, and Kunreuther, *On Risk and Disaster*, 2007, pp. 143–260.

[43]Frickel and Vincent, "Hurricane Katrina," 2007, p. 185; see also Allen, *Uneasy Alchemy*, 2003; Markowitz and Rosner, *Deceit and Denial*, 2003; Rosner and Markowitz, *Are We Ready?*, 2006; Gershon, Magda, Riley, and Sherman, "World Trade Center Evacuation Study," 2011; Gonzalez, *Fallout*, 2002; and Nixon, *Slow Violence and the Environmentalism of the Poor*, 2011.

[44]Knowles, "Lessons in the Rubble," 2003.

Pinch discuss the leaps that engineers take as they model risks. Tests serve as samples of reality, models scale up the knowledge gained from testing, and test-derived standards send risk knowledge out into the technical world. These are the tools of learning and confidence-building in high-risk technologies. And, importantly, performing the test and following the standard are what allow engineers to do their due diligence as guardians of technological safety. But, Pinch and Collins ask: "how similar is the test to the actual use?"[45] In the case of the *Challenger* it was revealed that engineers moved from an O-ring performance safety calculation where they attempted to find our exactly how big a critical gap was, to a recognition that they could not know, but that they had enough redundancy for a worst case, whatever the measurement. In the end, the "joint was not perfect, but neither were a lot of other components on the shuttle."[46] Normal accidents abound.

In almost every disaster investigation the investigators name a culprit, but a wider view usually reveals hundreds of culprits behind the one blamed – a systematic culture of risk-taking that ropes in entire industries, and entire government agencies. Stephen Hilgartner broadens the importance of the disaster investigation, describing it as an inherently performative, dramatic moment, when regaining "normalcy may depend on placing the episode securely within a narrative frame that restores confidence in the capacity of social institutions, especially the state, to protect the citizenry."[47] Restoring faith in technological progress has sometimes been of such a high priority that it necessitated direct Congressional or Executive action: witness the Kemeny Commission after Three Mile Island, and more recently the 9/11 Commission and the Hurricane Katrina investigations.

In the case of the World Trade Center collapse, the difficulty of regaining normalcy was compounded by a central confusion over the nature of the disaster itself. Was it a terrorist attack, something entirely beyond the wildest dreams of authorities? Was it an attack that could have been expected? Was it a failure of a civil aviation security system? Was it the failure of emergency management and the fire service? Was it the failure of structural engineers and architects, construction firms? Even today strong debate exists around these questions. It was the family members of those killed who managed to not only force the creation of the 9/11 Commission, but also two additional investigation (one governmental, one technical) into the specific causes of the collapse of the Twin Towers. Sally Regenhard's son, Christian, a probationary fireman was killed on September and his remains have never been identified. Regenhard was unable to discern what sort of investigative process was underway, except that a joint FEMA/ASCE team had been blocked from retrieving plans, 911 call data, or even seeing damaged steel beams – this much was reported in the press. Regenhard made common cause with fire protection experts who were also frustrated, initially by simply calling fire protection professor Glenn Corbett after reading an op-ed he penned in late 2001. Working together, the dissenting experts and the grieving families began lobbying the New York congressional delegation.

With the support of Senator Hillary Clinton, Regenhard drew press attention, and in the spring of 2002 the House Science Committee undertook two extraordinary hearings. Scientists from National Institute of Standards and Technology (NIST), fire protection engineers, insurance industry representatives, and representatives from the building trades

[45] Collins and Pinch, *Golem at Large*, 2002, p. 38.
[46] Collins and Pinch, *Golem at Large*, 2002, p. 48.
[47] Hilgartner, "Overflow and Containment in the Aftermath of Disaster," 2007, p. 154; see also Fortun, *Advocacy after Bhopal*, 2001; Hilgartner, *Science on Stage*, 2000; Larabee, *Decade of Disaster*, 1999; Shrum, "What Caused the Flood?," 2014; Vaughan, *Challenger Launch Decision*, 1996; and Jasanoff, *Learning from Disaster*, 1994.

all testified, explaining the confusing, overlapping authority structure that comprised the American "consensus code" system of high rise design and construction. From the hearings followed the National Construction Safety Team Act of 2002, in which congress directed the NIST to undertake forensic structural disaster investigations, appropriating $16 million for additional study of the failures of the Twin Towers.

NIST's study revealed systemic failures in the fire protection and egress capabilities of the Twin Towers. The structural engineering community pushed back on those findings, arguing that no designer could possibly have imagined the scenario that played out that day. Records of testing and design work that *did* anticipate jetliners hitting the buildings could not be found, nor could the records of fire protection measures such as the application of fire insulation for columns and beams. Blame was never assigned to any individual, firm, or profession. NIST did eventually release 30 recommendations to the nation's building code groups for changes – some quite extensive in areas of elevators, stairwells, design methodology, and communications – many of which have been enacted;[48] many of which have seen no action. Since building codes are part of an extensive technological system without centralized control, there is not one single engineer, architect, elected official, or regulatory official who is responsible for the outcome. It is impossible to blame one bad apple or one broken switch for the failures of a risky system.

Conclusion: Disaster Averted?

Central to Disaster-STS scholarship is the proposition that in the modern USA *we live in a constant condition of risk and disaster*. The "recover and build again" ethos is perhaps the key clue to understanding why disasters have become more frequent and more costly in the modern USA. We have built ourselves rapidly, profitably, and lawfully into harm's way. Disasters today are perhaps no more than externalities to be absorbed into the larger techno-political system of late capitalism.

Moving ahead scholars will want to take this first premise as a launching point for revision – we need to return to the history of heroic engineering and triumphant industrialization and tell a much more complete narrative. Studied closely, we find that disaster is not an aberration, but a central indicator of (mostly) profitable risk-taking sanctioned by government, and by extension, citizens. Achieving this type of "disaster consciousness" requires the steady work of scholars who can document and analyze the technical languages of risk and frame the political stakes of poorly restrained industrialization and land development. From this perspective technical and policy-minded experts are not viewed as working toward the eradication of risk and disaster, but toward their management at more or less "acceptable" levels. Acceptable to whom is, of course, a political question worthy of serious study and debate.

The importance of understanding "life in disaster" has been recently magnified by the accelerating frequency and cost of American disasters, and by the extraordinary political impact of September 11 and Hurricane Katrina. The ten most expensive hurricanes (adjusted for current dollars) in American history have come since 1989, and eight of them since 2004. In 2011 the USA set a record for the greatest number of billion dollar disasters (12) to occur in a single year. Since 2001 the nation has lost over half a trillion dollars to

[48] See Knowles, "Lessons in the Rubble," 2003; Knowles, *Disaster Experts*, 2011; see also Glanz and Lipton, *City in the Sky*, 2003; on the role of failure in shaping engineering design, see Petroski, *Success Through Failure*, 2006, p. 114; see also Petroski, *Design Paradigms*, 1994; and Pfatteicher, *Lessons Amid the Rubble*, 2010.

disasters (not including the September 11 attacks), and over 3,500 lives. Climate change and sea-level rise portend longer hurricane seasons, drought, wildfire, and a new age of stress on the American built environment.

Contemporary disaster research has also adopted a "vulnerability paradigm," locating and predicting the populations that bear the disproportionate burdens of disasters.[49] As Ulrich beck imagined in the 1980s, these are the populations who lack access to knowledge and political power, leaving them in the most hazardous terrains and neighborhoods, and without the social capital to demand protection. Connecting the vulnerability paradigm to the emerging science of environmental sustainability opens up a space for collaborative research and policy action in the name of democratic, equitable risk and disaster management.

Historical analysis of disasters may lead us to the "un-American" side of American risk-taking, the losing side, but it is also the side where we recover the context for choices made that create and exacerbate risk. American-disaster history lingers in the moments when disasters were predicted and expected, when the case for restraint has been argued, and where the powerful forces of land development, large-scale technology, and environmental transformation have come into question.

Engineering expertise has enabled risk and managed risk, contained disaster, and facilitated disaster. Analyzing these trends deepens our understanding of modern American history and has the potential to inform science and technology education, professional behavior, and public policy. This type of work fits what Gary L. Downey has called "Big STS," highlighting a "broader range of practices involved in not only analyzing dominant practices of science and technology in society but also formulating and scaling up practices that critically engage them."[50] Such practices of engagement in risk and disaster engineering could draw usefully upon historical episodes I have described in this essay, including: the application of engineering expertise to manage the excesses of unrestrained land use and infrastructure development, the development of codes and standards for safety, activism in the face of existential technological risk, and post-disaster technical inquiries. Going forward, Disaster-STS holds the potential to facilitate a meeting space for citizens to work toward sustainability alongside disaster experts in the social sciences and humanities, science and engineering, and public policy.

Now is a time for great interdisciplinary experimentation in engineering, growing directly from research and practice focused on environmental sustainability, climate change, and resilience. To the extent that these experts are open to collaboration, Disaster-STS provides an avenue to inject social science and humanities methodologies into their practices. Climate change mitigation, for example – now an established international priority – is an exceptionally vibrant interdisciplinary space, requiring historical study, political and sociological understanding, economic projection, and science and technology practice to co-exist, even collaborate toward shared goals.

Scholars working on very recent (and projected future) disaster contexts should strive to work creatively with and among engineers and other technical experts, especially where common interests and values emerge. Also, we can and should work to engage openly with the real estate industry, manufacturers (and polluters), the insurance industry, and the nuclear industry. Yes, privacy concerns will keep us from accessing everything – but *much can be learned* through attending professional conferences and trade meetings, and the

[49] Bankoff, Frerks, and Hilhorst, *Mapping Vulnerability*, 2004.
[50] Downey, "What Is Engineering Studies For?," 2009, p. 73.

accumulation of a historical record begins with patient document collection and interviewing. Participation on panels sponsored by disaster-focused agencies like NIST and FEMA can make a real impact as policy documents are drawn and research budgets established. Investigation of regulatory agencies, public watchdogs, and other disaster-focused non-profits is also a central area for Disaster-STS inquiry. Finally, scholars serve as educators – in their classrooms and through public lectures, media appearances, and popular writings. In these settings Disaster-STS can find a voice that may not only be instructive, but perhaps also disruptive.

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References

Aldrich, Mark. *Safety First: Technology, Labor, and Business in the Building of American Worker Safety, 1870–1939*. Baltimore, MD: The Johns Hopkins University Press, 1997.

Aldrich, Mark. *Death Rode the Rails: American Railroad Accidents and Safety, 1828–1965*. Baltimore, MD: The Johns Hopkins University Press, 2006.

Allen, Barbara L. *Uneasy Alchemy: Citizens and Experts in Louisiana’s Chemical Corridor Disputes*. Cambridge: MIT Press, 2003.

American Society of Civil Engineers Hurricane Katrina External Review Panel. *The New Orleans Hurricane Protection System: What Went Wrong and Why*. Reston, VA: ASCE, 2007.

Bankoff, Greg, Georg Frerks, and Dorothea Hilhorst, eds. *Mapping Vulnerability: Disasters, Development and People*. London: Earthscan, 2004.

Baranoff, Dalit. “A Policy of Cooperation: The Cartelization of American Fire Insurance, 1873–1906.” *Financial History Review* 10, no. 2 (2003): 119–36.

Baranoff, Dalit. “Shaped by Risk: The American Fire Insurance Industry, 1790–1920.” Published PhD diss., The Johns Hopkins University, 2004.

Barry, John M. *Rising Tide: The Great Mississippi River Flood of 1927 and How It Changed America*. New York: Simon and Schuster, 1997.

Beck, Ulrich. *Risk Society: Towards a New Modernity*. London: Sage Publications, 1986.

Beck, Ulrich, Anthony Giddens, and Scott Lash. *Reflexive Modernization: Politics, Tradition, and Aesthetics in the Modern Social Order*. Redwood City, CA: Stanford University Press, 1994.

Beriwal, Madhu. *Preparing for a Catastrophe: The Hurricane Pam Exercise* <www.hsgac.senate.gov/download/012406beriwal> U.S. Government Printing Office, 2006.

Birch, Eugenie L., and Susan M. Wachter, eds. *Rebuilding Urban Places after Disaster: Lessons from Hurricane Katrina*. Philadelphia: University of Pennsylvania Press, 2006.

Blanchard, B. Wayne. American Civil Defense, 1945–1975: The Evolution of Programs and Policies. Charlottesville, VA: University of Virginia (Doctoral dissertation, Department of Government and Foreign Affairs), 531 pages, 1980.

Burke, John G. “Bursting Boilers and the Federal Power.” *Technology and Culture* 7, no. 1 (1966): 1–23.

Carson, Rachel. *Silent Spring: Fortieth Anniversary Edition*. New York: Houghton Mifflin, 2002.

Clarke, Lee. *Mission Improbable: Using Fantasy Documents to Tame Disaster*. Chicago: The University of Chicago Press, 1999.

Collins, Harry, and Trevor Pinch. *The Golem at Large: What You Should Know about Technology*. Cambridge, MA: Cambridge University Press, 2002.

Colten, Craig E., ed. *Transforming New Orleans and Its Environs*. Pittsburgh: University of Pittsburgh Press, 2001.

Colten, Craig E. *An Unnatural Metropolis: Wresting New Orleans from Nature*. Baton Rouge: Louisiana State University Press, 2005.

Cronon, William. *Nature's Metropolis: Chicago and the Great West*. New York: W.W. Norton, 1992.

Daniels, Ronald J., Donald F. Kettl, and Howard Kunreuther, eds. *On Risk and Disaster: Lessons from Hurricane Katrina*. Philadelphia: University of Pennsylvania Press, 2006.

Dauber, Michele Landis. *The Sympathetic State: Disaster Relief and the Origins of the American Welfare State*. Chicago, IL: The University of Chicago Press, 2013.

Davis, Tracy C. *Stages of Emergency: Cold War Nuclear Defense*. Durham, NC: Duke University Press, 2007.

Downey, Gary Lee. "What Is Engineering Studies For? Dominant Practices and Scalable Scholarship." *Engineering Studies* 1, no. 1 (2009): 55–76.

Drehle, David von. *Triangle: The Fire That Changed America*. New York: Atlantic Monthly Press, 2003.

Eden, Lynn. *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation*. Ithaca, NY: Cornell University Press, 2004.

Eriskon, Kai. *A New Species of Trouble: The Human Experience of Modern Disasters*. New York: Norton, 1994.

Fortun, Kim. *Advocacy after Bhopal: Environmentalism, Disaster, New Global Orders*. Chicago, IL: The University of Chicago Press, 2001.

Fortun, Kim, and Scott Frickel. "Making a Case for Disaster Science and Technology." STS Forum on Fukushima, Virtual Conference, March, 2012.

Frickel, Scott, and M. Bess Vincent. "Hurricane Katrina, Contamination, and the Unintended Organization of Ignorance." *Technology in Society* 29, no. 2 (2007): 181–8.

Garrison, Dee. *Bracing for Armageddon: Why Civil Defense Never Worked*. Oxford: Oxford University Press, 2006.

Gershon, Robyn R. M., Lori A. Magda, Halley E. M. Riley, and Martin F. Sherman. "The World Trade Center Evacuation Study: Factors Associated with Initiation and Length of Time for Evacuation." *Fire and Materials* 36, nos. 5–6 (2011): 481–500.

Geschwind, Carl-Henry. *California Earthquakes: Science, Risk, and the Politics of Hazard Mitigation*. Baltimore, MD: The Johns Hopkins University Press, 2001.

Glanz, James, and Eric Lipton. *City in the Sky: The Rise and Fall of the World Trade Center*. New York: Times Books, 2003.

Gonzalez, Juan. *Fallout: The Environmental Consequences of the World Trade Center Collapse*. New York: New Press, 2002.

Greenberg, Amy S. *Cause for Alarm: The Volunteer Fire Department in the Nineteenth-Century American City*. Princeton, NJ: Princeton University Press, 1998.

Grossman, Andrew D. *Neither Dead Nor Red: Civil Defense and American Political Development in the Early Cold War*. New York: Routledge, 2001.

Hazen, Margaret Hindle, and Robert M. Hazen. *Keepers of the Flame: The Role of Fire in American Culture, 1775–1925*. Princeton, NJ: Princeton University Press, 1992.

Hilgartner, Stephen. *Science on Stage: Expert Advice as Public Drama*. Redwood City, CA: Stanford University Press, 2000.

Hilgartner, Stephen. "Overflow and Containment in the Aftermath of Disaster." *Social Studies of Science* 37, no. 1 (2007): 153–8.

Hoffer, Peter Charles. *Seven Fires: The Urban Infernos That Reshaped America*. New York: Public Affairs, 2006.

Hughes, Thomas Parke. *Networks of Power: Electrification in Western Society, 1880–1930*. Baltimore, MD: The Johns Hopkins University Press, 1983.

Irwin, Julia F. *Making the World Safe: The American Red Cross and a Nation's Humanitarian Awakening*. New York: Oxford University Press, 2013.

Jasanoff, Sheila, ed. *Learning from Disaster: Risk Management after Bhopal*. Philadelphia: University of Pennsylvania Press, 1994.

Kargon, Robert H., and Scott Gabriel Knowles. "Knowledge for Use: Science, Higher Learning, and America's New Industrial Heartland, 1880–1915." *Annals of Science* 59, no. 1 (2002): 1–20.

Kelman, Ari. *A River and Its City: The Nature of Landscape in New Orleans*. Berkeley: UC Press, 2003.

Kerr, Thomas J. *Civil Defense in the U.S.: Bandaid for a Holocaust?* Boulder, CO: Westview Press, 1983.

Knowles, Scott Gabriel. "Lessons in the Rubble: The World Trade Center and the History of Disaster Investigations in the United States." *History and Technology* 19, no. 1 (2003): 9–28.
Knowles, Scott Gabriel. *The Disaster Experts: Mastering Risk in Modern America*. Philadelphia: University of Pennsylvania Press, 2011.
Krugler, David F. *This Is Only a Test: How Washington D.C. Prepared for Nuclear War*. New York: Palgrave Macmillan, 2006.
Larabee, Ann. *Decade of Disaster*. Chicago, IL: University of Illinois Press, 1999.
Larson, Erik. *Isaac's Storm: A Man, a Time, and the Deadliest Hurricane in History*. New York: Crown Publishers, 1999.
Layton, Edwin M. *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession*. Baltimore, MD: Johns Hopkins University Press, 1986.
Leaning, Jennifer, and Langley Keyes, eds. *The Counterfeit Ark: Crisis Relocation for Nuclear War*. Cambridge, MA: Ballinger, 1984.
Lifton, Robert Jay. *Death in Life: Survivors of Hiroshima*. New York: Random House, 1967.
Lifton, Robert Jay. "Illusions of the Second Nuclear Age." *World Policy Journal* 18, no. 1 (2001): 25–30.
Maines, Rachel. *Asbestos & Fire: Technological Trade-Offs and the Body at Risk*. New Brunswick, NJ: Rutgers University Press, 2005.
Markowitz, Gerald E., and David Rosner. *Deceit and Denial: The Deadly Politics of Industrial Pollution*. Berkeley: University of California Press, 2003.
McEnaney, Laura. *Civil Defense Begins at Home: Militarization Meets Everyday Life in the Fifties*. Princeton, NJ: Princeton University Press, 2000.
McPhee, John. *The Control of Nature*. New York: Farar, Straus, and Giroux, 1989.
Melosi, Martin V. *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present*. Baltimore, MD: The Johns Hopkins University Press, 2000.
Mohun, Arwen P. "On the Frontier of the Empire of Chance: Statistics, Accidents, and Risk in Industrializing America." *Science in Context* 18, no. 3 (2005): 337–57.
Mohun, Arwen P. *Risk: Negotiating Safety in American Society*. Baltimore, MD: The Johns Hopkins University Press, 2013.
Mumford, Lewis. *The City in History: Its Origins, Its Transformations, and Its Prospects*. San Diego, CA: Harvest Books, 1989. Reprint of 1961 edition.
Nixon, Rob. *Slow Violence and the Environmentalism of the Poor*. Cambridge, MA: Harvard University Press, 2011.
Perrow, Charles. *Normal Accidents: Living with High-Risk Technologies*. New York: Basic Books, 1984.
Petroski, Henry. *Design Paradigms: Case Histories of Error and Judgment in Engineering*. Cambridge: Cambridge University Press, 1994.
Petroski, Henry. *Success Through Failure: The Paradox of Design*. Princeton, NJ: Princeton University Press, 2006.
Pfatteicher, Sarah K.A. *Lessons Amid the Rubble: An Introduction to Post-disaster Engineering and Ethics*. Baltimore, MD: The Johns Hopkins University Press, 2010.
Porter, Theodore M. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton, NJ: Princeton University Press, 1995.
Pritchard, Sara B., and Thomas Zeller. "The Nature of Industrialization." In *The Illusory Boundary: Environment and Technology in History*, edited by Martin Reuss and Stephen H. Cutcliffe, 69–100. Charlottesville: University of Virginia Press, 2010.
Pritchard, Sara B. "An Envirotechnical Disaster: Nature, Technology, and Politics at Fukushima." *Environmental History* 17 (April 2012): 219–243.
Pyne, Stephen J. *Fire in America: A Cultural History of Wildland and Rural Fire*. Princeton, NJ: Princeton University Press, 1982.
Reitherman, Robert K. *Earthquakes and Engineers: An International History*. Reston, VA: ASCE Press, 2012.
Reuss, Martin. "The Art of Scientific Precision: River Research in the United States Army Corps of Engineers to 1945." *Technology and Culture* 40, no. 2 (1999): 292–323.
Rose, Kenneth D. *One Nation Underground: The Fallout Shelter in American Culture*. New York: New York University Press, 2001.
Rosen, Christine Meisner. *The Limits of Power: Great Fires and the Process of City Growth in America*. Cambridge: Cambridge University Press, 1986.

Rosner, David, and Gerald Markowitz. *Are We Ready?: Public Health since 9/11*. Berkeley: University of California Press, 2006.
Rozario, Kevin. *The Culture of Calamity: Disaster and the Making of Modern America*. Chicago, IL: University of Chicago Press, 2007.
Sawislak, Karen. *Smoldering City: Chicagoans and the Great Fire, 1871–1874*. Chicago, IL: University of Chicago Press, 1995.
Schleifstein, Mark. *Upgraded Metro New Orleans Levees Will Greatly Reduce Flooding, Even in 500-Year Storms* < http://www.nola.com/hurricane/index.ssf/2013/08/upgrated_metro_new_orleans_lev.html > Times-Picayune, 2013.
Shrum, Wesley. "What Caused the Flood? Controversy and Closure in the Hurricane Katrina Disaster." *Social Studies of Science* 44, no. 1 (2014): 3–33.
Sinclair, Upton. *The Jungle*. New York: Signet Classic, 1906.
Slaton, Amy E. *Reinforced Concrete and the Modernization of American Building, 1900–1930*. Baltimore, MD: The Johns Hopkins University Press, 2001.
Smith, Carl. *Urban Disorder and the Shape of Belief: The Great Chicago Fire, the Haymarket Bomb, and the Model Town of Pullman*. Chicago, IL: University of Chicago Press, 1995.
Stein, Leon. *The Triangle Fire*. City: Carrol & Graff Publishers, 1962.
Tarr, Joel A. *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Akron: University of Akron Press, 1996.
Tarr, Joel A. "The Metabolism of the Industrial City: The Case of Pittsburgh." *Journal of Urban History* 28, no. 5 (2002): 511–45.
Tarr, Joel A. "The City as an Artifact of Technology and the Environment." In *The Illusory Boundary: Environment and Technology in History*, edited by Martin Reuss and Stephen H. Cutcliffe, 145–70. Charlottesville: University of Virginia Press, 2010.
Tebeau, Mark. *Eating Smoke: Fire in Urban America, 1800–1950*. Baltimore, MD: The Johns Hopkins University Press, 2003.
US Army Corps of Engineers. *Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System: Volume I, Executive Summary and Overview*. Washington, D.C.: US Army Corps of Engineers, 2009 .
Vaughan, Diane. *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*. Chicago, IL: University of Chicago Press, 1996.
Weart, Spencer R. *The Rise of Nuclear Fear*. Cambridge, MA: Harvard University Press, 2012 .
Wermiel, Sara E. *The Fireproof Building: Technology and Public Safety in the Nineteenth Century American City*. Baltimore, MD: Johns Hopkins University Press, 2000.
Winner, Langdon. *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago, IL: University of Chicago Press, 1986.
Wisnioski, Matthew. *Engineers for Change: Competing Visions of Technology in 1960s America*. Boston: MIT Press, 2012.