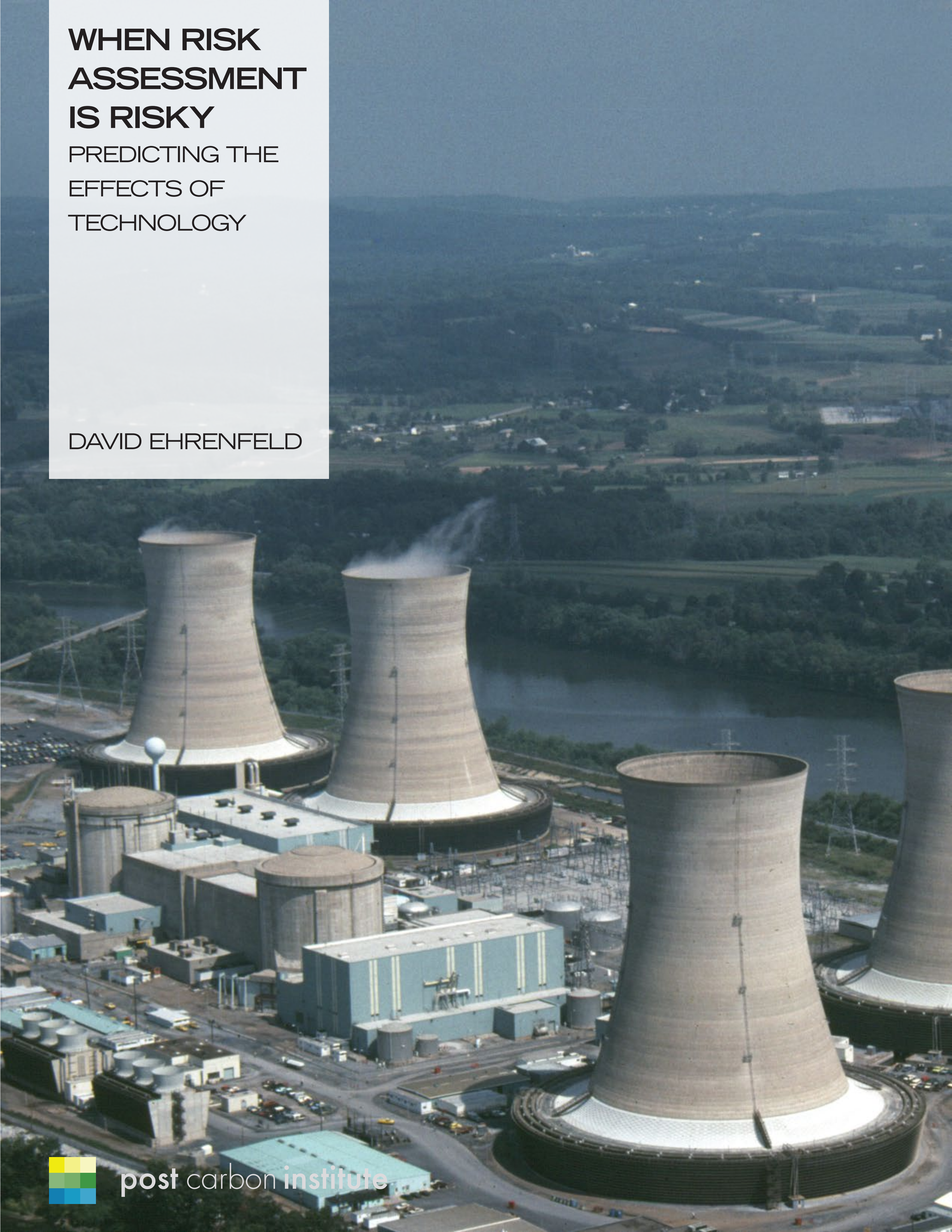
WHEN RISK ASSESSMENT IS RISKY

PREDICTING THE EFFECTS OF TECHNOLOGY

DAVID EHRENFELD



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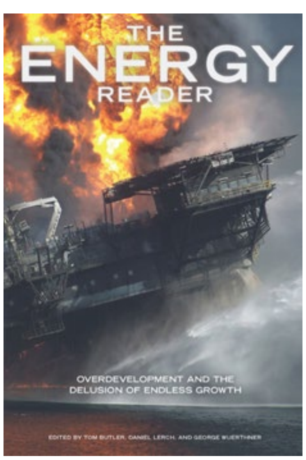

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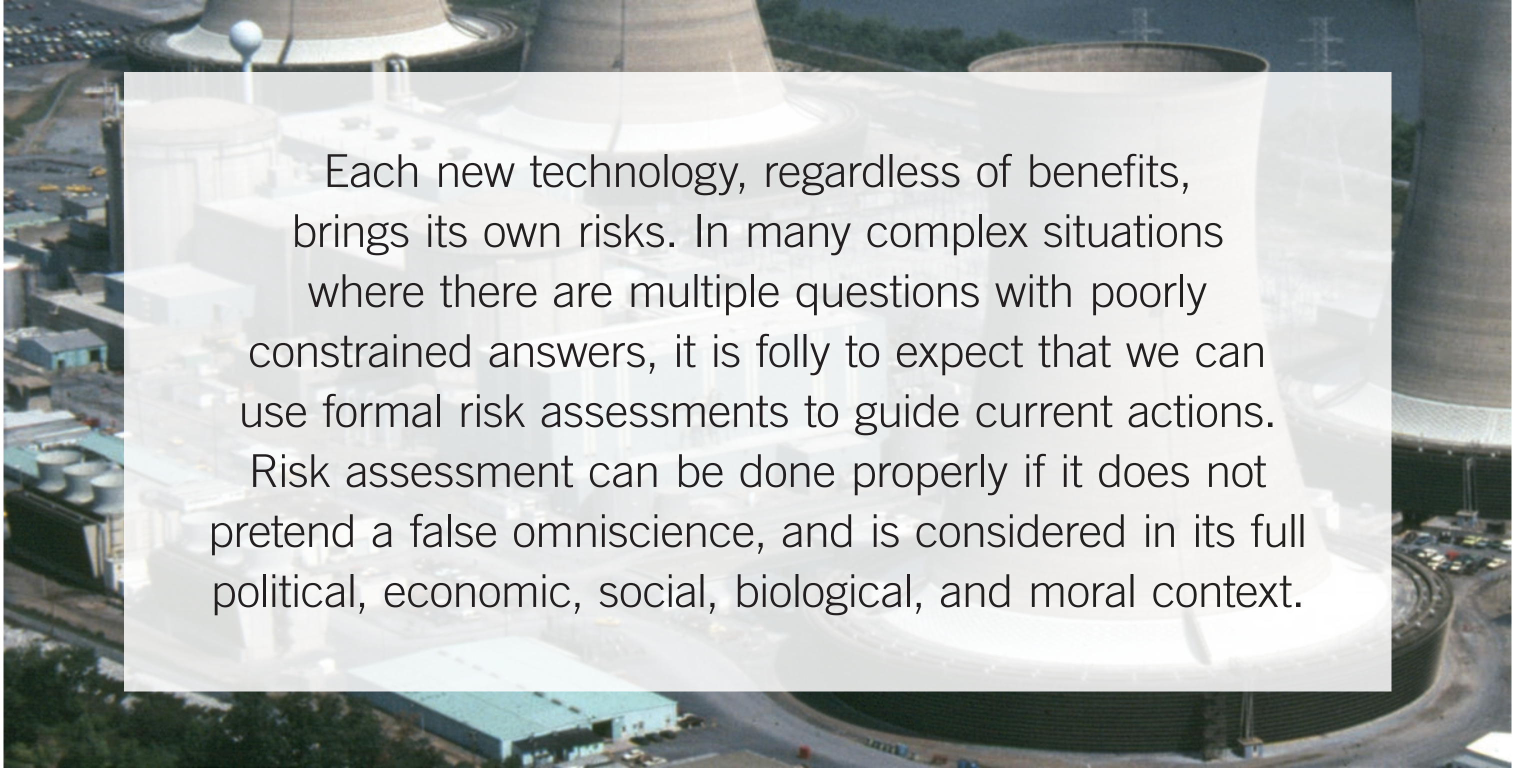
Photo: Breck Kent. *Three Mile Island nuclear plant, Pennsylvania. The United States' worst nuclear accident occurred here in 1979 when one reactor suffered a core meltdown.*



> Each new technology, regardless of benefits, brings its own risks. In many complex situations where there are multiple questions with poorly constrained answers, it is folly to expect that we can use formal risk assessments to guide current actions. Risk assessment can be done properly if it does not pretend a false omniscience, and is considered in its full political, economic, social, biological, and moral context.

Technology has its own momentum. Propelled faster and faster by profits, politics, and the thrill of discovery, it has gone out of control, although this is a misleading way of putting it because it has never been under control. Each new technology, regardless of benefits, brings its own risks: extinctions, explosions, nuclear plant meltdowns, chemical toxicities, soil degradation, invasive species, climate change, resource depletion, damage to human communities. Who has not been made aware of some or all of these mortal threats? Everyone has experienced the effects of technology—bad and good. We know or sense that new technologies bring new risks, and this can produce an understandable sense of danger, a fear of an unknown future.

Throughout history, people have worried about what is going to happen next. The Greeks had oracles, notably the one at Apollo's temple in Delphi. The Delphic oracle had alleged successes—it also had noteworthy failures, such as the prediction of victory for the Persians in the fifth-century BCE war with the Greeks. But Apollo's priestesses, known as Pythias, uttered prophecies for more than one thousand years, so the oracle must have gotten some things right. Its last recorded message, for the Roman Emperor Julian the Apostate, who tried to restore Apollo's temple and oracle in 362 CE, was a chilling description of the end of Greek prophecy:

> *Tell ye the king: the carven hall is fallen in decay;*
> *Apollo hath no chapel left, no prophesying bay,*
> *No talking spring. The stream is dry that had so much to say.*[1]

Of course, biblical prophecy has had an even longer run than the Greek oracles. The Hebrew prophets are still actively studied and invoked, although their writings do not seem suitable for predicting the specific effects of most current technologies. Now, because of the tremendous power of technology to change the world quickly and dramatically, we feel a new and very urgent need to predict the future accurately.

A very modern substitute for prophecy is the widespread belief that because technology can do so many extraordinary things it can predict its own side effects, letting us make effective plans to avoid future disasters. Technology is moving ahead whether we like it or not, and it is comforting to believe that we can figure out the problems we are likely to face, that we are the engineers of the hurtling freight train, not passengers locked in a windowless baggage car.

We don't rely on oracles; we now have scientific models that give us apparently reliable risk assessments and other quantitative probabilities of the occurrence of future events. The likely date of the extinction of an endangered species, the number of people who will be affected by an epidemic, the world's human population fifty years from now, the demand for electric power in 2030, the trajectory of the Dow Jones Industrial Average over the next three months—these are just a few of the kinds of predictions with specific numerical ranges. But as was the case with the Delphic Oracle, scientific prediction has had many failures. Twentieth-century predictions of the size of Canadian and New England cod populations based on models of sustainable yield, estimates made in the 1960s of U.S. electric consumption in the 1990s, most predictions of the robust growth of the economy made in early 2007, and reassuring risk assessments of the safety of injecting into the earth (then removing) millions of gallons of water and toxic chemicals to stimulate extraction of natural gas from the Marcellus shale formations in Pennsylvania and New York—all proved wrong, sometimes disastrously wrong.

Some of these forecasting failures have occurred because the data used to calculate the risk were preselected to give a politically or economically desired result—the books were cooked. Some forecasts fail because of statistical problems with predicting extremely infrequent outcomes (the "base rate fallacy"). Other predictions, including those calculated honestly, have been rendered worthless by the occurrence of rare, unpredictable happenings that lie outside the realm of our common experience. Predictions can fall victim to a combination of these factors. And as financial trader Nassim Taleb has written, "it does not matter how frequently [predictions succeed] if failure is too costly to bear."[2] It is not clear which of the two systems, prophecy or scientific assessment, will work better for many of the most critical predictions we have to make. We usually assume that the scientific method will give us the correct answers if we ask in the right way. Often it does, but frequently it doesn't. Can we tell ahead of time which of our forecasts will be reasonable and which will not? To date, there have been few systematic efforts to check whether previous forecasts were right or wrong, no track record to help us evaluate the reasonableness of new predictions. Climate scientists, who are subject to enormous public and scientific scrutiny, frequently make reality checks of their past predictions, but they are an exception. More often, we lack a forecasting track record to help us evaluate new predictions. Without quality control for our scientific predictions, we will make the same mistakes over and over again.

After the explosion of BP's Deepwater Horizon oil rig, which had been drilling the Macondo well in the Gulf of Mexico on April 20, 2010, we heard a good deal about risk assessment. Coast Guard Admiral Thad W. Allen, incident commander for the oil spill remediation, properly called for "a responsible assessment of the risks and benefits" of the various damage control tactics that were being used. He wanted to know how much oil they would remove and what their ultimate impact would be, years later, on life in the Gulf.

Important decisions hinge on assessments like the ones that Admiral Allen requested. Critical forecasts of this sort are made every day around the world. Some will be right and some will be grotesquely wrong. Can we find a general method for assessing the trustworthiness of a prediction before we start using it to set policy? The answer is yes—and we can start by taking a closer look at the process of risk assessment itself.

There are two kinds of risk assessment; they are quite different. The first, common in structural engineering, evaluates completely defined risks in systems that are visible and open to inspection. For example: At what point will this bridge collapse as we increase the load? Is this building likely to withstand an earthquake of magnitude 6.5? Risk assessments of this kind are proper and necessary, although like any scientific estimate they are subject to error.

The second type of risk assessment addresses complex systems with many interacting, tightly coupled subsystems, some of which are either poorly understood or beyond our power of inspection. These systems are subject to unexpected and unpredictable breakdowns that the Yale sociologist Charles Perrow called "normal accidents."[3] The Deepwater Horizon fell in this category: The critical events occurred nearly a mile beneath the ocean surface and were brought about or compounded by a confusion of conflicting command structures among BP, Halliburton, Transocean, and the Minerals Management Service.

The first major risk assessment of a complex system was WASH-1400, a report on nuclear reactor safety produced in 1975 for the Nuclear Regulatory Commission by a team headed by professor Norman Rasmussen at the Massachusetts Institute of Technology. The authors concluded that the risk of core meltdown was one in 20,000 per reactor per year, acceptably small. Around the same time the report was issued, the largest nuclear plant in the United States, in Browns Ferry, Alabama, was set on fire and temporarily put out of commission by a worker using a candle to check for air leaks. Core meltdown was narrowly averted. Had Dr. Rasmussen's team thought about including the effects of candles in their risk assessment? Of course not. Similarly, when DDT was first introduced, did anyone think to ask whether it would chemically mimic sex hormones, weakening the eggshells of ospreys and eagles? Of course not. The limitations of present knowledge can prevent us from asking all the risk-relevant questions. And if you can't think of all the important questions to ask, you can't make a useful risk analysis.

We have to try to predict the effects of the oil dispersants and other spill-control technologies on marine life and coastal marshes, but let's not kid ourselves that such predictions are more than informed guesses. We can't evaluate remedies if we don't even know every place where the dispersant-treated oil is going, or its effects on many thousands of species at different depths in the deep ocean, around reefs, and in intertidal zones. We don't really know the long-term effects of other proposed strategies such as the release of genetically engineered oil-eating bacteria, and the addition of huge quantities of nitrogen and phosphate compounds to stimulate the bacteria's growth. No lab experiment can be scaled up from a test tube to an ocean to give us complete answers.

In many complex situations where there are multiple questions with poorly constrained answers, it is folly to expect that we can use formal risk assessments to guide current actions. Fortunately, there is a way to determine those cases in which relying on risk analysis is inappropriate or dangerous. There are good criteria for rejecting some "scientific" predictions before they have a chance to do damage. The safety of using risk assessments decreases dramatically when: 1) the proposed strategies for preventing problems and minimizing damage have never been tested under real conditions; 2) when many interacting systems—especially ecological and human social systems—are involved; 3) when events that are beyond our inspection or even comprehension are likely to happen; 4) when the prediction extends unrealistically far into the future; and 5) when there are side effects of the proposed action that are already known to be serious. Not all of these five conditions need apply to invalidate a risk analysis; there is plenty of latitude for informed debate and judgment.

When confronted by an authoritative-seeming prediction, we should first ask whether it concerns a simple or complex system. This tells us how far we can extend our trust. For example, forecasts of eclipses to take place one hundred years from now are likely to be reliable. Astronomical calculations, appearances to the contrary, deal with relatively simple, well-described, purely physical systems. On the other hand, long-term weather forecasts (those extending beyond a few weeks) are often wrong. The weather is influenced by so many different variables on land, in the ocean, and in the atmosphere, and by so many random events, that detailed long-term forecasts are not believable unless they are so general as to be useless (it will be warmer in August than in November). Geologists Orrin Pilkey and Linda Pilkey-Jarvis have written in their book *Useless Arithmetic: Why Environmental Scientists Can't Predict the Future*,

> *If we wish to stay within the bounds of reality we must look to a more qualitative future, a future where there will be no certain answers to many of the important questions we have about the future of human interactions with the earth.… No one knows in what order, for what duration, from what direction, or with what intensity the various events that affect a process will unfold. No one can ever know.*[4]

A spurious aura of certainty about the future has allowed us to be imposed upon by the proponents of technology at all costs. Accident follows accident. The damages, some of them irreversible, accumulate. But if we strip away the veneer of certainty and reject the pseudoscientific, self-serving calculations about the future—if we remember the unlucky nuclear-plant worker with his candle—we free ourselves to make responsible decisions about our destiny and the destiny of the natural world. We free ourselves to listen to the advice of conflicting experts, and to ask the hard questions that ought to be asked when they should be asked. We are less likely to be stampeded into making decisions that imperil our future as well as the future of myriad other species. We can rely more on adaptive management that is responsive to the situation as it exists now, without prejudice by long-term forecasts. And we can make contingency plans that assume that our risk assessments may be wrong.

Risk analyst Paul Slovic has noted: "Risk assessment is inherently subjective and represents a blending of science and judgment with important psychological, social, cultural, and political factors." He advocates "introducing more public participation into both risk assessment and risk decision making in order to make the decision process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions."[5] If such an atmosphere of sanity had prevailed during the first submission of corporate risk assessments that claimed it was safe for Transocean's mobile offshore unit to sink an oil well a mile deep in the Gulf, drilling for the ill-starred Macondo well would probably have been stopped before it began. Then there would have been no oiled pelicans gasping for breath, drowned or burned sea turtles, ruined coastal economies, and desperate fishermen seeing the end of their life's work and the destruction of the cultural legacies of their parents, grandparents, and great-grandparents.

Knowing the limitations of prediction and risk analysis in the complex situations posed by modern technology does not have to paralyze our ability to plan and act. It allows us to use our science wisely and carefully, and to introduce into our decisions the values of concern for people and concern for nature that alone can make our technology safe and lasting. Risk assessment can be done properly if it does not pretend a false omniscience and is considered in its full political, economic, social, biological, and moral context. Above all, we can never let the dispassionate, academic nature of risk assessments make us forget that bad predictions can cause lasting misery for us and for the Earth we inhabit.

ENDNOTES

1 Sir William Marris, trans., quoted in Michael Mott, "Strong Voices," *Poetry* 27, no. 3 (December 1975), 59–64.

2 Nassim Nicholas Taleb, *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets*, 2nd ed. (New York: Random House, 2005).

3 Charles Perrow, *Normal Accidents: Living With High-Risk Technologies*, 2nd ed. (Princeton, NJ: Princeton University Press, 1999).

4 Orrin H. Pilkey and Linda Pilkey-Jarvis, *Useless Arithmetic: Why Environmental Scientists Can't Predict the Future* (New York: Columbia University Press, 2007).

5 Paul Slovic, "Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield," *Risk Analysis* 19, no. 4 (1999).