Daniel A. Farber*

"Beyond Imagination": Government Blind Spots Regarding Catastrophic Risks

Abstract: In the wake of the Fukushima nuclear disaster, decision makers described the reactor failures and the tsunami that triggered them as beyond imagination. Yet, the possibility of such a tsunami was understood by experts and the implications for reactor safety were clear. This was not an isolated phenomenon in natural or human catastrophes. This paper considers why the possibility of catastrophic event is often excluded from consideration and methods for incorporating low-probability catastrophes into risk assessment. In part, this phenomenon can be explained by the goals of decision makers and avoidance of cognitive dissonance. Moreover, professional cultures may blind even experts to risks that do not fit established paradigms. The paper considers some possible mechanisms for ameliorating the problem.

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> "*Imagination is not a gift usually associated with bureaucracies.*" – US 9/11 Commission[1]

> "*[A]s we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones.*" – Donald Rumsfeld[2]

During the Fukushima nuclear crisis, government officials and industry representatives said that the tsunami that struck the reactors was beyond imagination, thus excusing the failure to consider such a risk in the planning process.[3] As it

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1 National Commission on Terrorist Attacks Upon the United States, The 9/11 Commission Report 344 (2004) available at http://govinfo.library.unt.edu/911/report/index.htm.

2 Department of Defense News Briefing, Secretary Rumsfeld and Gen. Myers (February 12, 2002), http://www.defenselink.mil/transcripts/transcript.aspx?transcriptid=2636.

3 Eliza Strickland, *Q&A With a Former Fukushima Dai-1 Plant Manager*, IEEE Tech Talk (May 17, 2011) http://spectrum.ieee.org/tech-talk/energy/nuclear/the-scale-of-the-accident-was-beyond-

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***Corresponding author: Daniel A. Farber,** Sho Sato Professor of Law, University of California, School of Law (Boalt Hall), Berkeley CA 94720-7200, USA, e-mail: dfarber@law.berkeley.edu

turns out, there had been warnings about the possibility of a tsunami of this magnitude, but the warnings were ignored.

The reactors were situated on a small bluff, which was thought to provide sufficient protection.[4] There is a historical record of a large tsunami in the region in July 869, and geological evidence indicating a 1000-year return cycle.[5] Indeed, the historical record over the past 500 years includes a dozen tsunamis hitting Japan with heights over 10 meters, half of them over 20 meters.[6] However, the Tokyo Electric Power Company (TEPCO) designed the reactor to survive the worst event after 1896, considering evidence of earlier events inconclusive despite publications about such events in peer reviewed

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my-imagination/, ("The scale of the Fukushima Dai-1 accident was far beyond my imagination."); Eisuke Sasaki, *TEPCO Procrastinated Even After Tsunami Threat Shown*, The Asahi Shimbun (November 9, 2011), http://ajw.asahi.com/article/0311disaster/analysis/AJ2011110915073, ("On March 11, the Fukushima No. 1 nuclear plant was swamped by a tsunami "beyond imagination," in TEPCO's words."); Yomiuri Shimbun, *TEPCO Report Says Japan Govt Caused 'Unnecessary Confusion,'* ASIA ONE (June 22, 2012) http://www.asiaone.com/print/News/AsiaOne%2BNews/Asia/Story/A1Story20120622-354580.html. (TEPCO investigation blames "a giant tsunami beyond our imagination."); One Japanese expert said:

> This earthquake was a natural disaster that far exceeded conventional human knowledge. It reminded us of how vulnerable we are in the power of nature. The sea walls and barriers which we thought to be completely adequate based on the past experience proved to be utterly useless in the face of an earthquake and aftermath tsunami beyond our imagination.

Thoughts on Disaster – from Japan, QFDI Newsletter, http://www.qfdi.org/newsletters/thoughts_on_disaster.html (undated but clearly contemporaneous with the disaster events based on other material).

4 Yuri Kageyama & Justin Pritchard, *Fukushima Tsunami Plan: Japan Nuclear Plant Downplayed Risk*, HUFFINGTON POST (March 27, 2011), http://www.huffingtonpost.com/2011/03/27/fukushima-tsunami-plan-japan_n_841222.html:

> A TEPCO reassessment presented only four months ago concluded that tsunami-driven water would push no higher than 18 feet (5.7 meters) once it hit the shore at the Fukushima Dai-ichi complex. The reactors sit up a small bluff, between 14 and 23 feet (4.3 and 6.3 meters) above TEPCO's projected high-water mark, according to a presentation at a November seismic safety conference in Japan by TEPCO civil engineer Makoto Takao.
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> "We assessed and confirmed the safety of the nuclear plants," Takao asserted.

5 Rodney C. Ewing, Jeroen Ritsema, & David J. Brenner, *Fukushima: What Don't We Know?*, BULL. ATOMIC SCIENTISTS (June 30, 2011), available at http://thebulletin.org/node/8749.

6 James M. Acton & Mark Hibbs, WHY FUKUSHIMA WAS PREVENTABLE 12 (Carnegie Endowment for International Peace, March 2012), available at http://carnegieendowment.org/files/fukushima.pdf.

geology journals.[7] Even so, TEPCO had reason to distrust its own estimates. In 2008, TEPCO had performed some preliminary modeling that suggested that the tsunami hazard was much greater than its previous estimate.[8] Specifically:

> When the source of the Meiji Sanriku-oki event of 1896 and the source of the Boso-oki event of 1677 were relocated to the gap off Fukushima Prefecture, the simulations produced tsunami heights of 15.7 and 13.6 meters, respectively.
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> But TEPCO argued that these results included assumptions because the scenarios were not actually based on an event in the target location. It decided not to revise its official tsunami height prediction, although the simulated heights far exceeded 5.7 meters in both cases.
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> TEPCO management was also informed of the simulation results, but it merely said it would "prepare" or consider potential improvements on waterproof designs for reactor buildings and pumping equipment.[9]

In 1983, the International Atomic Energy Agency began to call for computer modeling of tsunami safety.[10] Until 2006, however, the Japanese government did not even discuss tsunamis in its safety guidelines."[11] The government's failure to address the possibility of tsunamis until such a late date, in a country with such a history of tsunamis and earthquakes, itself seems almost beyond imagination. Even in 2006 the Japanese government insisted that the "robust sealed containment structure around the reactor itself would prevent any damage to the nuclear part of the reactor from a tsunami ... No radiological hazard would be likely."

The events turned out differently. At 2:46 p.m. Japan standard time on March 11, 2011, a 9.0 earthquake struck off the east coast of Honshu, Japan, 109 miles ENE of Fukushima and 231 miles NE of Tokyo.[12] The earthquake also triggered a large tsunami that overwhelmed seawalls and contributed to massive destruction.[13]

7 Kageyama, *supra* note 5.

8 Acton, *supra* note 7, at 13.

9 Sasaki, *supra* note 4.

10 Acton, *supra* note 7, at 14.

11 Charles Perrow, *Fukushima, Risk, and Probability: Expect the Unexpected*, Bull. Atomic Scientists (April 1, 2011), available at http://thebulletin.org/node/8702.

12 Earthquake Hazards Program, Magnitude 9.0—Near the East Coast of Honshu, Japan, USGS, http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xgp/.

13 Norimitsu Onishi, *Seawalls Offered Little Protection Against Tsunami's Crushing Waves*, N.Y. Times (March 13, 2011), https://www.nytimes.com/2011/03/14/world/asia/14seawalls.html?pagewanted=all. In contrast, a hundred miles away from Fukushima, the Japan Atomic Power Company had begun an upgrade of its Tokai-2 plant. The company had completed construction of a wall around a pit where the seawater pumps were located, and as a result, it was able to keep two of its three emergency generators in operation. Acton, *supra* note 7, at 18.

During the earthquake, the Fukushima Dai-ichi lost its outside power connection to the electrical grid. Backup diesel generators came on at this time. The Dai-ni plant did not lose power, but safety systems were damaged.[14] About 46 minutes after the quake, the first waves of a large tsunami reached the Fukushima Dai-ichi power station. The tsunami reached about 14 meters (45 feet) at the Dai-ichi power station, overwhelming the 6-meter (18-foot) seawall. The International Atomic Energy Agency (IAEA) report provides a vivid sense of the post-tsunami state at the nuclear plant:

> The tsunami and associated large debris caused widespread destruction of many buildings, doors, roads, tanks and other site infrastructure at Fukushima Dai-ichi, including loss of heat sinks. The operators were faced with a catastrophic, unprecedented emergency scenario with no power, reactor control or instrumentation, and in addition, severely affected communications systems both within and external to the site. They had to work in darkness with almost no instrumentation and control systems to secure the safety of six reactors, 6 nuclear fuel pools, a common fuel pool and dry cask storage facilities.[15]

Explosions occurred at Units 1–4; the explosions at Units 1–3 were caused by a build-up of hydrogen and the cause for the explosion at Unit 4 remains unknown. Diesel generators at Unit 6 remained functional in the aftermath of the tsunami and workers were able to use it to achieve a cold shutdown[16] at Units 5 and 6. Emergency Situations were declared for both the Fukushima Dai-ichi and Fukushima Dai-ni power stations resulting in evacuations and emergency measures.[17]

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14 International Atomic Energy Agency, Mission Report: The Great East Japan Earthquake Expert Mission, 29, 37–38 (May 24–June 2, 2011), available at http://www-pub.iaea.org/MTCD/Meetings/PDFplus/2011/cn200/documentation/cn200_Final-Fukushima-Mission_Report.pdf.

15 *Ibid.* at 12. The operators suffered under great handicaps in responding to the crisis:

> The extreme difficulties that the operators on the site had to face in Fukushima Dai-ichi have to be once again strongly underlined: loss of all the safety systems, loss of practically all the instrumentation, necessity to cope with simultaneous severe accidents on four plants, lack of human resources, lack of equipment, lack of light in the installations, and general conditions of the installation after the tsunami and after damage of the fuel resulted in hydrogen explosions and high levels of radiation.

Ibid. at 43.

16 Cold shutdown is achieved after several days once the reactor is no longer critical (temperatures below 200°F) – even after the cooling rods are inserted and fission stops, the radioactive products continue to generate significant heat.

17 See the May 17th update of the TEPCO Roadmap towards Restoration here: http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110517e3.pdf.

This was not the first Japanese nuclear accident "beyond our imagination." On July 16, 2007 an earthquake damaged the Kashiwazaki-Kariwa Nuclear Power Plant. The designers used the historic record and added a margin of safety – but still reached only 40% of the actual quake strength. Apparently, what they thought were three small faults were actually part of one large fault. Also, the accident involved unforeseen mechanisms of harm. One company official said: "It was beyond our imagination that a space could be made in the hole on the outer wall for the electric cables."[18] This event should have been a warning about the unreliability of seismic predictions and the potential for unprecedented harm mechanisms. Yet officials and industry continued as if they had a full understanding of all the risks, rather than realizing the need for additional precautions.

We have seen similar issues in the United States. After 9/11, officials claimed that it had been impossible to foresee the use of an airliner against a commercial building by terrorists – yet it turned out that such efforts actually had been foreseen and indeed that terrorists had attempted to use a smaller plane as a weapon.[19] Before the BP Oil Spill, officials and industry actors also argued that the risk of a major blowout was too small to be a concern with respect to deep water drilling.

In each of these cases, a risk was brushed aside but later materialized with disastrous results. I will analyze this syndrome and discuss some possible ways of combatting it. Part I will provide a US case study relating to nuclear risks. Until a breach-of-containment accident occurred at Three Mile Island, officials maintained that such an event was so unlikely that it could be completely ignored. Even afterwards, they argued that they had no duty to consider such risks in the future. Similarly, the government has steadfastly refused to discuss the consequences of a terrorist attack on a nuclear reactor because it considers such an attack speculative. These incidents illustrate the syndrome of risk repression and the need to change agency behavior. Risk repression is a recipe for disaster. As one senior expert on nuclear safety puts it, "if, having made every provision for safety, you think for a minute that an accident is not possible, you put yourself at risk of being proved disastrously wrong."[20]

The 9/11 Commission said that it is "crucial to find a way of routinizing, even bureaucratizing, the exercise of imagination."[21] The article approaches from two

18 Ashwin Kumar & M.V. Ramana, *Nuclear Safety Lessons from Japan's Summer Earthquake*, Bull. Atomic Scientists (December 4, 2007), available at http://thebulletin.org/node/168.

19 9/11 Report, *supra* note 2, at 344–346.

20 *Special report, Nuclear Energy: Blow-ups Happen*, The Economist (March 13, 2012), available at http://www.economist.com/node/21549095/.

21 9/11 Report, *supra* note 2, at 344.

legal systems that could be used to address this phenomenon. Although they have similarities, the two approaches could play different functions in ensuring adequate attention to risks. One approach is the "worst case scenario" regulation, which formerly required US agencies to consider the environmental consequences of the worst plausible disaster scenario when making decisions. The other approach is the precautionary principle, which might be used as a lever to get agencies to consider a broader spectrum of risks and to place more emphasis on post-event resilience.

The Risk Repression Syndrome

If it occurs, an event may be extremely harmful, yet the probability may be so low that it is not worth discussing. For instance, the chances of a meteor strike at a specific location presumably do not need to be discussed. But whether a risk is significant enough for consideration is often hotly disputed. The incidents discussed in the Introduction show how risks have sometimes been repressed in the regulatory process rather than being adequately explored. Part A discusses some similar episodes in the United States in which regulators have refused to engage in a public discussion of the impact of certain risks, repressing them from consideration in the formulation of policy.

US Regulation of Nuclear Reactors

Is the risk of a radioactive release from a nuclear reactor significant enough to require consideration? In the United States, this issue arises in the context of the National Environmental Policy Act (NEPA), which requires the preparation of environmental impact statements (EIS). Nuclear power provides an important illustration of this issue. In *Carolina Environmental Study Group v. United States*,[22] the petitioners sought review of the issuance of a construction license to build two reactors about seventeen miles from a major city. The issue was whether the EIS should have discussed the risk of a breach-of-reactor containment accident. Such an event, which the government termed a Class 9 accident, involves concurrent rupture of the three-foot thick concrete containment vessel and the several inches of steel surrounding the reactor core, resulting in the exposure of the radioactive core to the atmosphere. The Fukushima reactor failures and Chernobyl both illustrate the potential seriousness of such a breach.

22 510 F.2d 796 (D.C. Cir. 1975).

A later judicial opinion quotes the EIS for the proposed reactors and explains its significance:

> The postulated occurrences in Class 9 involve sequences of successive failures more severe than those required to be considered in the design bases of protective systems and engineered safety features. The consequences could be severe. However, the probability of their occurrence is so small that their environmental risk is extremely low.***
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> What the [government agency] means by the small probability of such accidents is seen in its report: some experts held that numerical estimates of a quantity [of major accidents] so vague and uncertain that the likelihood of occurrence of major reactor accidents have no meaning. They declined to express their feeling about this probability in numbers. Others, though admitting similar uncertainty, nevertheless ventured to express their opinions in numerical terms. Estimations so expressed of the probability of reactor accidents having major effects on the public ranged from a chance of one in 100,000 to one in a billion per year for each large reactor. However, whether numerically expressed or not, there was no disagreement with the opinion that the probability of major reactor accidents is very low.[23]

The court upheld the government's refusal to discuss the impact of a Class 9 accident in the impact statement:

> The A.E.C. [Atomic Energy Commission] is required by NEPA to set forth the factors involved, to the end that the ultimate decision on a proposed course of action shall be enlightened by prior recognition of its impact on the quality of human environment. Viewing the record as a whole, we cannot say that the A.E.C.'s general consideration of the probabilities and severity of a Class 9 accident amounts to a failure to provide the required detailed statement of its environmental impact. That the probability of a Class 9 accident is remote and that its consequences would be catastrophic are undisputed. Neither the A.E.C.'s finding of low probability, nor its methodology or basis for that finding, are challenged here by appellant.
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> Because each statement on the environmental impact of a proposed action involves educated predictions rather than certainties, it is entirely proper, and necessary, to consider the probabilities as well as the consequences of certain occurrences in ascertaining their environmental impact. There is a point at which the probability of an occurrence may be so low as to render it almost totally unworthy of consideration.[24]

This analysis does not withstand careful examination. Suppose that the agency's analysis was correct and that the risk of a severe accident was at the high end of the range discussed by the court, one in a hundred thousand per year of

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23 The court observed that "A.E.C. report WASH-740, pg. viii, estimated that a Class 9 accident in a reactor approximately one-seventh the size of one of Duke's reactors would result in up to 3400 deaths, 43,000 injuries, and $7 billion property damage." *Ibid.* at 799 n.4.
24 *Ibid.* at 799.

operation. This may seem inconsequential. But the lifetime of a reactor can easily be forty years. That means that the risk of a severe accident at any particular reactor during its lifetime was one in 2500. A one in 2500 chance of a catastrophic outcome is something that a reasonable person would want to know about, and if the costs and benefits of the project were otherwise closely balanced, this risk could swing the scales against locating the reactor so close to a city. The risk might also be relevant to considering the program as a whole – with fifty reactors, the risk of a breach of containment would rise to one in fifty.

As it turns out, the agency's confidence in the near impossibility of a breach-of-containment accident turned out to be misplaced. The later Three Mile Island episode was classified as a Class 9 accident although the leakage of radioactive materials was, fortunately, very limited. Nevertheless, one appeals court held that the Nuclear Regulatory Commission (NRC) *still* did not have to consider the possibility of Class 9 accidents:

> As we have discussed above, the Commission did not conclude in its Statement of Interim Policy that its original assumption regarding Class Nine accidents was scientifically incorrect. Rather, it recognized the need for renewed study of the issue. The clear import of the Commission's Statement is that, until such time as its research yields a contrary result, the Commission continues to regard Class Nine accidents as highly improbable events.
>
> We do not consider that conclusion unreasonable. Neither the 1978 study by the Risk Assessment Review Group nor the accident at Three Mile Island established that the probability of a Class Nine accident with significant environmental consequences is anything but very small. … Because the environmental consequences of Three Mile Island were scientifically and legally inconsequential, the fact that the accident occurred does not establish that accidents with significant environmental impacts will have significant probabilities of occurrence.[25]

This analysis was rejected by another federal appeals court in *Limerick Ecology Action Inc. v. US Nuclear Regulatory Comm'n*; it was persuaded by the plaintiff's argument that "after Three Mile Island, it would be irrational for the NRC to maintain that severe accident risks are too remote to require consideration."[26] The court found the fact that the NRC was performing research on the likelihood of such risks indicated "that [the Commission] no longer considers such risks as remote and speculative," and a "discussion of severe accident potential" was therefore required in the environmental impact statement.[27]

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25 San Luis Obispo Mothers for Peace v. Nuclear Regulatory Comm'n, 751 F.2d 1287, 1301 (D.C. Cir. 1984), *vacated in part* 760 F.2d 1320 (D.C. Cir. 1985) (en banc).

26 869 F.2d 719, 740–41 (3d Cir. 1989).

27 *Ibid.* at 740, 741.

In addition to courts' disagreement about whether the risk of an *accidental* release is too low to be worth considering, in the post-9/11 world, they also disagree about whether the risk of terrorism requires consideration. The Department of Energy now requires reactor operators to prepare for attack by a "suicidal, well-trained paramilitary force, armed with automatic weapons and explosives," and the industry says it has spent over $1 billion in security-related capital improvements.[28] One federal appeals court rejected the NRC's view that the risk of terrorist attacks on reactors was too speculative to require discussion in an impact statement. The court said:

> If the risk of a terrorist attack is not insignificant, then NEPA obligates the NRC to take a "hard look" at the environmental consequences of that risk. The NRC's actions in other contexts reveal that the agency does not view the risk of terrorist attacks to be insignificant. Precise quantification is therefore beside the point.[29]

The court was also skeptical of the agency's claim that quantitative analysis was impossible.[30] The court seems clearly correct that the inability to quantify a risk does not justify failure to discuss it if there are other grounds for considering it significant. Many aspects of environmental impacts are difficult to quantify. The court's insistence that the agency actually *could* quantify the risk seems more debatable. Given the small degree of experience with major terrorist attacks, quantification in large part would have to be based on the subjective judgments of experts. This may be useful for some purposes, but it is not necessarily more useful as a method of disclosing risks to the public than a more qualitative discussion. Still, the risk is not so wildly unpredictable that any quantitative effort would be completely meaningless.

Notwithstanding the force of the court's reasoning, the Nuclear Regulatory Commission has adamantly refused to change its policy.[31] Another court agreed with the agency that an impact statement for a nuclear site re-licensing did not need to discuss the possibility of terrorist attack.[32] In so holding, the court did

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28 John L. Jurewitz, *The Current Outlook for the Nuclear Power Industry in the United States*, *in* International Perspectives of Energy Policy and the Role of Nuclear Power (Lutz Mez, Mycle Schneider & Steve Thomas eds., 2009).

29 *San Luis Obispo Mothers for Peace*, 449 F.3d at 1032.

30 *Ibid.*

31 In the Matter of Amergen Energy Co., 50-0219-LR, 2007 WL 595084 (N.R.C. February 26, 2007). Early, the agency had said that addressing terrorism was inappropriate because an EIS should only address environmental impacts that will result "with a fair degree of likelihood." In the Matter of Private Fuel Storage, L.L.C., 56 N.R.C. 340, 347 (2002).

32 N.J. Dep't of Envtl. Prot. v. US Nuclear Regulatory Comm'n, 561 F.3d 132 (3d Cir. 2009).

not focus on the difficulty of quantifying the risk, but on the causation issue.[33] It reasoned that both the criminal act of a third-party and "the failure of all government agencies specifically charged with preventing terrorist attacks" would have to occur to cause an actual terrorist attack.[34] The court held that "this causal chain is too attenuated to require NEPA review."[35] The court characterized this result as good policy because it prevents the agency from wasting its resources "assessing security risks over which it has little control which would not likely aid its other assigned functions to assure the safety and security of nuclear facilities."[36] The latter argument seems inapplicable to licensing of new plants, because the risk of a terrorist attack would increase the desirability of placing the facility in an isolated area away from any population concentration.[37]

The Third Circuit's analysis of causation seems peculiar. It is true that the government is not responsible for the occurrence of acts of terrorism. But in a number of circumstances, courts have held that owners of facilities (such as airplanes or the Twin Towers) have a duty to anticipate the possibility of a terrorist attack. Surely a rational government agency or a rational citizen in the vicinity would consider this risk to be relevant to assessing the continued operation of a reactor unless the risk was known with some certainty to be microscopic.

The relevance of such an attack does not mean that it should be decisive in terms of the licensing decision or even that it would necessarily carry a lot of weight in the decision. But it seems irrational to rule this risk out in deciding whether to hold radioactive fuel and waste at the site. If the decision is made to re-license the project, the agency might at least decide to increase security or to require more careful preparation of evacuation plans.

Mechanisms that Lead to Risk Repression

Part A provides another illustration beyond Fukushima of the reluctance of regulatory agencies to consider low-probability catastrophic outcomes when

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33 *Ibid.* at 132.

34 *Ibid.* at 140.

35 *Ibid.*

36 *Ibid.* at 141.

37 US reactors have been located close to population centers, including over twenty plants located within thirty kilometers of a city of 300,000 or more. One reactor has 17 million people within fifty miles. Thomas B. Cochran, Senior Scientists, Nuclear Program, Natural Resources Defense Council, Statement on the Fukushima Nuclear Disaster and its Implications for US Nuclear Power Reactors: Joint Hearings of the Subcommittee on Clean Air and Nuclear Safety and the Committee on Environment and Public Works (April 12, 2011) available at http://www.nrdc.org/nuclear/files/tcochran_110412.pdf.

they are deciding whether to allow a project to proceed. It remains important to understand some of the reasons for this syndrome of risk repression. The reasons for this reluctance are probably in part psychological and in part institutional.

In institutional terms, there are several barriers to considering catastrophic risks. Overly optimistic predictions can result from the "economic and political pressures placed on the technical consultants and the government managers, which lead them to use inadequate models and to misuse their predictive results."[38] The pressures can take several forms.

First, agencies are often politically close with industries that want to pursue projects, such as the nuclear industry. These industries are wealthy, well organized, and politically powerful. Potential victims of catastrophic risk are a diffuse group and may not even be aware of the existence of the risk. So political forces may favor approval of projects, and an agency can only cause political trouble for itself by acknowledging that it is approving a project despite a potential catastrophic outcome.

Second, project benefits will be seen soon after the project is completed. A catastrophic risk may never materialize or may be delayed for years in the future. An official can gain immediate credit for approving a beneficial project, while the possibility of blame for a catastrophic failure is small and might well occur after the official has retired or moved to another position. Thus, it may be more advantageous for officials to support projects rather than impeding them by focusing on potential risks.

Third, the parties who raise concerns about catastrophic risks are often opposed to agency actions on other grounds. An official who sides with these "enemies" of the agency may appear disloyal and suffer career consequences. We may see this to some extent in terms of the pressures exerted against the prior head of the Nuclear Regulatory Commission, who was somewhat more aggressive about pursuing safety than his colleagues. Officials who raise concerns about risks may also disqualify themselves from industry employment after their period of government service. Within industry, officials who raise concerns about risks relating to lucrative projects are even more likely to face career repercussions.

Apart from these institutional factors, there may be psychological reasons for dismissing potential catastrophic risks rather than taking them seriously. The first reason is sometimes called groupthink – the "tendency of groups, especially highly homogenous groups, to develop strongly held, extreme positions even

38 Robert E. Moran, *Is this Number to Your Liking? Water Quality Predictions in Mining Impact Studies*, *in* PREDICTION: SCIENCE, DECISION MAKING, AND THE FUTURE OF NATURE 187 (Daniel Sarewitz, Roger A. Pielke, & Radford Byerly eds., 2000).

in the face of contrary data."[39] Although this phenomenon is still the subject of on-going research, there is some evidence linking it with disregard of potential severe outcomes:

> [T]here is sufficient support for the notion that some form of groupthink leads to a predictable discounting of risks, which, in turn, bears some probabilistic relationship to bad outcomes, however they are defined. At a high level of generality, groupthink phenomena have been observed in the failure of corporate boards to conduct meaningful oversight in the wake of the Enron debacle, the stifling of dissent by administrative agencies, environmental regulation in general, and the conduct of the Army Corps of Engineers before Hurricane Katrina in particular.[40]

The dangers of groupthink are accentuated when the agency culture discourages discussion of risks and when individuals with contrary views are denied promotion or sanctioned, as appeared to be the case before the Deepwater Horizon BP oil spill.[41]

A related phenomenon involves confirmation bias:

> Group confirmation bias occurs when groups "search unduly for information and pay too much attention to arguments that confirm initial hypotheses." While individuals are of course subject to this same bias, it may become exacerbated in groups due to the group polarization phenomena described above. Thus, "[e]ven when some group members may be aware of information that undermines a group's initially preferred decision, the group may fail to consider the information to the same extent as it would consider confirming information."[42]

Because catastrophic outcomes are rare events, the agency may well have the experience of approving similar projects and observing for a number of years that no risk has materialized, reinforcing the agency's bias to disregard such risks as insignificant.

There are also aspects of individual psychology that may lead individuals to downplay risks:

> Prospect or loss aversion theory predicts that individuals generally will be risk-averse with respect to the receipt of gains but risk preferring with respect to the avoidance of losses. One implication of this theory is that, when choosing between the receipt of a sure gain and an unsure gain with equal expected value, people will choose to receive the sure gain.

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39 Michael Barsa and David A. Dana, *Reconceptualizing NEPA to Avoid the Next Preventable Disasters*, 38 B.C. Envtl. Aff. L. Rev. 219, 220 (2011).

40 *Ibid.* at 227–28.

41 *Ibid.* at 228–29.

42 *Ibid.* at 231–32.

> Conversely, when choosing between the avoidance of a sure loss and the avoidance of an unsure loss of equal expected magnitude, people will choose to avoid the sure loss.[43]

A related issue is known as myopia:

> A substantial experimental literature suggests that people value the avoidance of immediate or nearly immediate losses far more strongly than the avoidance of losses even in the not-too-distant future. This powerful drive to avoid immediate losses is not unique to human beings, and some have speculated it has deep roots in evolutionary biology. The myopic focus on immediate losses also may reflect the availability bias, as such losses typically are easier to imagine than losses that would occur, if at all, only years hence, and the optimism bias, whereby people may believe, even in the absence of any factual basis, that with time they will find a costless means to avoid future risks. The myopia bias suggests that decisionmakers will weigh immediate economic losses more heavily than they should in comparison with non-immediate health and environmental losses.[44]

Again, since catastrophes will often strike in the future (if at all), they may be downplayed compared with the prospect of losing the economic benefits of a project in the near future.

This combination of collective and individual biases can push hard against recognition of the relevance of catastrophic risks. It is no surprise that agencies like the NRC are reluctant to take seriously into account the possibility of disastrous events. The hard question, however, is how to change this behavior without saddling agencies with unreasonable obligations or ignoring their essential dynamics. We will consider two approaches to this problem.

Scenario Planning

For about a decade, the United States experimented with an interesting mechanism for forcing consideration of catastrophic risks. In 1978, the Council on Environmental Quality (CEQ), the executive agency supervising environmental impact statements (EISs) by federal agencies, provided direction to agencies on how to deal with scientific uncertainty.[45] The regulation applied when there were "gaps in relevant information or scientific uncertainty" about a project's environ-

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43 David A. Dana, *A Behavioral Economic Defense of the Precautionary Principle*, 97 Nw. U. L. Rev. 1315, 1323 (2003).

44 *Ibid.* at 1324–25.

45 See Edward A. Fitzgerald, *The Rise and Fall of Worst Case Analysis*, 18 U. Dayton L. Rev. 1 (1992).

mental impacts.[46] When such information was obtainable at reasonable cost, the agency was instructed to obtain it, but otherwise the agency was told to include a worst-case analysis in the impact statement.[47] In a 1981 guidance document, CEQ explained this rule as mandating "reasonable projections of the worst possible consequences of a proposed action."[48] On this basis, rather than focusing on the most likely tsunami severities in the Japanese situation, an agency would have been pressed to project the worst possible tsunami.

Sierra Club v. Sigler[49] was the leading case to apply the worst-case requirement. The case involved a controversial proposal to allow oil tankers to operate in an estuary near the Port of Galveston.[50] The EIS concluded that the project would not significantly increase the probability or likely harm of an oil spill.[51] The relevance of oil spills to the decision was unquestioned and the parties agreed that "an analysis of a supertanker oil spill involving a total cargo loss beyond 24 h after it occurs is beyond the state of the art."[52] The agency had thought this possibility was too remote to warrant discussion. Relying on CEQ's 1981 guidance document, however, the appellate court held that the EIS was invalid because it "failed to discuss the 'catastrophic impact' of a total cargo loss by a supertanker in the Bay." and the court faulted the agency for failing to consider "that impact and the probability of its occurrence" in deciding to proceed.[53]

In the court's view, the fact that a risk was extremely remote was relevant in assessing its ultimate import for the final decision but not relevant in deciding whether to include a discussion of it as the worst-case scenario.[54] The court hastened to add, however, that "while remoteness of a possible occurrence does not permit disregarding it in such circumstances as these, where a real possibility of the occurrence has been proved and a database for evaluating its consequences established, the Corps need not concern itself with phantasmagoria hypothesized without a firm basis in evidence and the actual circumstances of the contemplated project, or with disasters the likelihood of which is not shown to be significantly increased by the carrying out of the project."[55]

46 40 C.F.R. § 1502.22 (1991).
47 *Ibid.* § 1502.22(b).
48 Vicki O. Masterman, *Worst Case Analysis: The Final Chapter?*, 19 Envtl. L. Rep. 10026, 10027 n.14 (1989).
49 Sierra Club v. Sigler, 695 F.2d 957 (5th Cir. 1983).
50 *Ibid.* at 962.
51 *Ibid.* at 968.
52 *Ibid.* at 973.
53 *Ibid.*
54 *Ibid.* at 974.
55 *Ibid.* at 975 n.14.

The worst-case requirement was criticized as being excessively pessimistic and too intrusive on agency discretion.[56] In its 1981 guidance document, CEQ had explained the rule as mandating "reasonable projections of the worst possible consequences of a proposed action."[57] In 1983, CEQ had proposed (but later withdrew) a guidance document that would have required a worst-case analysis only when a risk crossed an "initial threshold of probability" and was reasonably foreseeable but its consequences were uncertain.[58] In the case of breach-of-containment accidents, for instance, this modification of the regulation would have allowed the NRC to avoid discussion of the breach-of-container accident based on low probability.

After withdrawing the 1983 proposal, CEQ called for public comment on possible methods of dealing with uncertainty. It received a range of complaints about the worst case requirement such as "the limitless nature of the task of conjuring the worst possible case," "the lack of expert support for worst-case analysis in the growing field of risk analysis," and the "minimal value of fanciful worst-case analyses to federal decision-makers who must balance a full range of proven competing interests."[59]

CEQ then issued a new regulation dealing with uncertainty, replacing the worst-case scenario requirement. The new regulation, which is still in effect, tells agencies that when important information is not available at a reasonable cost, they must summarize the available evidence about reasonably foreseeable impacts and discuss "the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community."[60] The regulations define "reasonably foreseeable" to include impacts "which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason."[61] The Supreme Court upheld this regulation in *Robertson v. Methow Valley Citizens Council* and held that NEPA does not require a worst-case analysis.[62]

The current regulation gives agencies more discretion than the worst-case scenario rule. Yet the new regulation does seem to have some bite. For instance,

56 See Charles Weiss, Note, *Federal Agency Treatment of Uncertainty in Environmental Impact Statements Under the CEQ's Amended NEPA Regulation § 1502.22: Worst Case Analysis or Risk Threshold?*, 86 Mich. L. Rev. 777, 807–09 (1988).

57 Masterman, *supra* note 49, at 10027 n.14.

58 *Ibid.*

59 *Ibid.* at 10028.

60 40 C.F.R. § 1502.22(b) (1991).

61 *Ibid.*

62 *Robertson v. Methow Valley Citizens Council*, 490 US 332 (1989).

the Eighth Circuit vacated the Surface Transportation Board's final decision approving a project to construct railroad lines to coal mines in *Mid States Coal. for Progress v. Surface Transp. Bd.*, in part because the Board failed to discuss an adverse impact due to incomplete information.[63] The corporation undertaking the project argued that the impact on air quality caused by the rail lines' supply of coal to power plants was too speculative to require consideration, but the court clarified that "when the *nature* of the effect is reasonably foreseeable but its *extent* is not," the agency's EIS must follow the regulation.[64] Despite instances of courts giving teeth to the new regulation, commentators still view it as less demanding of agencies than the earlier rule.[65] For instance, one court of appeals accepted a government estimate that the risk of a conventional explosion by a mishandled missile was far less than one in a trillion and that the Navy therefore did not need to disclose the consequences to the public, although the Navy itself considered the risk substantial enough to be a factor in designing its naval base.[66]

In light of the BP oil spill, one notable environmental scholar has called for changes in the current rule:

> The first [change] is the removal of the "reasonably foreseeable" threshold for events of catastrophic proportion, which has become an escape valve of choice for the federal family. Standard risk analysis tells us that, the more severe the potential consequences, the more precaution is required. The second is to restore the phrase "worst-case analysis" to its original place, calling the inquiry what it is. Ever since the Supreme Court picayunely seized on its absence to trash a worst-case claim, the federal judiciary has largely abandoned the field, and any rewrite will fare the same unless the labeling is unambiguous. Words matter.[67]

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63 345 F. 3d 520, 549–50 (8th Cir. 2003).

64 Likewise, in Cabinet Res. Group v. United States Fish & Wildlife Serv., the court set aside the Forest Service's final EIS because it failed to address gaps in a key study it relied on in assessing a motorized access plan's impact on grizzly bears. 465 F. Supp. 2d 1067, 1099–1100 (D. Mont. 2006). The court found that the missing information was "essential to a reasoned choice among alternatives" based on statements from the study's authors and other scientists in the field, and interpreted § 1502.22 to require agencies to explicitly "acknowledge and discuss any flaws," in studies relied on in an EIS. *Ibid.* at 1100.

65 See, e.g., George Cameron Coggins & Robert L. Glicksman, Public Natural Resources Law §10G:22, 10G-139 (2007) (describing the new regulation as "water[ed] down"); James Jay Tutchton, *Robertson v. Methow Valley Citizens Council and the New "Worst Case Analysis" Regulation*, 8 UCLA J. Envtl. L. & Pol'y 287, 299 (1989) (predicting that courts could use the language of new regulation to weaken the scope of environmental protection provided by worst case analysis).

66 Ground Zero Center for Nonviolent Action v. US Dep't of Navy, 383 F.3d 1082 (9th Cir. 2004).

67 Oliver A. Houck, *Worst Case and the Deepwater Horizon Blowout: There Ought to be a Law*, 40 Envtl. L. Rep. News & Analysis 11033, 11039 (2010).

The worst-case scenario requirement may be difficult for courts to enforce because of the need to determine whether a scenario is credible enough to be worth considering. Yet, at least in some cases, it may force agencies to consider risks that they might otherwise repress entirely from the decision-making process.

Scenario analysis is one method of pushing decision makers outside of their comfort zone by making them contemplate situations in which their own assumptions might fail.[68] Robert Verchick has emphasized the importance of scenario analysis – and of the act of imagination required to construct and consider these scenarios – in the face of uncertainty.[69] As he explains, scenario analysis avoids the pitfall of projecting a single probable future when vastly different outcomes are possible; broadens knowledge by requiring more holistic projections; requires planners to consider changes within society as well as outside circumstances; and most importantly "forces decision-makers to use their imaginations."[70] He explains that the "very process of constructing scenarios stimulates creativity among planners, helping them to break out of established assumptions and patterns of thinking."[71] In situations where it is impossible to give confident odds on the outcomes, scenario planning may be the most fruitful approach.

One thing we know from experience is that events can disprove the validity of models that purport to show some complex technological system is incapable of failing catastrophically. In many situations, "human error" is a contributing factor to a disastrous outcome, and such errors are not entirely avoidable when dealing with complex technological systems. One important scenario to consider is a serious mistake by system operators in response to an otherwise controllable accident. In today's world, it is also important to consider the risk of intentional malevolence by terrorists or criminals. Finally, natural events may occur outside the range of normal expectations – and when possible outcomes are sufficiently negative, we should be wary of efforts to rule out extreme possibilities.

There will often be a matter of judgment involved in deciding which scenarios to consider. The cutoff should not be based on probabilities alone but should also take into account the severity of harm and the degree of repeated exposure to the risk. A one-in-a-million chance that a reactor will release significant radioactivity in a given year sounds reassuring. But if a country has fifty reactors, each of which will operate for 40 years, the risk that such a release occurs rises to one in

68 For information about implementing scenario planning, see ALFRED MARCUS, STRATEGIC FORESIGHT: A NEW LOOK AT SCENARIOS (2009).

69 ROBERT R.M. VERCHICK, FACING CATASTROPHE: ENVIRONMENTAL ACTION FOR A POST-KATRINA WORLD 239–49 (2010).

70 *Ibid.* at 224–43.

71 *Ibid.* at 243.

four thousand (1/100,000×40×50). If the consequences would be severe, this is a risk worth considering during planning.

As we have seen, there are understandable pressures that work against consideration of such scenarios by an agency. Even telling the agency to consider the worst credible scenario or to exercise precautions against the unknown may be ineffective – the agency may feel that it is doing so because it has repressed awareness of possible pitfalls. In some cases, a court might be able to correct such an agency error, but realistically this is only likely to occur in cases of clear mistakes.

One possible approach is to borrow the idea of "red teams" from military and business planners. Red teams have the task of inventing ways to defeat defenses (whether in the form of physical safeguards or software) and devise strategies to inflict harm despite these defenses. These exercises expose flaws that can be corrected by design or operational changes. Similarly, in the case of complex systems, it may be useful to have a separate team of individuals whose mission is to find ways that wrongdoers and Nature might defeat safeguards. In particular, it may be useful to consider how intentional or accidental harm might result from linked vulnerabilities or common mode failures within the system.

European Use of the Precautionary Principle

Like the worst-case scenario, the precautionary principle is aimed at potential risks that may not fully surface otherwise. Although it is rooted most deeply in the European Union, the precautionary principle has spread much more broadly: "The precautionary principle is nothing short of ascendant on the international stage, so much so that many categorize it as constituting customary international law."[72] In its most general sense, the precautionary principle advises that lack of certainty is not a justification for inaction in the face of possible risks; more precise statements of the principle focus on situations involving unquantifiable harms, irreversible harm, or catastrophic harm.[73] The implication of the precautionary principle is that it is better to over-regulate than under-regulate new technologies, but this can actually result in more harm to public health or welfare under some circumstances.[74]

72 Jonathan Remy Nash, *Standing and the Precautionary Principle*, 108 COLUM. L. REV. 494, 499 (2008).

73 *Ibid.* at 502–03.

74 See Jonathan H. Adler, *More Sorry Than Safe: Assessing the Precautionary Principle and the Proposed International Biosafety Protocol*, 35 TEX. INT'L L.J. 173, 195–98 (2000).

The precautionary principle is endorsed in numerous international environmental statements and treaties. This principle has been explained on the basis of risk aversion or skepticism about the environment's ability to tolerate damage.[75] The precautionary principle now also appears as part of the Rio Declaration on international environmental law. Principle 15 of the Declaration states that "to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities," and that given "threats of serious or irreversible damage, lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[76]

The precautionary principle also appears in international conventions on ozone, global climate and biodiversity.[77] It has also been adopted by Germany as a guide to environmental policy and has been invoked by courts in Canada, Pakistan, and India.[78] The precautionary principle served as the basis for the EU's effort to regulate the use of genetically modified organisms in foods, with concerns about the possible adverse effects as the dominant concern rather than the balance between possible costs and benefits.[79]

Despite its broad international acceptance, the precautionary principle is controversial.[80] The most frequent criticism is its vagueness – or as one writer puts it, the principle's "squishiness."[81] For instance, Christopher Stone found it "increasingly frustrating that there is no convergence as to what it means, or as to what regions of action (environment, public health) it is supposed to apply."[82] In some formulations, the precautionary principle is seemingly a mandate to

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75 *See* Daniel Farber, Eco-Pragmatism: Making Sensible Environmental Decisions in an Uncertain World 170 (1999).

76 Rio Declaration on Environment and Development, Report of the United Nations Conference on Environment and Development, G.A. Res. 48/190, U.N. GAOR, 48th Sess., Supp. No. 49, U.N. Doc. A/48/49, at 167 (Dec. 21, 1992).

77 David Hunter, James Salzman, & Durwood Zelke, International Environmental Law and Policy 410 (2d ed. 2002).

78 *Ibid.* at 410–11. On the Canadian experience, see Juli Abouchar, *The Precautionary Principle in Canada: The First Decade*, 32 Envt. L. Rptr. 11407 (2002).

79 David G. Owen, *Bending Nature, Bending Law*, 62 Fla. L. Rev. 569, 575 (2010); Hunter, *supra* note 78, at 407.

80 For a recent update on the debate, *see* Fritz Allhoff, *Risk, Precaution, and Emerging Technologies*, 3 Studies in Ethics L. & Tech. 1 (2009), available at http://files.allhoff.org/research/Risk_Precaution_Emerging_Technologies.pdf. Allhoff suggests that "precaution *supplements* cost-benefit analysis *given uncertainty*." *Ibid.* at 23 (emphasis in original).

81 Edward A. Parson, *The Big One: A Review of Richard Posner's Catastrophe: Risk and Response*, 45 J. Econ. Lit. 147, 152 (2007).

82 Christopher D. Stone, *Is There a Precautionary Principle?*, 31 Envt. L. Rptr. 10790, 10791 (2001).

halt activities when a sufficient level of risk appears, whereas in others it merely creates a presumption against activities potentially harmful to the environment, placing the burden of proof on the advocates of those activities.[83] But none of these formulations is precise, and Stone doubted whether any general rule can be formulated that is any more specific than "be careful!"[84] An admonition to exercise care is not necessarily undesirable, but it falls short of the guidance one would hope that the law would give decision makers.

The vagueness critique may be overstated, or at least the problem may be remediable. In response to such criticisms, a number of efforts have been made to sharpen the precautionary principle in three settings: (1) where "the heartland of the precautionary principle encompasses situations where the risk cannot be effectively assessed or reliably cabined, i.e., settings in which there is uncertainty rather than simply risk;"[85] (2) where "a failure to regulate may result in irreversible harm," so that "an investment in regulation may be justified by a desire to retain flexibility by avoiding irreversible results;"[86] and (3) where harm "would be catastrophic."[87]

Critics of the precautionary principle argue that intervention creates risks of its own.[88] If the effects of regulation are also uncertain and present unforeseen risks to health and environment, then the precautionary principle seems to turn against itself, suggesting that we should not proceed with environmental regulations until we can pin down their effects. As Sunstein has explained, the precautionary principle might seem to call for stringent regulation of genetic engineering because of possible ecological risks, but the regulation itself would also create risks because "genetic engineering holds out a prospect of producing ecological and health benefits."[89] Thus, he says, "the precautionary principle would seem both to require and to forbid stringent regulation of genetic engineering."[90] Sunstein argues that the "same can be said for many activities and processes, such as nuclear power and nontherapeutic cloning, simply because risks are on all sides of the situation."[91]

A third criticism connects the precautionary principle with defects in human cognition. Sunstein has argued that when the precautionary principle "seems

83 *Ibid.*

84 *Ibid.* at 10792.

85 Nash, *supra* note 73, at 502–03.

86 *Ibid.*

87 *Ibid.*

88 *See* Adler, *supra* note 75; Frank B. Cross, *Paradoxical Perils of the Precautionary Principle*, 53 WASH. & LEE L. REV. 851, 872 (1996).

89 Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 11 YALE L.J. 61, 93 (2002).

90 *Ibid.*

91 *Ibid.*

to offer guidance," it is "often because of the operation of probability neglect," meaning the cognitive incapacity of individuals to attend to the relevant risks.[92]

The vagueness criticism has prompted various attempts to make the precautionary principle more specific by adding references to avoiding irreversible actions, keeping options open, and providing insurance against dangerous risks.[93] Alternatively, some supporters argue that the principle requires a kind of case-by-case, common law development.[94] The second criticism, regarding the existence of risks on both sides of regulatory decisions, may or may not always apply in practice. Regulations do not always create risks to health or the environment as a side effect. Often, they simply cost money. The third criticism, as it turns out, may be backwards: the precautionary principle may be needed to counter defects in the ways people process probability information; rather than being part of the problem of limited human rationality, the precautionary principle may be part of the treatment.[95] We can expect this debate to continue, but it may be possible to find consensus on narrower ground.

Cass Sunstein is a long-time critic of the precautionary principle. He recognizes, however, that catastrophic risks may be different.[96] Sunstein proposes a number of different versions of the catastrophic risk precautionary principle, in increasing order of stringency. The first requires only that regulators take into account even highly unlikely catastrophes in determining expected utility.[97] A second dictates that regulators recall that social feedbacks may amplify the harm.[98] A third version "asks for a degree of risk aversion, on the theory that people do, and sometimes should, purchase insurance against the worst kinds of harm."[99] Hence, he says, "a margin of safety is part of the Catastrophic Harm Precautionary Principle – with the degree of the margin depending on the costs of

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92 *Ibid.* at 94. Sunstein further elaborated his critique in Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PENN. L. REV. 1003 (2003).

93 See, e.g., Stephen Charest, *Bayesian Approaches to the Precautionary Principle*, 12 DUKE ENVTL. L. & POL'Y F. 265 (2002); Christian Gollier, Bruno Jullien, & Nicolas Treich, *Scientific Progress and Irreversibility: An Economic Interpretation of the "Precautionary Principle,"* 75 J. PUB. ECON. 229 (2000); W. David Montgomery & Anne E. Smith, *Global Climate Change and the Precautionary Principle*, 6 HUM. & ECOLOGICAL RISK ASSESSMENT 399 (2000); Stone, *supra* note 83.

94 See Stephen Toulmin, *The Case for Cosmic Prudence*, 56 TENN. L. REV. 29 (1998).

95 Dana, *supra* note 44. Dana elaborates his position in David A. Dana, *The Contextual Rationality of the Precautionary Principle* (2009), available at ssrn.com/abstract=1521802.

96 Cass R. Sunstein, *The Catastrophic Harm Precautionary Principle*, 6 ISSUES IN LEGAL SCHOLARSHIP 1–2, 29 (2007), available at http://www.degruyter.com/view/j/ils.2007.6.issue-3/ils.2007.6.3.1091/ils.2007.6.3.1091.xml?rskey=BeA2Ba&result=2&q=sunstein.

97 *Ibid.* at 28.

98 *Ibid.*

99 *Ibid.*

purchasing it."[100] Finally, Sunstein suggests, "it sometimes makes sense to adopt a still more aggressive form of the Catastrophic Harm Precautionary Principle, one that follows maximin by selecting the worst-case scenario and attempting to eliminate it."[101] (Maximin means selecting the strategy that has the *least bad* worst-case outcome – the decision maker "maximizes" the "minimum" utilities possible across the strategy space.) Sunstein added a caution, however that maximin is "not *generally* a sensible strategy in the environmental context or elsewhere" because it makes no sense when risks can actually be quantified even roughly and is not attractive when the worst-case scenario is only mildly bad or when the cure inflicts "serious losses of its own."[102]

In Sunstein's formulation, the catastrophic precautionary principle connects with the worst-case scenario, but the precautionary principle is subtly different than the worst-case scenario requirement. The worst-case scenario pushes the government to investigate, identify risks, and then project the results of a particularly serious identified risk. It differs from conventional risk analysis primarily because it does not attempt to quantify the probability of the "worst" risk. Donald Rumsfeld famously distinguished between known risks, known unknowns and unknown unknowns. The worst-case scenario is aimed at the second category: risks that are identified but where the probability is not known. This makes it especially useful for considering methods of countering such risks through additional safeguards.

The precautionary principle, in contrast, has its greatest bite in dealing with unknown unknowns – that is, events that are outside of the decisional calculus either because they actually have not been imagined or because they have been erroneously dismissed as inconsequential. Through use of scenario planning and red teams, we may be able to reduce the likelihood that risks will be overlooked. Still, we can never be sure that we have considered all the conceivable risks, and trying too hard to do so may be too time and energy intensive. The precautionary principle is a warning that our risk calculations, no matter how elaborate they are, may be dangerously mistaken. In the nuclear arena, the precautionary principle takes the form of "defense in depth" – a requirement that reactors include safeguards against the possibility of a beyond-design accident.[103]

For instance, designers and planner may have had good reason to think that it would be impossible for a reactor to suffer the multiple systems impairments

100 *Ibid.*
101 *Ibid.*
102 *Ibid.* at 28–29.
103 David Lochbaum and Edwin Lyman, US Nuclear Power Safety One Year After Fukushima 19–20 (Union of Concerned Scientists 2012), available at http://www.ucsusa.org/nuclear_power/nuclear_power_risk/safety/fukushima-anniversary-report.html.

which later occurred at Fukushima. Even if it was too much to expect them to anticipate a tsunami of such severity, we might expect them to take into account the possibility that their models were wrong for some unknown reason. This precautionary approach might have resulted in in taking more care to protect backup power generators and to provide operators with safer and more useable facilities for use in the event that such a serious accident did take place. It would also lead to care about the placement of facilities in tsunami-prone areas and to greater disaster-response capacity. In other words, the precautionary principle can lend greater force to arguments for disaster resilience, not just disaster prevention. It is hard to incorporate unknown unknowns into the analysis, but when the consequences would be grave, the precautionary principle is a good reminder of the need to make allowances for the limits of our understanding and even our imaginations.

Conclusion

Improving the ability of organizations to deal with catastrophic risks rather than repressing them is not easy, and we should not expect an unrealistic measure of success. A crisis offers an opportunity for organizational improvement, but organizations that await major failures before adapting tend to enter crisis mode and find learning and response even more difficult.[104] Experience suggests that we should not overestimate the capacity of institutions to reform after disasters. Following the demise of the space shuttle *Challenger*, the National Aeronautics and Space Administration (NASA) faced political pressures, inertia, and resource constraints that expedited some organizational changes but made other structural and cultural adjustments more difficult.[105] Leadership is essential but cannot be created by legal mandate. The Columbia Accident Investigation Board report said:

> The White House and Congress must recognize the role of their decisions in this accident and take responsibility for safety in the future...Leaders create culture. It is their responsibility to change it... The past decisions of national leaders – the White House, Congress, and NASA Headquarters – set the Columbia accident in motion by creating

104 Karlene H. Roberts, Peter Madsen, & Vinit M. Desai, *The Space Between in Space Transportation: A Relational Analysis of the Failure of STS 107*, *in* ORGANIZATION AT THE LIMIT: LESSONS FROM THE COLUMBIA DISASTER 81–98 (William H. Starbuck & Moshe Farjoun eds., 2005).
105 HOWARD E. MCCURDY, INSIDE NASA: HIGH TECHNOLOGY AND ORGANIZATIONAL CHANGE IN THE US SPACE PROGRAM (1993).

> resource and schedule strains that compromised the principles of a high risk technology organization.[106]

Diane Vaughan reports that both economic strain and schedule pressure still exist at NASA. She notes that it is unclear how the conflict between NASA's goals and the constraints upon achieving them will be resolved, but that one lesson from *Challenger* and *Columbia* is that system effects tend to reproduce.[107] Furthermore, in the absence of a significant environmental change or destabilizing event, lessons learned in organizations often tend to be forgotten or misapplied.[108]

Outside monitors such as courts can place greater pressure on organizations to confront the potential for catastrophic system failures rather than repressing those risks. We should not be overly sanguine about the prospects for making officials more cognizant of catastrophic risks. The syndrome of disaster blindness does not lend itself to an easy cure and perhaps can never be completely cured. It may be more like a chronic medical condition that can be managed but not eliminated: even with improved treatment the odds of improvement may be limited. Still, any success in reducing disaster blindness is beneficial and may avoid some future catastrophic outcome. The first step is to realize that business as usual is an invitation for future disasters that we will once again claim were "beyond our imagination."

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106 Columbia Accident Investigation Bd., Nat'l. Aeronautics and Space Admin. (NASA), Columbia Accident Investigation Report (2003).

107 Diane Vaughan, *Systems Effects: On Slippery Slopes, Repeating Negative Patterns and Learning from Mistakes*, in Organization at the Limit: Lessons from the Columbia Disaster 41 (William H. Starbuck & Moshe Farjoun eds., 2005).

108 Pablo Martin De Holan & Nelson Phillips, *Remembrance of Things Past? The Dynamics of Organizational Forgetting*, 50 Mgmt. Sci. 1603 (2004); James G. March et al., *Learning from Samples of One or Fewer*, 2 Org. Sci. 1 (1991).