



How Safe Is Safe?

Coping with Mother Nature, Human Nature and Technology's Unintended Consequences

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Preface

This treatise on risk was prepared a backdrop for the analysis of the cause and cure of the failures associated with the Deepwater Horizon drilling and completion operations in the Gulf of Mexico. I do not regard myself as a theorist in the field of risk management. Instead, I have led a professional life of exposure to elevated risks, of managing risks to which others were exposed, and of advising public officials at the highest levels of government on strategies of risk abatement. From extended observations at ringside, I have down-loaded and sorted memories so as to share experiences that define fundamental properties of all risk environments created by acts of nature, from human frailty and from unintended consequences of technology.

The product is not an encyclopedia of risky situations, nor a how-to handbook on risk management. It is not a post-crisis analysis of the Macondo well blowout nor of its calamity twins. It is not a check off list of **what** parameters to think about in the risk equation, but rather a tool on **how** to think about the quintessential questions of “How safe is safe” and of the exercise of social responsibility to limit harm.

This treatise has been prepared for readers ranging from professionals in risk management to non-specialists with heavy portfolios to adopt and implement policies to shield citizens from threats of bodily harm or of property damage. Finally, it is directed toward citizens exposed to involuntary risks who feel responsible for participating in civil decisions that affect their safety and security and that of the community.

This survey, suggested methodologies of assessment, and conclusions related to the Macondo well are based on case studies starting with the wreck of the *Exxon Valdez* where the author was directly involved with the post-mortem analysis. Other cases include the spacecraft *Challenger*, the eruption of Mt. St Helens volcano, the Bhopal, India, chemical spill, the air attack on the twin towers, 9/11, the failure of intelligence for opening the war on Iraq, and about 100 artificial cases prepared over two decades by graduate students in the Program for Social Management of Technology at the University of Washington. The perspective for analysis is systems based and interdisciplinary, elaborated in *Tradeoffs: Imperatives of Choice in a High Tech World* (1986).

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1. Introduction

How Safe is Safe?

The Macondo well disaster in 2010 exposed a technological failure of inadequate defense against a predictable, risky and potentially lethal event. Recent studies, including this latest one from the Center for Catastrophic Risk Management Deepwater Horizon Study Group, focus on death and destruction from hydrocarbons that were released by the blowout of the Macondo well. Studies of cause acknowledge the extreme forces of nature but also cite the human and organizational errors (HOE) that now occur more conspicuously because the engineering of physical parameters has been refined. HOE failures now exceed mechanical sources.

Because protection against human weaknesses is more art than science, the study of cause and of remediation requires a context for risk analysis. As systems based and interdisciplinary, that depiction should be of help to non-specialists with policy and management responsibilities so as to understand the enigmatic question of “How safe is safe?” In other words, what level of risk is acceptable when making decisions on public safety and security.

Risk is usually defined as a condition where either an action or its absence poses threats of socially adverse consequences, sometimes extreme. Risk happens from acts of nature, from weaknesses of human nature, and from side effects of technology, all situations that mix complex technical parameters with the variables of social behavior. Although each risk event is unique, all display commonalities that permit systemic analysis and management. These recurring properties lead to certain principles.

To begin, the acceptability of risk cannot be extracted from science or mathematics; it is a social judgment. The spectrum of risk thus embraces both the physical world defined by natural laws, and the human world loaded with beliefs instead of facts, values, ambiguities and uncertainties. Among other features, the physical world may be thought of as a mechanism whose behavior follows principles of cause-and-effect because each internal element has fixed properties regardless of which function it is expected to perform. On the other hand, the human world performs more like an organism whose components are not fixed but may grow, be altered by the thrust of external events and by interplay with other internal elements.

Following a notion that what you can't model you can't manage, a systems model is needed to represent the processes by which both physical and societal factors are defined, interconnected and interact. Such technology-based human support systems are labeled by their intended social functions-----food production, shelter, military and homeland security, communications, transportation, health care, energy production, conservation of natural resources, water supply and sanitation, education and even entertainment. In our modern era, all these functions have been enormously strengthened by applications of scientific knowledge, then applied through engineering.

It helps to think of technology as more than the hardware of planes, trains and computers. Rather, it is a social system comprising many organizations, synchronized by a web of communications for a common purpose. It is energized by forces of free market demand, of popular demand for security and quality of life, and by forces of scientific discovery and innovation. It is best understood as a Technological Delivery System (TDS) that applies scientific knowledge to achieve society's needs and wants

Technology then acts like an amplifier of human performance. With water wheel, steam engine and bomb, it amplifies human muscle. With the computer it amplifies the human mind and memory. It also amplifies social activity, mobility, quality and length of life.

A paradox arises when technologies introduced for specific benefits also spawn side effects. These can induce complexity, conflict and even chaos. Most of these are unwanted by some sector of stakeholders, now or in the future. This paradox is dramatized when technologies are introduced to defend against violence of nature or against human and organizational error but themselves spring unintended and possibly dangerous consequences.

The investigation of risk and of measures to contain it within safe limits requires both hindsight and foresight. The past can illuminate failures, their causes and their control as lessons for engaging new ventures and threats. The future commands the exercise of foresight, an imaginative preparation of scenarios stirred by such questions as, “what might happen, if,” or “what might happen, unless.” Those inquiries should then examine the timing of impacts (immediate or hibernating) and identity of players on the risk horizon who trigger risk, those parties responsible for risk abatement and those adversely affected now or in the future.

Modeling then becomes essential to represent a full cast of stakeholders and their inter-relationships, including both the private and the public sectors. The concept of a TDS discussed later is simply an attempt to model how the real world works.

The responsibility to manage risk stems from the American Constitution, from custom, and from a growing body of public law. Federal, state, and local governments are heavily involved in all of the technologies itemized previously, contrary to popular belief that technology is private industry’s territory.

That achievement carries significant but subtle implications. For one thing, safety costs money. The federal budget is constantly challenged to meet a rainbow of different demands, the total of which always exceeds Congressional appropriations. The mismatch must then be reconciled through tradeoffs at the highest policy levels stretching all the way to the President of the United States and the Congress.

Indeed, the President becomes the nation’s systems manager because all agencies responsible for citizen security report to the Chief Executive, because he is arbiter of budget priorities and author of annual budget requests. He is held to account for quality of performance and for design of public policies if authority or performance is lacking. Serious threats of nature also require the mustering of resources that are available only through the armed services of which the President is Commander-in-Chief.

Often, a focus on power of the Federal Government misses a major premise of democratic governance. As the Declaration of Independence states, those who govern should do so only with the consent of the governed; we would say the informed consent.

This notion is reflected in such regulatory legislation as the National Environmental Policy Act (NEPA). Section 102(2)c. It requires estimates of harm that could result from technological initiatives, along with alternatives to accomplish the same goals but with less harm. After preparation, these environmental impact statements (EIS) are made available for public comment and possible amendment. The point is that this process makes every citizen a part of government to negotiate the question of how safe is safe and thus provide citizens the levels of safety and security that they desire.

Implied is a prospective national policy that those put in harm's way have a voice in what otherwise could be involuntary exposure to risk. This principle leaves implementation of the concept to the responsible federal agencies, subject to Constitutional safeguards. That doctrine of anticipation was the policy spine of NEPA and the 1972 legislation to create Congress's Office of Technology Assessment (OTA).

That agency functioned as radar for the ship of state to estimate future effects of today's decisions. It was killed in an overnight action by House Speaker Newt Gingrich in 1995. In one sense, OTA served as a risk manager for the Congress and the agency's production of unbiased reports gained commendation, sufficient to warrant its rehabilitation in a new policy venue sharply focused on risk management.

Managing risk demands attention to operational details. For example, *informed* consent assumes that every citizen has access to the facts, all the facts. And it assumes they are readily understood by individuals without specialized training. Here the print and electronic media become conveyers of raw information to help citizens judge their exposure, but also to serve as watchdogs through investigatory journalism as an independent check on truth. This condition places a burden of responsibility on both the media and citizens to grasp the risk equation sufficiently to better understand their own risk exposure and their risk tolerance, thus to frame their informed consent.

Despite a tendency to flare the sensational, the media can enrich understanding with a back story because disasters so agitate a functioning system as to reveal the full cast of stakeholders, their roles in increasing or decreasing risk and their degree of injury. Managing editors require that the subject "have legs" to justify time and space of repeated coverage.

Even if this process works perfectly, the outcomes would not be free of conflict. An individual's judgment on matters that threaten lives, property and the natural world is heavily colored by their portfolio of values. Moreover, different stakeholders have different interests to guard. In deciding how safe is safe, disparate views may require bargaining so as to reach a consensus.

A serious problem then surfaces when all parties argue from their short-term self interest. Little attention is accorded the longer term. Left out of the bargaining process is our progeny, the future generations. It can then be argued that the federal government should not simply act as umpire but try to balance long- with short-term effects using foresight, to compare options that do not penalize children by harm or bankruptcy.

The engineering profession has long practiced social responsibility by a technique of over-design, to compensate for uncertainties in loading, in materials, in quality of construction and maintenance, etc. This may be accomplished by adopting some multiple of loading as a margin of safety ranging from 1.3 to 10.0. How these margins are set and by whose authority is of critical importance, especially where tradeoffs with cost or other compelling factors such as deadlines may compromise the intended reduction of risk.

This method of safety assurance is more applicable to design of mechanisms not subject to human and organizational errors. The term "errors," incidentally, is shorthand for a broad spectrum of individual and societal weaknesses that include ignorance, blunder, folly, mischief, pride, greed, and hubris.

Protecting technological systems against violence of nature such as with earthquakes, volcanic eruptions, tsunamis, floods, landslides, hurricanes, pestilence, droughts and disease may utilize the concept of over-design, based on meteorological, hydrological, seismic and geophysical data of past extreme events; e.g. the highest flood or most severe seismic event in a century. Equally pertinent is

the scale of losses. Beside the previous techniques of safety enhancement is one of redundancy where, for example, commercial airliners are required to have at least two engines, one of which may suffice to assure a soft landing.

Protecting technological systems against violence of terrorists entails additional practices of a customized precautionary principle. This intervention may be adopted as a preventative measure or one of damage control.

Learning from documented failures is a powerful method for reducing risks of repeated losses. Another is to learn from close shaves. Many dangerous events fortunately culminate in only an incident rather than an accident, but the repetition of similar incidents can serve as early warning of danger. Indeed, the logging and analysis of such events on the nation's airways partially accounts for their impressive safety record. A system for reporting close encounters was installed decades ago. Anticipating the possibility that perpetrators of high risk events might be reluctant to blow the whistle on themselves, the Federal Aviation Administration that has cognizance arranged for NASA to collect incident data and to sanitize it to protect privacy of the incident reporter. NASA also screens reports to identify patterns as early warning of a dangerous condition. Similar systems are in place for reporting incidents with nuclear power plants.

With the growing recognition of human factors in accidents or in failures to limit damage, a class of situations has been uncovered entailing uncommonly high risks but conspicuously good safety records. In the Navy, for example, high risks attend the crew on submarines and on carrier based aircraft. Yet accident rates are paradoxically low.

Careful analysis has shown that certain qualities of leadership and organizational culture foster integrity, a sense of responsibility among all participants, a tolerance by authority figures for dissent, and consensus on common goals of safe performance. High safety performance has especially been correlated with an institutional culture that was bred from the top of the management pyramid. The most critical element of that culture was mutual trust among all parties in a technological delivery system.

Long experience with military and paramilitary organizations such as first responders proves the value of rehearsals to reduce risks and control damage. Of special virtue is proof of satisfactory communications. Evaluation of dry runs has repeatedly turned up serious problems in communication. So has post-accident analysis of real events when delays or blunders in communication of warnings and rescue operations cost lives.

This leads to recognition that successful management of risk depends ultimately on the prudent exercise of political power by leaders at every level. Deficiencies may still remain in political will, in fiscal resources, in vigilance, and in ethics. Hard to define and to measure, these elements may sadly define themselves in emergencies by their absence.

To sum up, the context for analyzing the Macondo well failures illustrates several realities. The most compelling imperative of life is survival. Yet, the experience of living teaches that there is no zero risk. Some exposures must be tolerated as “normal,” whether in rush hour traffic or coping with nature, with human nature or with unintended consequences of technology.

In this modern era, society has demanded better protection against threats to life, to peace, justice, health, liberty, life style, private property, and to the natural environment. These challenges are not new, but two things have changed—the increased potency of technology and increased coverage by media. Technological factors are more robust in speed of delivery and in potential harm. Media covers events live, 24/7, and worldwide. Events anywhere have repercussions everywhere.

The better informed public tends increasingly to be risk averse. Apprehension and fear peak after a calamity with demands for better protection through better governance. Higher expectations are legitimate because so many threats just itemized are due to human and organizational errors either in catering technologies to meet market demand or in guarding against hazards. This current study shows that the Macondo well failures event fits that pattern. As in Hurricane Katrina, Government at all levels failed to provide security to citizens before and during the catastrophe. In New Orleans, victims are justified in asking how did the pathology of a mundane levee technology develop? In both disasters, how can pathological knowledge be applied to prevent a reoccurrence? Then there is the quintessential question of “How safe is safe?”

As said earlier, answers cannot be found only from natural laws of science. Safety is a social judgment. Those exposed to risk have a right to information about their exposure to danger and about the strategic issues of protection.

Ultimately, these decisions are made by government, and that process entails wrestling for power. In that matrix of conflicting interests, in our democracy, this authority should flow from citizens taking responsibility to become informed on their exposure to risk and to assure the opportunity to express an informed consent.

At the federal level, both the President and the Congress need objective, expert advice, and counsel to fulfill their responsibilities under the Constitution. They also need to increase their respect for independent analysis of risks in order to restore citizen trust.

The preceding situation analysis opens a window on a number of issues treated in more detail in subsequent sections:

- The design of precautionary measures requires inspired foresight, to fantasy alternative futures.
- Tradeoffs are inevitable between short- and long-range events and consequences, between safety and cost, between special interests and social interests, between who wins and who loses and who decides.
- All human support systems entail technology, and all technologies project unintended consequences.
- Society embraces a spectrum of values that often conflict, as with the goals of efficiency in the private sector and of sustainability and social justice in the public
- Key decisions regarding citizen safety and security are made by government through public policies to manage risk. These policies dominate the legislative agenda.

This mandate imposes a heavy burden on the President and on the Congress, both bodies requiring access to authentic and immediate information.

Making decisions and assuring implementation draws on political capital in the structure of authority by the exercise of political power and political will.

- In our democracy, this authority should flow from citizens following the principle that those who govern do so at the informed consent of the governed.
- The quality of risk management can best be judged by the effects on future generations.

- The geography of risk crosses boundaries as between federal, state and local entities, and between the United States and other nations.
- Different cultures have different risk tolerances, including attitudes distinguishing voluntary from involuntary risk.
- Analysis of risk and its control extracts lessons from past failures, although the most catastrophic events are so rare as to frustrate projections.

This portfolio of issues illustrates the anatomy of risk and the complexity of its management. They sound a wake-up call for deeper understanding by those responsible for risk management and by those attentive citizens who are exposed and are entitled to a voice in the decision process.

Risk Analysis as a Survival Skill

Humans have always lived at risk. From early times, we experienced threats of hunger, natural disasters and extremes of weather, dangers of accident and violence at the hands of other people. Brutality wasn't just physical. Some threats were psychological and emotional as by deprivation of human rights, freedom and dignity, of equitable access to resources and of opportunities for self-expression. Only a tiny elite lived with reasonable security; others were dominated, exploited, and enslaved.

A big bang of change occurred with a twin enlightenment of democracy and of modern technologies. People live longer. Quality of life is higher and more widely and evenly spread. Everywhere, citizens expect government to provide overarching security.

With progress, however, have come new risks. Nuclear, biological and chemical weapons expose every human to extinction, and weapon delivery systems can be so distributed and hidden as to make total safety pure fantasy. On the other hand, arms control treaties of 1963 on non-proliferation and limits to testing demonstrated how nations can negotiate risk reduction for common survival, even in a hot atmosphere of a cold war. That same ingenuity is required to manage twenty-first century risks.

Periodically, philosophers and theologians have peered into that future, some with lenses colored by optimism, others by the obverse. By the 1930s, a literature emerged of pure speculation and conjecture. Some promised only entertainment; some was serious and usually pessimistic. By the 1960s, risks were being charted by scientists and engineers..

In 1962, for example, Rachel Carson wrote in *Silent Spring* about the loss of bird song because DDT sprayed to wipe out malaria laden mosquitoes had side effects. Egg shells of birds were thinned enough to halt reproduction. That wigwag captured public attention that echoed in the chambers of policy making. In 1970, the United States adopted the National Environmental Policy Act to protect the environment broadly. It required analysis of ecological, economic, and social impacts triggered by technological initiatives. It also required their publication and opportunities for citizen reaction.

This achievement challenged the public process as to whether society was prepared to deal with the new information on which to form judgments of safety.

In 1972, two related events occurred. First, the United States Congress awakened to the unintended consequences of technology and founded a new advisory agency, the Office of Technology Assessment, the OTA. It was mandated to look ahead and unpeel the ubiquitous side effects of almost every technology. The Act brought the future into the decision process in a vigorous spirit of early warning.

Second, a group of European corporate executives (called the Club of Rome) took time away from their internal management to study and publicize extreme pathological trends in the world at large. Interactions were examined among spiraling population, rising insults to the environment, limits on food production, on such natural resources as energy, and on effects of urbanization. The study, *Limits to Growth*, sounded an alarm that in perhaps 75 years, dangerous trends would become irreversible. Although the study's methodology was questioned, its warnings attracted world wide, policy level attention.

As the public became aware of the two faces of technology, the future was probed not only of physical limits to the carrying capacity of the planet, but limits to human knowledge, ingenuity, judgment, objectivity, and mastery of problem solving. My contribution to the inquiry was to test a portfolio of dangers from unintended consequences of technology against two measures of risk reduction. One lay in defensive technology. The other lay in the muscular practice of politics!

Table 1.1 summarizes conclusions reached in 1977, almost 30 years ago and published in *Margins for Survival*, 1979. The different forms of menace have all happened at one or another scale, including terrorists with weapons of mass destruction (WMD) in Japan. The most effective pre-crisis intervention still seems to be through politics, not new techniques. The poorest guesses were on imminence. Perhaps the author was spooked by total immersion in doomsday subject matter of that era and a close shave with the Cuban missile crisis.

These projections are interesting but not as important as planning a risk analysis strategy for survival. While government has that responsibility, a post-mortem of the Macondo well failures may reveal endemic malfunctioning and the need for broader awareness and involvement of citizens.

Lessons from Disasters and Close Shaves

Engineers remember that until two centuries ago, they learned mostly from failures; occasionally, they still do. The Macondo well and 9/11 have been cruel teachers. With a global span of high-speed communications, we can study catastrophes at great distances. We can construct a rich case book to extract patterns of risk that are universal because natural phenomena are global and new technologies no longer have geographical, national, economic or cultural boundaries. Even our humanitarian concerns encompass people everywhere.

The short compendium that follows is not intended to be comprehensive. It is only a sample of events selected from a swarm of news stories where media editors and TV producers thought them important enough to earn repeated headlines. As the media jargon goes, “the stories had legs.” The initial story had many sequels. That publicity was justified by the scale of impact in lives or property lost, by the surprise lack of early warning, by the likelihood of the pattern being repeated so as to deserve hyper vigilance, and by effectiveness or its failure with damage control.

Table 1.1 – Menaces, Outcomes, Probabilities, and Interventions.

Menace	Worst Case Casualties (millions)	Worst Case Imminence (years)	Probabilities and Trends		Pre-Crisis Intervention		
					Minimum Time (years)	Successful Means (scale 1 - 10)	
						Technical	Political
WMD, Terrorism	30	0	High	↑	10	8	2
Famine, Natural Disasters	1,000	10	High	↑	15	8	5
Environmental Accidents	2,000	25	Medium	↑	15	8	7
Climate Change	1,500	75	Low	↑	50	3	7
Urban Chaos	500	15	High	↑	30	5	3
Resource Depletion	1,500	30	High	↑	20	7	4
Economic Collapse	1,000	15	Medium	↑	15	6	5
Institutional Collapse	500	15	Medium	↑	25	5	5
Decline in Values	2,000	25	Medium	⇒	20	7	3

Consider these large scale disasters, perceived threats, or close shaves:

a) *Hostile Military or Diplomatic Actions*

- A-Bombing Hiroshima and Nagasaki, 1945
- Soviet Space Shot, 1957
- Cuban Missile Crisis, 1962
- Capture of U.S. naval vessel in Tonkin Gulf, 1967

b) *Actions by Terrorists*

- Truck bomb damages New York’s World Trade Center, 1992
- Bombing of Oklahoma City federal building, 1995
- Bombing of U.S. Marine Barracks in Lebanon, 1983
- Bombing of U.S. embassy in Kuwait, 1983
- Bombing of U.S. naval vessel in Yemen, 2000
- PanAm #103 exploded over Scotland, 1988
- Airplanes crash into World Trade Center and Pentagon, 9/11/2001

c) *Violations of the Environment*

- Torrey Canyon tanker spill, 1967
- Exxon Valdez tanker spill, 1989
- Gas emissions damaging the atmosphere’s ozone layer
- Greenhouse Gas emissions triggering global warming
- DDT and PCBs distributed in waters, worldwide

d) *Technology-related Disasters*

- Rash of steamboat boiler explosions, 1830s
- Explosion of chemical plant in Bhopal, India, 1984
- Nuclear power accident at Chernobyl, Ukraine, 1986

- Challenger spacecraft failed on reentry, 1986
- Infrastructure lags behind urban growth
- Long outages of electricity, phones, water and waste disposal
- Failure of whole systems
- One thousand Savings and Loan Bankruptcies, 1980s
- Health care fraud and lack of coverage
- Continued shrinkage of passenger railroads in U.S.

e) Acts of Nature

- Tsunami in Indonesia, 2005
- Earthquake in Kashmir, 2005
- Katrina Hurricane on U.S. Gulf Coast, 2005
- Global flu epidemic, 1918
- Drought and famine, Africa
- Evolution of Avian Flu to threaten humans, 2005

f) Resource Depletion

- Increase in energy demand not matched by new supplies
- Depletion of ground water resources

g) Pathological Violence by People

- Holocaust, Germany and occupied Europe 1939
- Genocide, Sudan, 2001
- Genocide, Uganda, 1985
- Genocide, Iraq, 1996
- Suicide bombers in Israel
- Loss of freedom by concentration and control of media

All these threats share common elements: hazards potentially affecting greater numbers of people than ever before, risks extended geographically and through the future. All involve technology and require human intervention in both prevention and mitigation. In most cases, this depends on government, through legislation, specifically tighter regulation.

Each threat has three back stories: (a) the history and immediate context for the main event, (b) the event and its effects, and (c) the post event consequences and application of lessons learned. Present at every stage are challenges to decision making, mainly by public officials. The political stage is tense: anxiety, frustration, and stress rise over lack of crisis prevention and of damage control plans, over weak communication networks, over conflicts among parties at interest, and over threats to the status of the decision makers themselves. Spotlights focus on first responders, but ultimately on the nation's Commander in Chief. The President is functionally the nation's system manager!

This inventory demonstrates the close bond between technology and government, the centerpiece of a book by this author, *The Double Helix: Technology and Democracy in the American Future*. As these examples are tweaked in the following sections, the reader should focus on a particular class of technologies, those installed to deal with extreme violence of nature or of terrorists, either to prevent disasters or to limit and ameliorate damage.

Tradeoffs Between Risks, Cost of Mitigation and Performance

Safety costs money. That unwelcome truth creates dilemmas in the social management of all technologies as demonstrated in trends of safety measures for automobiles. Here is a sketch of that evolution

Looking back, during World War II, the production lines of cars gave way to production of armaments; fuel was strictly rationed. With peace, the pent-up consumer demand exploded. One unintended consequence was a sharp rise in highway fatalities. As a creature of auto manufacturers, the National Safety Council opened a publicity campaign to reduce accidents, pointed at “the nut behind the steering wheel.” The industry blamed crashes entirely on driver error. Up until then, the most significant improvement in auto safety had been a requirement for brake lights. The public bought that rationale and began training drivers in high schools but ignored safety measures for vehicles themselves.

As fatalities continued to rise, newspapers featured weekend carnage, for example on Route 1 between Baltimore and Washington, D.C. The public became agitated but it lacked mechanisms for protest other than the AAA. Even insurance companies were silent. Safety advocacy then grew following Ralph Nader’s model of credible documentation. Things happened.

State and federal governments mandated turn signals, shatter proof windshields, rear view mirrors, tubeless tires, winter treads, emission controls, seat belts, and stiff penalties for DWI. In most cases, the industry resisted initiatives on grounds that improving safety would boost cost and, following elementary economics, would shrink the customer base. Battling the industry were national leaders in engineering, in public health and in consumer rights. The era of citizen activists and responsive government was just dawning and industry had to be dragged, screaming and kicking, toward safer cars.

Albeit not with mathematical equations, the public asserted how safe is safe. Their tolerance for fatalities in the U.S. remained around 50,000 per year. Beyond that mortality rate, drivers demanded improvements and were willing to pay the added costs.

This story echoes earlier advances in railroad safety and then air transportation. It is also a model of what has happened over the last century regarding citizen protection by immunization, requirements for pure food and drugs, and by preservation of such common property as air and fresh water. Apart from these tangible measures, similar interventions by government were demanded for the less visible harm of monopoly pricing, security trading fraud, etc.

Before elaborating further on the concept of tradeoffs, it is useful to extract further lessons from the case of transportation. Here are some:

First, the public began to say “how safe is safe.” Until after World War II, the cast of inventors, entrepreneurs and manufacturers soft-pedaled the issue of auto safety and targeted most research on fatigue failure of axles. Protection was expected by regulatory processes of government, but in the contest between sources of risk and victims, the most vigorous lobbying came from industry, not drivers.

That changed dramatically by the 1960s. For one thing, the love affair with cars made imperative more and safer highways. Federal support of farm-to-market roads underwent a quantum leap with 1956 legislation to build a national network of superhighways that had been sketched first in 1923 by General Pershing. The breakthrough was intense public support, inflamed by advocacy of the Hearst newspaper empire. The Public Roads Administration set higher standards for states to follow in highway design and construction, on sight distance by limits on grades, curvature, width, and lane separation and freedom from intersections.

The public had found its voice for safer roadbeds to be funded through taxes, and that imperative of risk management slowly leaked over to the cars themselves.

A second lesson was that with safety awareness and education, the public would pay higher car prices for greater safety. Note that the issue was pressed not by car companies or by government but by the public, media, and public-interest associations. Then insurance companies reacted to the suits for negligence brought successfully against manufacturers, highlighted by evidence that risks were known to the companies but not mitigated voluntarily. That pattern improved with legislation mandating recalls. Today, safety sells cars. What a switch!

A third lesson lies in how the growth in public appetite for technology required growth in public services to manage risk. A corollary is that government stepped in only after the fact, practically never in the spirit of preventive medicine. That stance of reaction rather than proaction as a doctrine of anticipation stems from historical American antipathy to big government, and partly from the power of lobbies to influence political leadership. As elaborated later, technology has become more political and politics more technological; sometimes, that reality stings.

A fourth lesson is that the government's role in modern life has greatly increased simply to manage risk. Most of the recent (and not just reorganized) agencies of government were created for the troublesome purpose of regulation. That theme harmonizes with the Constitutional mandate, among others, "to promote the general welfare."

One problem is that each risk is managed by different criteria and different agencies with different cultures, vertically through federal, state and local bodies, and horizontally within each layer. The first broad attempt to improve the risk management process was Section 102(2)c of the National Environmental Policy Act of 1970 requiring environmental impact statements. With a ground swell of popular support, it capped the 1968 presidential election with all candidates driven by public sentiment to stand for environmental protection. The courts later stretched the scope of the act to encompass social and economic dimensions of the human environment and not just those to preserve nature.

That breadth was sharpened by 1972 legislation to create the Office of Technology Assessment (OTA). Its purpose was to provide radar for the ship of state, an early warning system for Congress that required every technological initiative of the federal government to postpone implementation until an assessment was completed focused on questions of, "what might happen, if, or what might happen, unless." This gave public advocates a handle to dig out potentially harmful consequences and through the political process gain mitigation. OTA was killed in 1995. A similar provision for foresight was mandated in the 1976 mandate creating the White House Office of Science and Technology Policy; it has been ignored.

The preceding brief that was concerned with tradeoffs between safety and cost used auto safety as an example. Similar patterns are present in other modes of transportation, by sea, by air and by railroad. A second mode of tradeoff is present when independent parameters of design performance interact with both safety and cost. The most compelling example is with combat submarines.

As context for this case study, recall that submarine hulls must be designed to withstand the intense hydrostatic pressure of surrounding sea water when submerged to operating depth. Given the catastrophic nature of hull failure and the exposure of crew to such risks, precautions are taken to compensate for uncertainties in design theories, in materials, workmanship, aging, or from operating error. This additional strength usually entails additional weight and that poses a dilemma.

Submarines operate close to neutral buoyancy. This affords diving simply by admitting sea water to external ballast tanks. Surfacing then entails blowing the ballast tanks with compressed air carried on board. With such a delicate balance of weights between the sub's hull, propulsion, weapons, life-

support functions, crew, and sustenance; the incentive for adding strength to reduce risk to crew and sub itself carries a serious penalty. The weight for additional strength must be traded with weights of other components required for combat.

The design process requires serial trial-and-error calculations, varying the safety margin. For civil construction, the building codes dictate a factor of four. For special boilers, it may be as small as three. For submarines, that high a margin would prejudice war fighting characteristics, and practice for naval subs has been as small as 1.7. For research subs, it has been set as low as 1.4. For sightseeing subs, it has been set at 4. The 1.7 level means that for a sub designed to operate safely at 700 feet, its crushing strength would be about 1100 feet.

The risk of such a small margin is accepted because for each new class of subs, complex calculations are refined, confirmed by tests of small scale models in a pressure tank, then warranted by a heavily instrumented deep submergence trial of the first one operating. Other assurances lie in superior workmanship in hull assembly with x-ray examination of welds and close tolerances on shape. Operation at sea assumes high competence of crew.

In other ways, similar margins are introduced in all technologies as an act of social responsibility. The public exposed to risk is seldom consulted, and this raises a major issue in risk management that is epitomized by the familiar notion of “Informed Consent.”

Voluntary versus Involuntary Risk

Exposure to risk may be voluntary or involuntary. The two types differ in definition in the acceptable levels of risk and in the degree to which the public expects government to regulate safety. When citizens believe they are in danger with limited options to escape, and when a large number of people is simultaneously exposed, the public demands greater protection. Here are some examples.

When planes became more numerous and larger, there were more crashes and more passengers lost. The public demanded more stringent regulation and enforcement. Commercial airlines were regarded as common carriers in which people lose control over costs, comfort, privacy, schedules, routes, intermediate stops, destinations, and risk. Except for short flights, other modes could not compete in speed so that the primary tradeoff was in cost of tickets. As in all common carriers, by air, rail or sea, people felt at involuntary risk and demanded more protection. With encouragement by members of Congress, most of whom fly home every weekend, intense oversight has been mandated regarding equipment, pilot training, traffic rules, maintenance, etc. The annual death rate peaked at about 200 per year and is now much lower, far lower than for travel by car.

In contrast, passengers in private planes—termed “general aviation,”—enjoy all the previous options but at a higher transportation cost. To keep that within bounds, this class of passenger tacitly accepts higher risks revealed by more fatalities per million passenger-miles compared to commercial aviation. Because these passengers usually have options to fly by safer commercial aircraft, FAA risk analysis deems the higher risk acceptable because general aviation risk is voluntary rather than involuntary.

A more mundane example lies in skiing. Cable lifts are regulated by local authorities as common carriers because the clientele are regarded as at involuntary risk in having no options to gain the top and no options to exit at intermediate elevations. Lift safety is carefully regulated. Coming down, however, skiers are on their own, at voluntary risk. If the number of accidents going up were as numerous as those coming down, there would be hell to pay from public complaints and from lift operators hit with higher insurance premiums and possibly more liability suits.

This question of voluntary versus involuntary risk gets blurred in consumer protection, especially with pharmaceuticals and medical apparatus. Both in liability jurisprudence and in safety standards, a major issue arises on which type of risk is present, and for each type, how does the public decide on acceptable limits.

That enigma is further strengthened because of a growing public distrust of manufacturers. Statistics from drug trials have been faulty (Merck) and short circuits in heart rejuvenators have been concealed (Guidant). This malfeasance injects another uncertainty in the calculus of risk—the pressures of the health industry on Congress to let free market forces control safety with a minimum of government interference. That could work only if the public is literate on drug therapy; that is unrealistic.

The situation is further tangled by paradoxes in health affairs on the virtues and penalties of single payer health delivery and by advances in technology teasing consumers to believe there is a cure for every ailment, at diminishing risk.

Regulation of safety for miners at involuntary risk under ground began 100 years ago after annual fatalities exceeded 2,000. Occupational safety is now broadly regulated by OSHA.

Coping with Threats to Life, Liberty, Property and the Environment

Restated for emphasis, the most compelling imperative of life is survival. For most humans, that condition is more than biological. It means being both alive and free. Toward that end, living teaches that there is no zero risk, that some exposures must be tolerated as “normal.” In the last two technological centuries, however, society has demanded that threats to life, to peace, justice, health, property, liberty, life style, sustainability, and the natural environment be minimized. Such stewardship was anticipated in a preface to the Constitution whereby founders of the nation committed our federal government to assume responsibility to tame these risks.

Life also teaches that threats to survival are episodic, that citizen and media sensitivity to both threats and appropriate response waxes and wanes. Apprehension and fear peak immediately after a calamity, then subside to a stable level that depends on pain of the consequences and proximity to the event, chronological and geographic. The size and continuity of news headlines mirrors and often arouses public awareness. With the Deepwater Horizon Macondo well failures, chagrin was triggered over impacts of a recurring phenomenon that exposed failure of government at all levels to take precautionary steps for safety and security. The loss of life and property and the subsequent neglect of victims (people and the environment) then led to outrage. People ask, Why did a tragedy on this grand scale occur? How can it be prevented from happening again?

This essay is not a post-crisis analysis of the Deepwater Horizon Macondo well failures or of its disaster kin. For one thing, critical data are still being evaluated. However, it is clear from a number of interim reports already issued by other bodies that the failure can be attributed to human and organizational error. This source of calamity has also been found in a wide spectrum of disasters; the nuclear accident at Chernobyl, the oil spill by the *Exxon Valdez* discussed later, Human factors lie behind the failure of intelligence and initiation of the Iraq war, sinking of the *Titanic*, terrorists crashing planes into New York’s twin towers, 9/11, loss of the spacecraft *Challenger*, and the chemical spill at Bhopal, India. This source, incidentally, includes failure to anticipate potential disasters, make damage control plans, take accident avoidance measures, or make prudent choices as between safety and cost.

It is worth reiterating that the answer to “How safe is safe” cannot be deduced from natural laws of science and mathematics. It is a social judgment. Assuming people comprehend that there is no zero risk, what level do citizens accept or at least tolerate?

This inquiry is most often left to experts because the public thinks risk analysis is accessible only to professionals. Yet, individuals make many decisions each day without consulting authority. Ponder the close shaves in highway traffic, the choices of home remedies for illness, the strenuous avoidance by those allergic to nuts, and the tradeoffs in investments between return and risk. Albeit in new forms, modern risks have antecedents.

Always, there have been accidents from ignorance, error, blunder, folly, greed, and hubris.

One new reality is that powerful technologies add to the risk portfolio. The public and policy makers need to understand that technology is more than a technique, more than palpable hardware. It is a social system of organizations interconnected and animated for all life support functions.. Clearly, technology has a huge effect on all human affairs, not only for what it can do **for** us, but also what technology can do **to** us.

Every technology, however, has unintended consequences. Many increase complexity, conflict, personal stress, and socio-economic strains. To the point of this discourse, technology such as in health care can ameliorate risks, but it can also trigger risks. With many medical procedures the patient must sign “informed consent” acknowledging awareness of threats to life and function. Parenthetically, that practice deserves refinement because simply listing potential injuries does not illuminate the probabilities.

Because of modern information technology, events anywhere have effects everywhere and immediately. The village has morphed into an inhabited planet. While technology has historically driven weapons development of the spear and chariot, nuclear devices now spin a risk of mass extermination. Perpetrators may not be nations but anonymous and ubiquitous terrorists. We have also advanced the risk of a slow tsunami by global warming that melts the ice cap so that the oceans flood low lying habitation in coastal wetlands and alter agricultural seasons.

As context to the strategic issues in risk management, consider these features:

- Dangers can be grouped according to origin, from natural causes, from human behavior, and from unintended consequences of technology such as environmental damage from mining runoff.
- The design of precautionary measures requires inspired and vigorous foresight—to fantasy what might happen, if, or unless, and a comparison of options to identify those that minimize harm.
- Foresight mandates tradeoffs as between short and long range events and consequences, as between safety and cost, between special interests and social interests, between who wins and who loses and who decides.
- Technology can best be understood as a “Technological Delivery System,” that applies scientific knowledge to achieve society’s needs and wants. A TDS models reality with inputs of knowledge, fiscal, natural, and human resources synchronized by a network of communications. Outputs are both intended and unintended. The system is driven and steered by three operating instructions--- market place economics, public policies, and social norms.
- Technology lies at the core of all human support systems.

- Conflicts arise from different values in the private sector as compared with the public. Strategies to achieve desired goals contrast efficiency against sustainability and social justice
- All technologies trigger side effects; most are harmful to some community of specified or accidental stakeholders, now or in the future.
- Key decisions regarding technology in terms of outcomes are not made by scientists or engineers, or by executives in the private sector. Rather they are made through the public policy process, in the U.S. as defined by the Constitution, the President, the Congress, and the Courts.
- The decision process inevitably entails wrestling for power; its intensity depends upon what is at stake as between winners and losers.
- The most compelling decisions are negotiated as “politics,” here defined as the legitimate process by which stakeholders negotiate their individual interests against collective interest within a structure of authority.
- In our democracy, this authority should flow from citizens following the doctrine that those who govern do so with the informed consent of the governed.
- Decisions in this class can be judged by their impacts on future generations.
- Technology has also shrunk time and distance so that isolation is no longer dictated by geography. We live in “one world.”
- The management of risk should be based on lessons from failures. However, data may be sparse with rare events of catastrophic scale.
- Different cultures have different risk tolerances. Moreover, there are significant distinctions as between voluntary and involuntary risk.
- Once there is agreement on “how safe is safe,” tension is likely to continue between the sources of risk and those harmed. In the interest of social and economic justice, all three branches of government play pivotal roles.
- Since enactment of the National Environmental Policy Act in 1970, a process of impact analysis has been required of all federal technology initiatives. It applies to other classes of threat extended by legislation in 1972 that created the Office of Technology Assessment to serve Congress as a system of early warning of dangers from new technological initiatives.
- The media plays a critically important role as a source of information to all citizens and parties at interest about threats and public safety, about failures of institutions responsible for precautions, and as an editorial source of advocacy for citizens marginalized in the power structure.

2. Government's Responsibility for Security

Risk Management: Our Constitution, Public Policy, and our Culture

Restated, the TDS is a symbolic network assembled for a specific purpose with socially desirable outcomes. It incorporates customized organizational components, internally differentiated, hierarchically interrelated, and interconnected by a lacework of communications. While this production function is generally the territory of private enterprise, all elements of the system influence decisions by business management; the most powerful signals link government to the enterprise managers. In eight different ways, public policies hammered through government shape

strategic decisions in the private sector as much as the market place of all citizens. Consider these categories:

- **Providing an umbrella of security for citizens** as set forth in the preamble to the Constitution. Translated to “normal risks,” providing security is the core of managed risk. It is exemplified by preparing for the common defense. That priority for federal funding in 2005 exceeded support for all other federal functions, combined. Beyond threats from organized national states and from terrorists, security also relates to domestic tranquility, social and economic justice, and especially, promotion of the general welfare when life, health, and property are threatened by natural calamities. Civic responsibilities now include preserving health of the environment and natural species.
- **Purchasing technology** for national defense that also generates full employment and technology spin-off whereby military innovations cater to the civilian market, e.g., satellite assisted global positioning devices (Global Positioning Services, GPSS).
- **Directing economic assistance to private enterprise** has been accepted as a tradition to foster prosperity and social satisfaction, not to mention economic vitality to assure a healthy tax base. In 1845, the government granted railroads a ribbon of land for trans-continental service. Wider than needed for track, these grants let rail lines profit from sales of excess land to track-side factories. The Corps of Engineers surveyed most of the mountain route at no cost to the companies, following a maritime subsidy of charting coastal waters for safety of commercial shipping. Other subventions include a rainbow of tax breaks, import quotas and market guarantees.
- **Providing indirect economic assistance to private enterprise** through support for higher education, for most of the nation’s basic and applied research, for such services as the Export-Import bank, launching of commercial communications satellites, weather forecasting, and guidance for American companies doing business overseas. In short, government funds our social overhead.
- **Influencing the capital market** by deficit borrowing, fiscal and tax policies, by manipulation of interest rates, balance of payments, and facilitation of venture capital for new starts and ability to meet foreign competition.
- **Functioning as steward of common property resources** such as fresh water, forests, fisheries, minerals, and pasture on federal property that includes petroleum reserves on the outer continental shelf, and the radio frequency spectrum.
- **Building or financing infrastructure** such as of shipping channels, highways, airways, Amtrak, intangibles of the radio frequency spectrum, and the Internet.
- **Regulating** private technological activities that may be inimical to the public interest. These interventions range from anti-trust legislation, abolition of child labor, safety of transportation and mining, to purity of food, air and water, occupational health, effectiveness and safety of drugs, toxic waste disposal, and other measures attending hazards of powerful new technologies.

These functions led to growth in government size and scope, the unintended consequences of greater dependence on high technology. All trigger conflicts, especially on the issue of the appropriate role of government in a society that considers itself a capitalist democracy. History teaches that regulatory legislation was consistent with Constitutional law and later of custom. The courts expect government to make the most fundamental and influential decisions contributing to security. Beyond “national security” that justified our attack on Iraq, government regulates by ranking social priorities, allocating resources, helping to organize economic, social and political activity, and tries to resolve conflicts among contending parties. That menu carries no warranty, however, on performance.

Some conflicts arise, incidentally, from ideology: when those asserting conservative doctrine believe that the best government is the least government. Some conflict arises from the concept of federalism, the cyclic tension between state and federal governments. Some arises because claims on the public purse are not matched to resources so that losers perceive themselves as victims of a game for winners.

Persistent conflict arises because most hardware of technology is produced by the private sector. Its Wall Street performance balances only direct costs against profit but not the indirect costs, the externalities, and the unintended consequences. Because citizens have only limited opportunities to voice the pain of side effects, government is expected to act as a surrogate. Even when represented by public interest bodies, remedies can only be enforced by government operating under legislative mandates. That damage control, however, is not guaranteed.

The act of governing begins with identification of issues, dramatized by political actors to focus political energies on the choices ahead. Often that process sounds exclusively like wrestling by special interests for influence on the outcome. At some point, differences are negotiated for a consensus on public policies as to become laws.

In other words, public policies are what governments do or what they may not do. They are the primary guidance signals by which a pluralistic society sets the course for the future. These policies should also set the ground rules, for example, of opportunities to express a collective judgment on “How safe is safe.”

Public policies deal with both ends and means. Two legislative steps are required, of authorization and of appropriations. Ultimately, all policies require the President’s signature, making the incumbent the nation’s uncertified systems manager.

Evidence is clear that government has grown because of technology, and technology blossomed because of government. As uncomfortable as is this trend for some, especially around April 15, one way to look at the new or growing functions is to test their content against a concept of “enhancing security by managing risk.”

Resolution by Political Power and Political Will

The word, “Politics,” suffers from erosion of its high status in Greek culture, 2500 years ago. It was meant to define a social process by which individuals with differing opinions could argue and try to persuade contrarians of their preferred course of action. This was the grist of democracy, the honorable steps to generate consensus.

Now, the word, politics, is often modified by a second one, “dirty.” That derogation implies that tactics of argument violate social norms of truth and fair play. Indeed, the phrase has been stretched to imply that all political actions are contaminated, either by distortions of content or by foul play.

In the political arena when stakes are high, there are many temptations to stray from a moral ideal. However, the historic definition still works. Simply put, politics is the mechanism by which the parties at risk with divergent opinions reach agreement on what risk level is acceptable. The political process, however, goes beyond argumentation. It offers a structure of power to resolve differences, then to enforce an action plan to achieve the goals about which there was debate. In the United States, while that power lies in the three branches of government, from earlier disclosures and discussion, in the present era, the President and Executive Branch dominate the stage.

Presumably, voices of different constituencies have been heard and the Chief Executive has determined the degree of popular support essential for success of a particular course. Penalties are assessed for having to use political capital to win a preferred alternative. Since a president's political capital ebbs and flows, each decision event imposes a political risk. As with risks to security, in politics there is hardly ever zero risk.

Indeed, all the stakeholders are at political risk before, during and after a quest for consensus. Each must choose how much existing political capital they can risk. That strategic reality colors the entire context of risk management because the outcome can seldom be settled on rational grounds alone. Risk managers understand distinctions between the desirable against the feasible.

At policy levels, all players have access to varying amounts of power. The party with the most may not prevail, however, unless there is a conscious decision to exercise political will as well as power.

In a democracy, the media have a major role similar to that in the economic operations of the free market. For it to work best there is a tacit assumption that all parties have ready access to the same base of information. That assumption also applies in political warfare.

In the theater of risk, that principle may not hold. Parties at risk seldom have the same information as those managing risk. We also must distinguish between voluntary and involuntary risk because social judgments for these two cases are vastly different. It is one thing if the parties at risk are advised in advance which mode they are subject to. It is another thing to be subject to involuntary risk surreptitiously.

In an age when small disturbances can have disproportionate effects, integrity of all negotiating parties may be more important to risk management than technical virtuosity.

Human nature, however, may shatter this ambition. As suggested earlier, the term politics snaps the mind to electoral politics. Included are the strategies and tactics of ethical lobbying, electioneering, and legislative horse-trading. Still, the politics of public life, as the TDS suggests, is more than about governmental structure and process. Indeed, deciding how safe is safe is what democracy is all about.

Democracy is not a spectator sport. Citizens should regard themselves as part of government. This role requires civic literacy and commitment to shared values. Civic discourse should avoid intense partisanship and hidden influences of campaign funding. Values, unobtrusive and subtle, lie at the heart of political process, thus connecting more and more dots on the TDS.

This focus on ethics applies to other venues—corporate board rooms, academia's cloistered walls, and religious institutions. They differ greatly with regard to what is at stake, to measures of integrity, to an organization's culture, its ethical standards, its style of conflict resolution, and the degrees of coercion exerted by management's power to control its environment.

In the interest of earning public esteem or minimizing exposure to liability claims, organizations and individuals must balance temptations to conceal, distort, exaggerate, or lie about facts against the harm they may do. The public interest is all too often sacrificed for private benefit, tempered only by the self-conscious exercise of social responsibility.

Building trust takes time, especially in an electronic era when participants in a transaction may be strangers. Personal contact to test integrity by intuition may be squeezed out.

The issue of trust has always been with us, but recent polls uncloak a new low in public confidence in all our institutions. This is not surprising. Innumerable business executives have been indicted or jailed for misbehavior, for which the 2006 Enron trials serve as a poster child. Simultaneously, charges have been brought against Abramoff, the best known of Washington's lobbyists. Several members of Congress face felony charges, have left office, resigned, or are awaiting trial. In both public business and private business, many display an inordinate appetite for wealth as well as power.

Although not subject to proof, the public seems to demand higher ethical standards in public service than in commerce. There may be a danger, however, that the distinctions have been blurred. Social indicators as well as economic indicators suggest a weakening of all the nation's vital signs. The future for children is less promising than for their parents.

This theme has been examined by a growing chorus of public interest bodies such as Common Cause, Move On, ACLU, Natural Resources Defense Council, Interfaith Alliance, etc. Over a broad spectrum of predicaments that seed new or more threatening risks, there is neglect of harmful long term costs balanced against short term benefits. The fault lies in limits to foresight blended with inflated political and corporate ambitions, hubris and greed.

The President and the Congress: Needs for Advice and Counsel

Given society's encounter with different and more threatening risks over the last half century, the burden of responsibilities on the Chief Executive and the Legislature has grown enormously. Risk management is not a function that can be outsourced. At the same time, it is difficult to shoehorn all risk-related functions into a single unit. Consolidation of homeland security functions into a mega-sized, cabinet-level agency still requires coordination with such other departments as State, Defense, Commerce, Interior, Labor, and so on. Only the President and Vice President have the Constitutional authority and the operational centrality to effect a seamless integration of bureaucratic resources each exposure to danger requires.

The problem is that both the President and the Congress are suffocating under workloads that drain energy because new threats arise without relief from earlier ones, and because the technical management of risk requires expertise that is in short supply. Especially lacking is an independent staff for both branches of government to provide advice and counsel in a *modus operandi* committed to a doctrine of anticipation.

To be sure, both branches have sensed a need for professional expertise related to other complex, even arcane, functions. Both branches have responded by creation of specialty staff arms. The Executive Office of the President was created in 1939 and has added numerous special subdivisions as circumstances dictated. These include the National Security Council, the CIA, the Office of Management and Budget, the Council on Environmental Quality, the Office of Science and Technology Policy, even FEMA at one time. Congress has created for itself the General Accountability Office, the Congressional Budget Office, and the Congressional Research Service.

These latter three have earned a high reputation for integrity, non partisanship, and insulation from political pressures to tweak facts to fit ideology.

This issue of staffing to deal with catastrophic risk is raised here to alert the reader to arguments arising from substantive issues that may suggest a review of staff capabilities to match the challenge of security in a more dangerous and complex world.

As detailed elsewhere, a small staff could follow methods of impact analysis developed over 25 years of experience with the National Environmental Policy Act and be available in a dire emergency to keep the President well informed. Experience of the Congressional Office of Technology Assessment could also be resuscitated.

3. Technology and Its Side Effects

Beyond Technique, Technology as Social Process

The term, “technology” has a rainbow of definitions and deserves clarification on usage here. Very simply, technology is considered a social process by which specialized knowledge from science and empirical experience is employed through engineering to deliver a system to meet specific human needs and wants. But not just through engineering. Other fields of knowledge such as economics, social and political science, psychology, and even philosophy must be tapped and synthesized with technique.

This concept carries virtues and problems. One virtue is the distinction thus drawn between the notions of “engineering” and “technology.” Confusion arises because institutions of higher learning have used both words as equivalents in their titles [MIT, CIT, GIT, RPI, etc.] The problem triggered by technology’s broader definition is the mixture of disciplines that are not familiar to engineering practitioners. I have joked with colleagues about engineers treating the world as though it were uninhabited except by Newton’s laws and their kin. Students in Civil Engineering learn how to design bridges for specified traffic over a specified span, but are generally unable to answer questions of why build the bridge at all, and if so, why there?

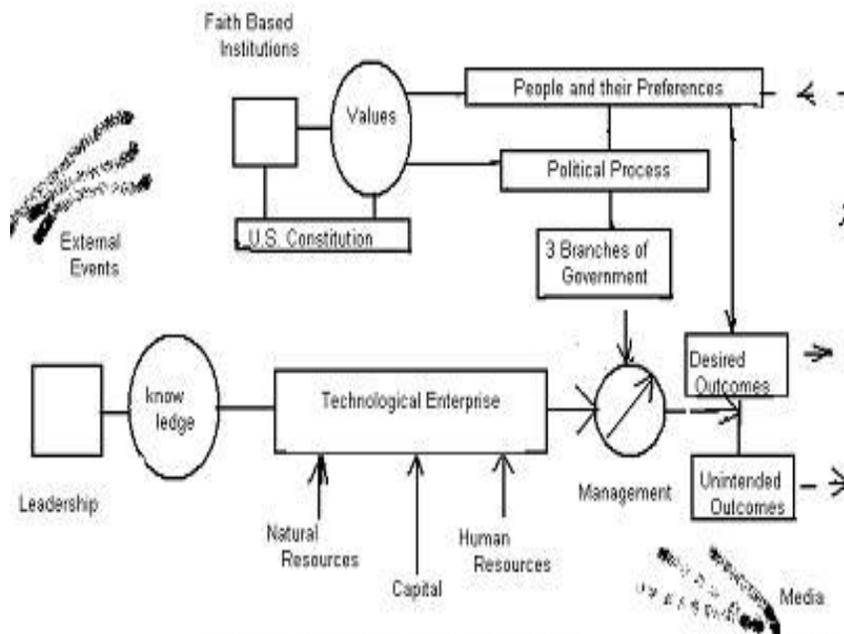


Figure 3.1 – Technology Delivery System.

In 1970, I clarified the definition with a mental model of a delivery system, a "Technological Delivery System." As shown in Figure 3.1, the TDS meets a standard definition of a "system" in having inputs, outputs, organizational components, and information linkages. The inputs comprise knowledge plus human, natural, and fiscal resources. The outputs are of two kinds, the desired goods or services plus unintended consequences, most of which are harmful to some people or to the natural environment, immediately or in the future.

To tour the diagram, we start with technological enterprise, what the economist, John Kenneth Galbraith, termed a "technostructure." It is assembled by entrepreneurial leadership, motivated by the push of innovation or by the pull of external market demand. Under resourceful management, the enterprise feeds on capital, human resources, natural resources including energy, and on knowledge. These are inputs.

The system then spins two kinds of output, the intended goods and services and the unintended and often unwelcome. Such powerful processes fuse technical, economic, social, political, and cultural factors.

There are two instruments of these influences: a) the institutions of government reflecting structure and processes specified in the Constitution, and b) faith based institutions following a wide range of value-oriented doctrines.

All of these functions and their vehicles are portrayed in the TDS diagram. Their communication linkages are portrayed by solid lines. There are, however, other powerful influences that cannot be encapsulated because their influences are spread throughout the system. These are impacts of external events and messages from the media.

Metaphorically speaking, the TDS is like a wiring diagram for a stereo set. The system not static, however, but is animated. The TDS equivalent to music coming through a stereo is the communication traffic leading to public policy.

The message content is shaped and steered by three operating instructions, the invisible hand of the free market place, public policy, and values embedded in the culture that ignite moral vision and mold conduct.

Validity of this analytical model was tested over two decades by graduate students who applied it to nearly 100 different technologies. The purpose over many years was to capture commonalities, that is, patterns of performance. They are condensed to 12 axioms, some mentioned previously:

- Technology empowers all life support systems—food production, transportation, communications, military security, shelter, urban infrastructure, health affairs, environmental management, energy production, banking, criminal justice, education, entertainment, even religious institutions.
- While manifest as hardware—planes, trains and automobiles—technology is best understood as just described, as a purposeful arrangement of public and private organizations synchronized by information networks.
- Most hardware is conceived, designed, produced, and marketed by private enterprise in a capitalist industrial economy under a mantra of "efficiency."
- All technologies spawn surprise side effects, most unwanted by some sector now or in the future.

- All technologies pose risks from accidents triggered by human or organizational error with unprecedented scale and geographical distribution. Accident prevention must thus be integrated with engineering design.
- Technology generates wealth and enhances living standards, but it also fosters materialism, concentrates rewards, and increases appetites for both..
- Major decisions about technology are not made by scientists, engineers, or business executives. The most salient are in the design of public policies. Technology thus tends to concentrate political power, just as power tends to concentrate technologies as corporate structures.
- We enjoy what technology does *for* us, ignoring what it can do *to* us. One counter trend is shifting from “Can we do it?” to “Ought we do it?” and “Can we afford it?”
- These cultural impacts appear as paradoxes: more communications but less sense of community, more information but less understanding, and more machines for living but less leisure. Technology distorts perceptions of time and tends to focus on the short run at the expense of longer term costs and benefits. It also distorts perceptions of space because the entire planet is wired,
- Technology tends to weaken human relationships and to foster self-indulgence and isolation.
- In an age glorifying information, we neglect its transformation into knowledge and then into understanding. These steps require time for cogitation and for preparing the mind.
- Despite its material benefits, technology induces anxieties and stress because the pace of change seems to exceed natural human rhythms, and because of greater complexity, multiple information feedback loops, and uncertainties about the future.

Technology’s Unintended Consequences

One of the three classes of risk deals with unintended consequences of technology. As with the Deepwater Horizon Macondo well failures, there may be combinations of forces by nature, by human error, and by technology’s side effects. This drama entails machines whose function is valued for its benefits, but which spontaneously also birth serious disadvantages. To define this phenomenon more emphatically, I argue that all technologies have unintended consequences, most but not all of which pose surprise costs on innocent victims, to the extreme of lethality. Even when catastrophes are foreseen, they may not be preventable because intervention is too impracticable, too costly or too unpopular.

Once I thought the technology of immunization was an exception because the number of lives saved far exceeds the tiny number of people injured by this prophylaxis. Then I was reminded that this benefit partly accounts for the planet’s overpopulation and hunger. Even life-saving measures have malignant side effects. Incidentally, the technology of prevention is more than a needle or a spray; it includes all elements of a TDS, especially many layers of government.

Economists call these subsidiary features “externalities,” a characterization of costs that implies a studied neglect in the calculus of economic performance by shifting the burden to other actors beyond the boundary of a particular organization.

Another euphemism reborn during the recent Iraqi wars is “collateral damage.” Whatever the term, risk analysis carries a premise that every technology plays “Jekyll and Hyde.” So we must learn to live with ubiquitous risk. Risk happens.

Consider these concrete examples. Nuclear weapons at the pinnacle of national defense left hazardous waste at the manufacturing plants, with long radioactive half lives. At the Hanford, Washington, weapons plant, leakage from single-shell, underground tanks is migrating toward the Columbia River to threaten drinking water down stream. Civilian nuclear power has dangerous byproducts that, 30 years after pledges of safe disposal at Yucca Flats, Nevada, continue to fuel debate.

Automobile transportation discussed earlier for its evolution of safety has had enormous consequences besides people killed or maimed. There are air pollution, noise, stress, lost time, and wasted fuel from dense traffic, superhighways puncturing urban centers, disruption of rural life by housing developments, and an insatiable thirst for fuel that shapes geopolitics with oil producing states. The American system for health care entails costs of 16 percent of the nation’s GDP, or in other terms, \$1,500 per GM vehicle, almost ten percent of the sticker price.

As we struggle with these relentless gremlins of high-tech society, the public that ordains how safe is safe has become more sensitive to involuntary exposure to risk and seeks protection from the perpetrators through political action. Citizens demand governmental action.

The management of risk is perhaps the greatest challenge of the modern world—risks of terrorist nuclear bombs, risks of global warming, risks of corporate or national bankruptcy; indeed risks across the portfolio catered earlier. The dilemmas are intensified because society looks neither sideways nor ahead. At best, vision stretches to Monday morning.

That cost of being nearsighted is widely understood. The commercial world took precautions against losses of ships and cargo through insurance companies hundreds of years ago. When these costs mounted, reinsurance was invented to share risks. Now, we seek protection against the full repertoire of hazards, partly out of greater literacy about risk through the media, partly because we have become a litigious society, and partly because the insurance business can be quite profitable.

Government is a reluctant partner of the private sector in dealing with risk by a wide range of instruments. Farmers depend on price supports for their products in the face of crop uncertainties and on tariffs to blunt foreign competition. Flood insurance was offered when corporate America chose not to indemnify the vulnerable. The nuclear power industry was protected by a powerful cap on liability, and a swarm of federal and state measures have been proposed or enacted to cap liability with suits on medical malpractice.

For all parties in technological delivery systems, consciousness has risen on the imperative of foresight. Now a different question arises: If all technologies trigger side effects, why? Was this always true?

Consider the TDS of farming 150 years ago. The family farmer took title to some land, planted and reaped with steam propelled tractors, chewed fingernails when weather turned hostile with drought or freezing or a late, wet spring. At harvest time, farmers took produce directly to market and often sold directly to the local consumer without any middle men. The farmer took all the risks of crop failure. The TDS was a primitive combination of only three entities, the land owner, the farmer, and the customer.

In 1878, the Hatch Act created the Department of Agriculture with the objective of producing more food of superior quality at lower cost. With federal assistance, science and technology began to replace tradition and folk lore. Government funded an education system of agriculture colleges and research laboratories, and extension services translate academic findings for field hands. Then with the 1930s depression, government sponsored numerous subventions to hedge against soil blowing away and creating a dust bowl and against other disabilities..

With these advances, the private sector found new and profitable enterprises, manufacturing farm machinery and trucks, distilling fuel and chemicals, contracting to build farm-to-market roads, harvesting seed, and selling pumps for artificial irrigation. And the private sector lent farmers money to buy seed and fertilizer for the next season, and to expand acreage as machinery made larger plots amenable to management. In a perspective of the economy, the Ag-business blossomed as organizational size and heft offered efficiencies not available to the family farmer. Their demise as a side effect has become a topic for concern.

In recent decades, transportation by sea, land, and air made possible the sale and consumption of food far from the producer at reasonable cost. That condition had a downside also in turning the entire planet into a single market place. Try to trace where the tuna fish were caught that you find locally in cans.

This story is dramatized by comparing the simple TDS of 1900 with that today. The increase in number of components in the TDS, information circuits, speed of transportation, sophistication and complexity of modern farming, the need to follow world prices, supply and demand, spread of blight and disease, cost of money, and possible climate change adds to complexity and challenge. These influences also add to risk, especially as the system engages a highly decentralized cast of uncontrollable characters. Each element of a TDS introduces some market advantage but also some additional risk of uncertainty depending on which political force is strongest and has access to the policy apparatus.

In the calculus of risk, the most compelling requirement in a TDS is a viable information system. That technology is necessary but not sufficient. To produce desired outcomes, information must be transformed to knowledge, then to understanding, and finally to the exercise of foresight so as to minimize unintended consequences. That motivation and capability to look ahead may be more important in managing risk than new scientific discoveries and technological techniques.

Parenthetically, humans have always been curious about the future, especially regarding the role of fate. The Hebrew Bible tells a story of rewards for forecasting years of famine and years of plenty. Astrological calendars to read portents from the planets and stars dates back 5,000 years and is still found in today's newspapers. Individuals who claimed to divine the future held honored posts in many societies. Some still inhabit stock brokerages. Games of GO, checkers, and chess are won by plotting several moves ahead.

Looking ahead assumes greater significance in modern cultures that treasure speed. Progress in computer science depends on the speed of chips, modems, and services. Autos are rated by the shortest time to reach 60 miles per hour. Failing to look ahead more attentively has higher costs. A clean windshield and an unimpaired driver may be the metaphor for safety. In atmospheric fog, we slow down. In social fog, we complain.

That conditioning has its rewards and we need to seek this kind of analogy when dealing with other situations to probe ahead so that glittering benefits do not blind us to their dangers.

In that respect, society shifted gears in the 1960s regarding insults to the environment. The public acted through the political process to look ahead through environmental impact analysis at what might happen, if, and the tradeoffs for perceived long term benefits against costs, and for finding the optimum delivery system.

This concern for the future of our children was broadened by the concept of technology assessment in the Congressional Research Service in 1964 that systemized a doctrine of anticipation. It has nine steps:

- Define the technology delivery system in terms of purpose (ends) and content (means) of hardware and operating systems.
- Define the economic, political, ecological, and social context, and the institutions comprising the TDS and their behaviors.
- Establish a base of facts, uncertainties, and conditional consequences.
- Forecast what is foreseeable with awareness of how the hardware and software advance, how public attitudes change, and how management learns.
- Imagine action alternatives to mitigate risk and trace impacts of side effects.
- Identify impacted parties, including future generations.
- For each option, compare positive and negative impacts.
- Design a policy and implementation plan that has the best promise of reconciling achievement of goals with satisfactions of different stakeholders.
- Monitor and report post-implementation performance.

The Congress deserves praise for adopting this legislative remedy to near sightedness and tunnel vision. It is unfortunate that the Congress didn't peer ahead at what the longer term penalties could be for zeroing out the OTA.

What You Can't Model You Can't Manage

This section's title is an aphorism that states; unless you can build a mental model to represent reality, attempts to manage will fail. On the principle of linkage between cause and effect, it may be possible to examine an event and describe *what* happened, but not *why*. Measures to reduce risk may end in futility.

Toward using the TDS as that generic model to conduct analyses, managing risk entails mapping the interaction of people, politics, and technology. Across a spectrum of multiple stakeholders with different cultures and conflicting purposes, the universal goal is to achieve socially satisfactory outcomes. The TDS architecture combines seventeen components diagrammed in Figure 3.1. That static map can be switched on by discerning system dynamics.

To explain, for each life support system, a TDS is assembled by entrepreneurial leadership in response to market demand or to the opportunity created by invention and innovation. Aware of requisite inputs of human, natural, capital, and information resources to spin out the desired outcomes; management acts. In the investors' expectation of profit, the free market mechanism spins to do its thing.

Citizens also use the market mechanism to signal their displeasure with unintentional and undesirable outcomes. For over a century, however, experience has taught that market forces don't suffice. Government is obliged *post facto* to enter the arena with a pallet of regulations for reward and punishment. The TDS shows these dual avenues for people to express their preferences, one by

purchases directly in a mall and one by public policies hosted by political process. All three branches of government participate.

In our democracy, the political process serves as a steering system, thus the earlier appellation of the President as the nation's system manager.

From analysis of decisions generated in the TDS case studies, we observe that both society and its political apparatus are strongly shaped by values of society as a whole and of key individuals in the decision chain. In a sense, the primary sources of values are the U.S. Constitution and indelible influences of early education in a variety of faith-based institutions.

Two other conditions drive policy design, external circumstances, and the media. . Consider this sequence of events: the Great Depression of the 1930s, the attack on Pearl Harbor, the Marshall Plan, the Soviet space shot in 1957, assassinations of President Kennedy, Robert Kennedy and Martin Luther King, the resignation of Richard M. Nixon, the multiple bombings by terrorists, and the Iraqi war. All left scars on individual citizens and the national psyche.

As to the media, a revolution has occurred in techniques within information technology. Both the geographic span and the speed of communications grew rapidly in text and graphics, in both print and electronic media. Within the technology of electoral politics, in campaigning since the 1960 election, the purchase of TV time has become imperative. As Marshall McLuhan predicted, the medium has become the message

Yet another recent development is the concentration of media ownership. Objectivity became vulnerable to manipulation by lies and misuse of news as propaganda. On the positive side, however, the press continues as the "fourth branch" of government. From the birth of the nation with the Declaration of Independence the backbone of power is said to lie with "we, the people." That social process is exercised only if "those who govern do so at the consent of the governed." That famous expression should be modified to say "informed consent of the governed," informed by the media that can also double as advocates for citizen rights.

Beyond aiding political literacy of the electorate, the media facilitate all internal elements in the TDS having access to the same base of information. That faculty is crucial to synchronizing all elements of the TDS to achieve outcomes that have been negotiated by bargaining among stakeholders. Given society's fractionation by geography, by wealth and income, by urban vs. rural, native vs. immigrant, white collar vs. blue, by religious faith and tradition, by aesthetic preferences, etc., without a free and talented press, there is no way the TDS could perform as intended

This reservoir of constantly changing information is now widely available, 24 hours every day. Stock prices change daily. However, public policies take longer to germinate, a trial of patience but also a salvation against impetuosity, secret deals, and hysteria. Social norms change more slowly, usually no faster than in one generation. The sociologist Margaret Meade argued that, in her time, it took three.

Again, the media portray the instant situation, but with few exceptions, the client is expected to place current events in historical perspective, a process noted more for its absence than its presence.

The two TDS elements of external events and media content are in a constant state of turmoil. This is what animates the system of otherwise relatively fixed components.

In short, coping with risks from acts of Nature, of Human Nature, and from unintended influences of technology requires understanding of the statics and the dynamics of the socio-technical process. With an operating model and assuming a consensus on goals and implementation

processes, all of the stakeholders can separately contribute to the system design to deliver satisfactory life support systems.

Risk analysis starts with mapping the enterprises introduced either to further human progress or to shield it from harm.

Over-Design as a Safety Margin

Engineers learn from failures. By post-mortems, most are found due to inadequate knowledge of variables: the service loading, the service life, properties of materials, quality of materials, metal fatigue, quality control in fabrication, vulnerability to deterioration, operator error, poor maintenance, application of design theory beyond known limits, and even human mischief. Beyond uncertainties with novel designs, we must acknowledge human and organizational error.

Several empirical techniques have been adopted to enhance safety. One is the principle of redundancy. Hospitals and high rise buildings typically have independent backup electrical systems if primary sources power fail.

The second mode of risk management in engineering is to practice over-design. The simplest examples can be found with buildings where structures intended to carry a certain floor, wind, or earthquake loading are designed instead with some multiple like four as mandated by a local building code.

That multiplier is termed the “safety margin.” Its size is arbitrary, a matter of judgment in order to exercise social responsibility by groups of professionals who act as surrogates for the public.

When I was with the U.S. Navy and responsible for strength design of submarine hulls, I learned that the safety margin for decades had been a low 1.7, with no structural weaknesses. The submarines *Thresher* and *Scorpion* have been lost subsequently but not believed from hull collapse. This margin was in the same range as that for aircraft and for the same reason, to minimize weight of the hull. Otherwise, in a delicate balance with buoyancy, equipment to meet specified ship performance of speed, endurance, armament, etc. might have to be limited and thus penalize war fighting capability. The design solution, however, generates a paradox. Operating submerged is highly dangerous because of vulnerability to enemy action and the tendency of structural failure to be instantaneous, catastrophic, and without early warning. To reduce that risk to crew, the margins should be high. However, that desideratum has a cost. Inordinate safety is at the sacrifice of function.

I also recognized that the prospect of nuclear propulsion required a step increase in hull diameter. That raised doubts as to whether past structural design methods were valid with the larger boats. A further growth in diameter was anticipated as subs became missile launching platforms. Past design methods thus warranted reevaluation by both theoretical and experimental techniques. Research involved complex mathematical analysis of ring stiffened cylinders, and the theoretical strength compared with structural response of models in a pressure chamber to simulate hydrostatic loading when submerged. The research was extended beyond contemporary requirements. Traditional design methods were found inadequate and thus were upgraded.

The low safety margin was also reviewed and was deemed valid because of these considerations: (a) high confidence in quality control during fabrication, (b) in materials being carefully screened to meet specifications, (c) in the X-rays of all welds, (d) in careful control of tolerances for out-of-roundness, and (e) in inspections for deterioration after extended service at sea. There was also high

confidence in responsible operators, especially confidence that they would not dive below the approved maximum depth for each class.

With these precautions, there was a history of submarine structures never failing from design errors. The 1.7 margin was continued. Subsequently I raised questions on validity of my analysis because nuclear propulsion promised higher speed and unprecedented frequency of dives. With the sea pressure then fluctuating more often, hull components were subject to metal fatigue, especially those experiencing unprecedented tension rather than compression. Precautions to limit risk were adopted, in effect increasing the safety margin.

A somewhat different issue arose in the design of nuclear boilers, here subject to constant internal rather than fluctuating external pressure. The universally adopted boiler code of the American Society of Mechanical Engineers called for a design with a margin of 5 over the operating pressure. The thick shell selected to enhance safety could, paradoxically, have an opposite effect. Radiation from nuclear fuel tends to weaken steel with extended exposure. Thicker would not necessarily be stronger. The safety margin for nuclear service was first reduced to 4, then to 3, expecting special care in fabrication and operation.

There are other ways to over-design. In civil engineering, dams must sustain hydrostatic pressure on the upstream face corresponding to the height of water impounded. With severe storms, stream runoff could increase the water level above that of the spillway and raise hydrostatic pressure substantially. Strength design of dams thus requires an assumption as to the height of water above the spillway, and this is selected on the basis of stream flow statistics measured over an arbitrary period of time. The longer the interval selected for severe storms, the greater the height of runoff and thus the greater the pressure used in the design calculations. The pressure assumed with the “perfect storm” is further increased by a safety margin to accommodate all of the uncertainties mentioned earlier for metal structures.

Of passing interest may be historical learning from failure. Early Gothic cathedrals with the airy flying buttresses fell down after a few years and led to pragmatic studies of cause. Mostly, it was due to uneven settlement of the foundation soil under the weight of the rock walls. Cracks in masonry followed, then total collapse. The solution was not to make the structure stronger and degrade its aesthetic appeal but to pile building materials on the site for gravity to compact the soil before construction began.

There is a further example of learning in the emerging age of science. In the 1820’s when steam propulsion began to replace sails, boiler explosions on Mississippi River vessels began to take a large toll of human life. Skippers would race each other. The reckless and ruthless ones, bribed by gamblers to try and win, extracted additional propulsion by disabling safety valves. Explosions followed killing scores. Outraged by these losses, citizens demanded that government intervene.

The first research on boiler strength was sponsored in 1830 by the federal government at Franklin Institute, Philadelphia. No doubt, the investigation extended the engineering of boilers to employ safety margins sufficient to accommodate material deficiencies and also consequences of human blunder and folly.

That risky practice of pushing the performance envelope continues to this day, often in tradeoffs of safety for cost. Consider this personal experience of a tradeoff for hubris. Immediately after a sub completed its deep submergence trial, I watched in astonishment as the skipper took over command and ordered a crash dive at about 30 degrees. Here was the background. Two identical vessels had been built in different shipyards and both were instrumented for their deep dives so as

to compare dive-induced stresses as indicators of comparative construction quality. The skipper had my permission for the second, crash dive, except on this one he deliberately skidded below the certified maximum depth. Why? So he could boast diving the deepest of all subs in the fleet.

Skippers of Mississippi River boats and hot combat pilots and submarine skippers have juvenile counterparts on the nation's highways. Managing these risks goes beyond the control of any engineering designer. Additional precautions are demanded by challenges beyond the laws of nature, the laws of human nature. These concern the ethics of safety.

In a high tech world the complexity of technological delivery systems denies to those exposed to risk the opportunity to participate in decisions as to what levels are acceptable. Initial decisions are made by engineers at the design stage, where practice is guided by law, by licensing, and by professional codes of practice.

Such protocols have been published, for example, by the National Society of Professional Engineers and the American Society of Mechanical Engineer. Consider these interpretations:

- Hold paramount the safety, health, and welfare of the public.
- Uphold the law, beginning with the Constitution.
- Be honest; serve the public, customers, clientele and staff with fidelity.
- Be vigilant of malfeasance and corruption; do not punish dissent and legitimate whistle-blowing.
- Recall that all technologies have unintended consequences, many harmful, so make a practice of looking ahead to anticipate and prevent loss in human life, health, property, intended function, or the natural environment.
- In daily operations, demonstrate from the highest levels of internal management respect for truth, openness, and equity in benefits when making tradeoffs.
- Counter one-way communication and loss of personal relationships by the growing reliance on electronic apparatus.

Sadly, these principles sound like a farce when one tracks the trends from media reports of indictments and jail of corporate executives convicted of felonies. Elected members of Congress are not totally immune to charges of corruption, of lying, and of fraud. Decisions on involuntary risk must earn trust of all exposed.

4. Bed Rock Values in Public Policy

The Rainbow of Stakeholders

Some readers may be discombobulated by a discourse on values in a treatise about risk. At the least, it may seem inappropriate. In defense, I draw on experience in the policy milieu, with both the Congress and the White House. As a science and technology advisor, I endeavored to collect and analyze facts and report their role in the design of policy. My clients, however, based their decisions on more than the facts. Directly or unselfconsciously, they listened to values of their constituents and their own.

Consider these two loaded questions—“what role, if any, should philosophy of life play in risk assessment?” and “Whose values dictate choice?” These values may be as stark as that of human life, or as subtle as truth, the whole truth. I would argue that the dominant issues of our times are harshly ethical and beyond guidance by science, market place economics, by public law, or their combination. Unintended consequences of technologically rich activities threaten innocent victims

with repercussions more intense, more far reaching, more swiftly injected, and potentially irreversible than in the past. Hard edged and hard wired innovations seduce us with clear benefits, but their side effects often stretch the risk horizon beyond accessible technological fixes.

So with dangers that result from choice and not chance, we seek protection by doctrines of anticipation, of foresight to deal with the reality of uncertainty. The point is that these choices are not just choices of technique. They are tough moral choices that require moral vision. How many lives must be lost at a dangerous intersection before costly traffic signals are installed? How do we decide?

Basic principles lie in lessons from history, from philosophy, from Shakespeare, and from spiritual values of sacred texts. People must decide how safe is safe, and establish social norms on degrees of tolerance for risk. This process is especially vital if lives, liberty, or the pursuit of happiness are threatened and if risks have human origins, escalate because of human failings with extreme consequences.

Two scales of consequences need review, those which occur immediately and those which may hibernate and explode decades later as a bitter legacy for our children. Leakage of radioactive waste stored since the 1940s at the nuclear weapons factory at Hanford, Washington is a poster child of negligence. Indeed, how actions or inactions threaten our children can be a yardstick of successful risk management.

Introducing this longer term perspective exposes limits in the process of risk management. At policy levels, acceptable risk is usually negotiated by opposing parties. Often, both argue from their estimates of short term self interest. Surrogates for children are not present at the bargaining table except when society mandates the government to play that surrogate role and not simply be an umpire.

Dimensions of the future shine in the National Environmental Policy Act of 1970 and the Technology Assessment Act creating the OTA in 1972. A blanket policy with global reach was drafted in 1980 as a Bill of Rights for Future Generations by Jacques Yves Cousteau and has been considered by the United Nations. Beyond an abstraction, this concept would require impact assessments beyond cost/benefit analyses, to test risk-centered choice by imperatives of social responsibility. This ingredient of public policy was punched into public awareness with a paradigm shift in the 1970s. In what was a vigorous technology-driven culture, the question, “Can we do it?” was balanced with “Ought we?”

Questions of moral vision pivot on the exercise of foresight. This does not mean claiming to predict the future as does astrology. As a vehicle of early warning, it means asking, “What, if?” This powerful tool exposes a surprise.

Whoever controls technology controls the future. That axiom has a twin. Whoever controls technology in effect raises our children. Perhaps that is already happening. The media, electronic games and cell phones, popular musicians, advertisers, and their agencies may have more influence on our children than do parents or religious faith.

If this situation accurately maps reality, and society really does care about its progeny, then risk management must balance the short and long term interests by more than commercial values. Without abandoning rights of private property and canons of capitalism, decisions must be tested by norms of social and economic justice.

While American society may commit to high ethical standards, an objective survey of print media of record reveals the frequency of breaches not only of ethics but also of law. Powerful

members of Congress have been indicted and sentenced for a wide range of transgressions. So have corporate officers as with the Savings and Loan scandals of the 1980s and extending to trials of Enron executives in 2006.

Part of the problem is bare faced corruption. But another part of the problem lies in our heterogeneous population. We don't have one public but many different publics, and when polled on their preference as to acceptable levels of risk they show major variations. These may be differentiated by wealth, by proximity to the source of danger, by social, religious, and political ideology, by urban vs. rural, by regional cultures, parental counseling, and by ethnic origins. The point is that reconciling diversity in risk tolerance challenges the mustering of consensus.

On that issue, we in a democracy have rich experience from practicing the thesis that those who govern do so by the consent of the governed. Implied is "informed" consent. Then the question rises as to who does the informing. Is the source objective? Do citizens have minds prepared to interpret information they receive, for example to understand the critical tradeoffs of safety for cost?

Polls on citizen perceptions of comparative risks are not encouraging. One overarching conclusion to the medley of issues raised is the intense complexity of our technological delivery systems.

The reader might now be convinced that the design of technological systems must meet the social needs and safety preferences of a broad spectrum of stakeholders. That achievement is a political act. Once again, we must look to the nation's systems manager, the President, to muster credibility, coherence, and consensus.

Conflict Management to Balance Benefits and Costs

Three premises condition this analysis. All the support systems of our society have a core of technology that we depend on, first, to the degree that we are totally dependent on it as the *Zeitgeist* of modern life. Second, technology blends technical systems with social systems. Third, benefits and costs may not be balanced. We applaud mounting living standards but overlook technology's cultural impacts greater than those of religion, philosophy, ethnic traditions, social mores, and a growing body of law.

Technology sows complexity not just in hardware but also in delivery systems. In less than two centuries what began as small, orderly and predictable systems and at a human scale have become large, remote, and incomprehensible, sometimes hazardous and even catastrophic. In that vulnerability, social performance demands virtuoso intelligence (both kinds) and striking leadership. Modern communications facilitate achievement but a convenient capability can overload human resources by more transmissions, more invisible actors, and more actions, reactions, and overreactions.

Decision making at all levels suffers from ambiguity of facts, commercial pressures from muscular lobbies, a noisy public forum for serial conflicts, and personal idiosyncrasies. Add duplicity, lying, fraud, and other crimes to recognize that the key issues are ethical and both business and government suffer from gross violations of trust. Moreover, familiar relationships of cause and effect yield to confusion and incoherence. As said before, we cheer what technology does *for* us while neglecting what it does *to* us. The challenge to the engineer *cum* problem solver is reconciling direct benefits against hidden surprises of unwanted impacts. Achieving a compromise between benefits and penalties entails reconciling goals, values, and organizational cultures as between business and government, and within both sectors.

In essence, risk management requires a social strategy of foresight that does not come naturally either to individuals or to society. Parsing the concept, foresight entails strategic vision, pre-crisis planning, contingency resources, fixing what is broken, and entrepreneurship to explore new opportunities. Finally, there must be political will to do the people's business and not solely that of vested interests and political supporters. And there must be respect for high integrity.

Neither market economics nor public law suffices to frame protection for future generations. Both societal steering and propulsion depend on the human psyche, on courage, integrity, resilience, ingenuity, free will, self-sacrifice, and hope for a better future for all people. These constitute humanity's survival kit in a technological world.

In short, user-friendly technology with its harmful gremlins must be visualized as a social rather than technical enterprise. It acts like an amplifier. With lever and wheel, and the bomb, it amplifies human muscle. With the computer, it amplifies the human mind, its memory and speed of calculation. Technology is also a social amplifier. With modern banking, communications, and transportation, catastrophes anywhere have effects everywhere. Two minutes after President Reagan was shot in 1981, the gold market in Zurich began to twitch.

This reality of an interconnected world—what columnist, Thomas Friedman, deems a flattening of a world with metaphoric mountain ranges stems from the gift of electronic communications, what we identify as information technology, IT. Telegraph wires morphed to telephony, vacuum tubes in radios, and television to silicon chips. Add satellites and fiber optics. With such innovations, it became feasible to assemble highly complex TDSs to meet more strenuous demands.

In short, information constitutes the TDS's nervous system. As visualized in the earlier diagram, information channels are crucial to synchronize all of the 17 normal components of every TDS. The information age displays a ballooning of traffic over greater distances and moving faster. Security is enhanced by early warnings of tsunamis and hurricanes or degraded by mischief of spam artists and terrorists.

There are, however, unintended side effects. Every morning on bringing up Windows, many people suffer an information explosion, or perhaps implosion. Beyond junk and spam, the volume suffocates priority messages. The fire hose of bytes lacks any warranty as to truth. Paradoxically, wider access to information is not necessarily accompanied by deeper understanding. Technologies introduced to reduce risk can inadvertently increase them.

For example, information overload induces stress, especially when making decisions. Outcomes may be uncertain and errors threaten punishment. We have the luxury of more choices but less time to choose. In a frantic search for truth, facts may be elusive or laden with the mists of probability. The social context and preferences shift unpredictably. When the technological delivery system engages competing players, each with a self-interested economic or political agenda, no actor has the comfort of ever being in control.

That shock is dramatized when adding to the TDS diagram a suit of feedback loops that exist in the social process. My own research efforts to accommodate that reality and explore repercussions totally failed.

Suffice it so say that the culture of modern society is the 800 pound gorilla in the room; our culture has not spawned a guidance system to harmonize with technology propelled change. Since it is unproductive to speculate on where the culture may be going, we must focus instead on how to cope with the role of culture in designing technologies with concern for costs as well as benefits but measured by parameters well beyond the narrow incentive of economic self-interest.

Confusion engendered by complexity and interdependence makes all the more relevant the earlier aphorism on modeling.

Tensions between Industry and Government

Two major components of technological delivery systems, industry and government, have a paradoxical relationship. Neither can get along without the other, yet their relationship is marked by enduring tension. Government depends on a vigorous, healthy industry to drive the economy, from which to create jobs and extract a tax base. Industry thus depends on government to create a favorable economic climate, including direct financial assistance. That congenial partnership, however, is accompanied by an adversarial stance with government's obligation to serve as regulator. Industry, in its boisterous role as innovator and entrepreneur, acts in its profit-driven self interest which often collides with social interest. Corporations are expected to turn a profit, but in this era equal emphasis is placed by Wall Street on the creation of wealth. The so-called free market fails by various distortions and excesses that violate norms of economic justice or have severely harmful consequences. With government mandated to protect citizens from harm—physical, economic and psychological—we observe a muscular wrestling match.

Merging corporate and public purposes to nourish a vigorous economy is strained when industry fails to get its way. Government is accused of blocking “free enterprise.” Industry then adopts defensive measure to weaken or block the legislative process or administration of laws already passed. It has been so since the nation's birth.

Tired of pressures to ease constraints, Congress invented special regulatory bodies to act on its behalf and set the rules and penalties for violations. Thus were created agencies to regulate the economic life of railroads, buses and trucks, merchant shipping and airlines, and later regulation for passenger safety. Soon other independent agencies were founded to deal with safety of food, drugs, water and air, of the mining industry, of the workplace, and with preservation of the environment. Private enterprise countered by seeking to corrupt regulatory bodies by urging appointments of individuals known to be favorably disposed to their interests, thus undermining the regulatory process from within. Headlines single out the FCC, FDA, EPA, NRA, FTC and others.

In recent years, industry has adopted two other tactics. In this television age, the influence of that medium on public opinion is essential to political campaigning. Candidates for election and reelection raise funds to purchase broadcast time. Industry found a potent avenue to grease access to policy makers.

A second tactic is for lobbyists to be present at what used to be off limits to outsiders, closed sessions when members of Congress negotiate final wording in a bill or final agreement on budgets. Midnight conferences are opportunities to insert clever loopholes or pork barrel bridges to nowhere to benefit a community and facilitate reelection. Today, there are 34,000 registered lobbyists in the nation's capital, roughly sixty-five for each member of Congress.

This phenomenon caught the public's ear for the first time with President Eisenhower's complaint in his farewell address about the self-serving greed of the military industrial complex. That was almost a half century ago. The iron triangles of industry, a government agency, and senior members of Congress on appropriations committees are today even more powerful. Perpetuation of what President Dwight Eisenhower called the war machine, the “military industrial complex,” regained public attention in the 2006 movie, “Why We Fight.”

The central problem is clear. Industry cannot regulate itself. Self interest always trumps public interest. In the context of risk management, this history is important because the avalanche of new

technologies has opened more risks from side effects. When industry fails in exercising social responsibility, conscientious government is obliged to intervene.

That condition complicates the management of risk. A contest erupts between the sources of risk and those who are the victims. Thus is exposed a cultural contradiction of capitalism in that it works best under an umbrella of social norms.

Contrary to popular belief that government is too zealous a regulator, the reality is that it has been diffident. Very rarely does it act in anticipation of harm; almost always government reacts when the severity of impacts has aroused public opinion to a boiling point that political leaders cannot ignore. Even then, industry fumes at fiscal and social accountability and seeks new avenues to get its way, fair or foul. Take the case of Boeing aircraft now challenged by government charges ranging from theft of a competitor's papers to complicity in hiring a former government contract officer.

In many respects, the tension between government and industry is a sign of health of both. Too much friction can distract both parties from their optimum performance. On the other hand, too little tension could lead to or be a signature of a corporate state.

In the context of risk management, such an evolution of governance would trigger two problems. Business and government have vastly different values. Commerce measures success by short-run profit, growth in size and market share, and respect by Wall Street brokers. Its legal concerns center on protection of property rights and against accountability. Its culture is strongly task oriented and its management style that of an independent CEO with a tame board of directors. Government, on the other hand, is concerned with freedom and human rights, social and economic justice, including concern for future generations. The structure of government mandates principles of building consensus and of accountability.

The second problem arises from a tendency of technology to concentrate wealth and power. In just the recent decade, acquisitions to morph into mega-corporations have been conspicuous in military-space technology, in petroleum operations, in both print and electronic media, in air transportation, and other areas with questionable benefits to all but shareholders. Violations of corporate ethics have earned serial headlines.

Government is not immune to sleazy and even illegal activities. Members of Congress from both major parties have been indicted and jailed. Others have resigned. A major fuss has been raised because White House officials are alleged to have leaked the identity of a CIA agent in a crude attempt to intimidate the role of the agent's spouse in contradicting President Bush's assertion that Saddam Hussein sought nuclear weapons.

While this unhealthy situation may seem foreign to risk management, the effective functioning of democracy and of technological delivery systems depends not only on the discipline of law but on mutual trust. Citizens cannot be expected to master all of the facts and analysis dealing with complex technical issues. In the main, citizens must depend on government to provide protection against the ultra-violet rays of the sun, from the exaggerated claims of pharmaceuticals, from terrorists bent on torching a calamity, or from their holding a nation hostage with threats to detonate a nuclear device.

It is in this situation that we observe a confluence of science and engineering with disciplines of public administration, business administration, economics, psychology, sociology, history, communications, law, and even theology.

5. The Ethics of Informed Consent

The Role of Media in Exposing Risks

On the earlier sketch of a standard TDS, the media were shown as a blurred image. That representation is intended to reflect the ubiquity of media as a source of vital information to all TDS constituents. For those potentially exposed to risk, this capacity serves either as early warning for slowly evolving events or as instruction from another's harmful experience on how to offer informed consent when it is invited.

This critical role carries a burden of social responsibility for the media. Information should obviously be accurate, based on authoritative sources, even handed, timely and accessible to non-technical stakeholders. The year 2005 is overloaded with natural disasters that could not be prevented, where vulnerability was not heeded, and where media played a crucial role. With the tsunami in Indonesia and the earthquake in Pakistan, the number of deaths and injuries and extent of property losses exemplify inept emergency preparedness. The situation along the Gulf coast with the Deepwater Horizon Macondo well blowout reveals in post-mortems similar painful deficiencies, but there is also evidence of miscalculation by government stewards who had a mandate to protect lives and property under recurring circumstances.

It can be argued that those at risk should have a say in decisions vital to their safety. Because of secrecy surrounding funding decisions, the consequences are unlikely to be known in advance except by zealous probing of reporters. Even that expectation may not be met where news organizations or reporters have cozy relationships with decision authorities in both government and commerce. Both parties thrive on leaks.

There are other challenges to investigative journalism. Probing too aggressively may violate canons of national security or personal privacy. The pace of information may exceed the human capacity for information processing. Objectivity may be subverted by news organs with self interest threatened. Mega-corporations that own the broadcast networks also own subsidiaries that may be the subject of unwanted publicity over their failures to protect citizens adequately.

That dilemma of self interest versus public interest also applies with individual stakeholders. Copper smelters in the Puget Sound area emitted smokestack fumes of arsenic and lead that poisoned nearby soils in which children played. The plant's owner asked affected citizens to choose between continued emissions versus correction so costly as to jeopardize the plant and sacrifice jobs. Jobs won the contest until the plant was shut down by bankruptcy. By themselves, accurate information and posing options did not alone lead to a socially responsible outcome.

Often, stakeholders face information overload that includes unreliable sources. Moreover, transmission speeds overtake a natural cadence in human affairs. Add frustration when an inquiry is funneled through a chain of telephone button pushing, perhaps to lead to an ominous and anonymous, "The computer is down." When a voice is reached, its artificiality drains away any sense of communication with another resident of the planet. Some prefer to be safely uninvolved even at the expense of losing control to an invisible authority structure. Squeezed out by information technology (IT) is a dialectic process wherein after each conversation, live participants may change.

A similar effect occurs with emotionally loaded information as, for example, live TV reporting of battles in Iraq or of destruction of New Orleans. Pictures have greater punch than prose. Intense images brand our minds, injecting content without context. Revised patterns of belief structures alter our perception of reality, even our sense of time. The medium has become the message.

Even the content suffers mutation because of techniques exploiting volume and speed of transmission. Side effects are shorter attention spans and subversion of purpose from education to persuasion, to market a brand of politics or of faith like a soap product.

If the premise is adopted that safety is a social judgment, society must have both timely information and objective analysis to convert that bundle to a state of knowledge. The treasured jewel of understanding emerges amidst a further stage of discourse and debate and mulling where individuals hear many sides of an argument, consult their memory and critical thinking, then make up their mind and join with others of like mind.

That stage occurs last when public preferences reach decision authority, a member of Congress for example. Voices of we, the people, may best be heard if an individual finds and helps fund a public interest organization to serve as collective advocate. On the TDS, that process can be visualized as a lump in the box of citizen preferences.

As footnotes, we have to understand that information flowing in a TDS is both substantive *in* the process, and administrative *about* the process. That is, participants need a mental model of the particular case to learn the cast of actors on the political stage, their culture, interests they guard, avenues of access, and the timetable of action.

Whatever the dynamics of a particular issue, seldom does it gain attention in isolation. Environmental policy interacts with fiscal policy. Farm policy is affected by foreign policy, and U.S. policies have to be weighed in the context of free trade, globalization, outsourcing, and now the uncertainties of terrorism.

There are further complications. Incoming information must pierce a garment of emotion. What I may say is not necessarily what you hear. As a metaphor, assume that every one wears a helmet. This is a screen of past learning, biases, attitudes about change, conflict, and especially experiences that leave scars. In penetrating the helmet, the new information is distorted, attenuated, or filtered out completely. This is especially dangerous in political leaders.

Most pathologies of information processing have counterparts in the media itself, the merchant communicators of common information. Given that the media is an intelligence function serving business, citizens, and government officials equally they are often considered a fourth branch of government. The integrity of the press is thus at least as critical as that of public institutions. Confidence in that process can be shaken with revelations of media on corporate or government payrolls. One wonders what Orwell had in mind as the precursor to the central control of information in his metaphoric “1984”.

Now the media encounter new stresses of deadlines with 24/7 reporting, of penalties they pay if found in error or, worse, treating handouts as news. They are trapped by an appetite for leaks while facing the risk of spilling classified beans.

Business depends on the media regarding equity markets, indicators of future profits or losses, shifts in tax and fiscal policies, investor confidence, threats to oil supplies, and stability of foreign governments. What happens in Washington must be followed carefully

Even elected leaders sift the news, polls, and editorial feedback on political performance. President Bush seems to be an exception, proud to receive news only through trusted staff messengers.. Scholars who follow world and domestic affairs feast on media reports, perhaps alone in subjecting them to close scrutiny for accuracy, objectivity, and balance. Several privately financed foundations engage in the same watchdog function.

Of all the organs of a TDS, the press has the most seminal responsibility for facts and their understanding so as to what is at stake and in time to practice democracy. In a complex, confusing and noisy world, that's a high expectation.

As newspaper advertising shrinks, more daily papers feel threatened and seek defensive measures to stay alive. TV as increasingly the media of choice forces producers and anchors to mix in entertainment at the expense of analysis in depth. Text is dumbed down, and the flash card style of ads causes viewers to be numbed down.

Most telling about the media is its strategic influence in every TDS. It is the prime source of facts and their future implications; they play a legitimate role as a Greek Chorus of early warning about a rainbow of threats and loss of a shared vision; through editorials, they can serve as advocates for victims. Sometimes that zealotry is overdone. Coverage of Clinton's sexual encounter with an intern played to a prurient interest in body fluids and DNA confirmation. In a feeding frenzy led by Republicans in Congress, the media were willing partners in this American tragedy.

McLuhan had it right four decades ago. The medium not only morphs the message; it morphs the messenger. The lesson to be learned again and again is that democracy depends on truth. In his fictional 1948 account, Orwell projected a nation's slide toward being a corporate state. It happened when partners in business and government gained control of the media. Perhaps his scenario was a metaphor, accurate except with regard to timing.

In this author's view, there is no more critical role for media than reporting the facts on national security, the validity of perceived threat and response, the compromise of truth in the interest of political victory, and the tradeoffs of national treasure and honor negotiated out of sight.

The Power of Informed Consent

First, reader, please take time for a deep breath. Some who have progressed this far may feel frustrated in not finding a handbook on risk management. The author promised none but apologizes if he inadvertently raised such expectations. This exploration focuses on the context, not on *what* to think about but *how* to think about "how safe is safe."

That question triggers as many as 20 issues that characterize operations of a standard technological delivery system. With each having 17 major components, I focus here on information networks that connect organizations and function as their nervous system to detect the external world and to synchronize the internal parts.

One role is to assure that the tacit consent of those at risk is an informed consent. People cannot feel safe if they are left in the dark. From very early childhood, humans want to know, and it is the obligation both of sources of risk and the security conscious government (which can also double as a source of risk) to assure that satisfaction.

That process, however, has several impediments. As explained before, history teaches that all technologies have side effects, many harmful. And it teaches that the vendors of technology are not always forthcoming about the unwanted and possibly lethal consequences. To counter that secrecy, for example, the FDA requires pharmaceutical houses to embroider their advertising with cautions about abstaining with some existing health conditions, and about physiological effects of hyper sensitivity. Parenthetically, these catalogues of possible risks are silent on the frequency with which products pose particular threats. If very rare, the risks are ignored. There are no warnings on peanut

butter because those who are ultra sensitive are assumed to have had close shaves and practice risk avoidance.

This example illustrates how potential victims need to face risk with a prepared mind. Otherwise, they might not understand a label that warns that, even though a food product contains no peanuts, it was processed in a plant that also handled peanut confections. This act of social responsibility by the vendor reflects on the ubiquity of threats and also the heightened awareness in our culture that risks of human origin could and should be minimized.

That scenario is played out in news headlines almost daily. Consider the wrangle over proposed wind farms in Nantucket Sound off Cape Cod. Assessment of environmental impact mandates that all side effects be publicized and evaluated by the public and by a government agency. These side effects constitute hazards to navigation where traffic is dense, disruption of fisheries, and visual pollution of waterfront property. These costs are weighed against benefits of generating non-polluting energy, even if more costly. Public commentary at hearings will be considered before a policy is set.

One problem is that individual stakeholders do not often attend these sessions. Some who do attend often fail to do their homework to explain concerns and also fail to consider tradeoffs that require compromise. Others, however, may be effectively represented by public interest organizations that buttress their arguments with facts and importance of transforming information to knowledge and then to understanding.

Converting information to knowledge requires assessing the credibility of source, the consistency with other sources, an explanation of contradictions, and finally an enrichment of initial basic information with vital context. A final stage of understanding occurs when knowledge is squeezed to identify implications for the issue at hand. Content is merged with context. For example, recognizing that a particular technology can be harmful is elaborated by identifying the full rainbow of parties at risk, including the virtual stakeholders, the future generations.

In a next step, all elements of risk analysis are mustered, especially the distillation from history of past failures, of the frequency of the threat (probability), and the scale of consequences if not prevented or damage controlled. That history is especially important to rank interventions by degrees of their success and the tradeoffs entailed, especially of benefits versus cost. A further challenge arises in converting all benefits and all costs to a common currency because both have intangible as well as tangible elements. Both have a combination of immediate versus long term effects.

Illumination of context requires description of the political process by which the threat and response is mediated. The TDS can serve as a generic model to identify organizational participants, from perpetrators of risk to its amelioration.

All the desired information may not be readily available. In the political theater, complexities of the facts and the confetti of ethics leads participants to put a premium on confidence in the authority and objectivity of the information source.

Consider these realities. First, in the frenetic atmosphere of policy making, those responsible for decisions rely more on verbal rather than written material, especially if it is boiled down. Who talks to whom is highly significant. Lobbyists know that members of Congress cogitate over an upcoming vote as they walk from their office building to the Capitol. On that trek, advocates would like to be the escort and have the last word.

These intricacies are of great importance. Recall the two-year, continuing investigation by a special counsel of who leaked the name of a female CIA operative to intimidate her spouse who was charging administration malfeasance. In political maneuvering, most information is tainted by self interest of the source. This is rare but not unknown in the technical community as well. Congress has access to such credible facts and analysis in the Government Accountability Office, the Congressional Budget Office and the Congressional Research Service.

In his Executive Office, the president also has access to presumably objective information, but such support may be distorted by incompetent appointees.

In short, the paramount role of information in risk assessment is to help those exposed to risk understand their predicament and have an opportunity to express their consent or dissent. Critical comprehension demands a preparation of mind so as to distill information effectively to knowledge and then to understanding.

I was involved with risks of oil spills by tankers from a 1971 filing of omissions in the Environmental Impact Statement regarding the marine extension of the pipeline to the 1989 investigation of the *Exxon Valdez* disaster. In 2006, there are still repercussions from boisterous complaints of fishermen and indigenous peoples whose livelihood was hurt. They won a legislative provision for government-supported citizen watchdogs to reduce future risks. That safety measure is relevant to the study of the Macondo well blowout.

6. Lessons from the Past

The *Exxon Valdez* as a Metaphor for System Failure

History records many disasters caused by human or organizational error (HOE) that could have been prevented and the adversity minimized. In what follows, the oil spill of the tanker *Exxon Valdez* in Prince William Sound, Alaska, is summarized as a metaphor for system failure, of an accident waiting to happen.

On March 24, 1989, the tanker loaded with 50 million gallons of Alaskan crude fetched up on Bligh Reef in Prince William Sound and spilled 11 million. Oil leaked for four hours at a rate of 1,000 gallons per second! With the slick staining a spectacular wilderness, damaging habitat, fishing, and tourism; blame was immediately focused on blunders by the ship's operators. Given the calm sea and clear night, how could this have happened? Were there no lessons on safety measures from the first supertanker spill off Land's End, England, in 1967 and others worldwide?

The spill animated intense media coverage focused both on the harm to the environment and wildlife and on the frenzied efforts to contain and cleanup the oil. Less photogenic but equally vital were revelations of almost total system failure in terms of accident prevention and emergency preparedness.

As with every shock to routine human affairs, the curtain was opened on the stakeholders impacted by the accident and others responsible for cause, for prevention, or for limiting damage. Investigations were mounted by several federal agencies as well as by Exxon, and by a citizens' commission appointed by Alaska Governor Steve Cowper, which included the author of this treatise.

That probe attacked questions of what happened and why, and how to keep such a calamity from recurring. The commission's report issued in January 1990 told some alarming stories. In

applying the TDS concept to map the oil delivery system, we find almost every entity contributed to the disaster.

Obviously, the ship operators were the immediate cause of the accident. The master was in his cabin; a mate was steering; and a lookout presumably at the bow who should have spotted a navigation light on the wrong side of the ship except that she was at the pilot house chatting. By their negligence, many others contributed to the disaster.

For example, to limit first costs, the Exxon Corporation chose to build the largest possible ship with the thinnest permissible plating, the least compartmentation, and single hull rather than double hull construction except under the engine room. There was no redundancy in propulsion or steering. None of these steps to enhance safety would have prevented the accident but a double hull could have reduced the volume of spill.

Human error was obvious. Exxon had retained a master with a history of alcohol abuse and ran the ship with the smallest possible crew (reduced twice with Coast Guard approval) on the assumption of an uneventful voyage and immunity to sleep deprivation. Both these corporate policies reveal a classical tradeoff of safety for profit.

The Commission also faulted Alyeska, the operator of the Valdez loading terminal and responsible for spill prevention and emergency response. Exposed were apathy, incompetence, and carelessness. That company proved incapable of reacting during the short window of opportunity for containment before the spill spread widely and irretrievably. The U.S. Coast Guard was also faulted for reducing power of their radar monitoring the inlet in order to cut expenses, such that their human operator did not provide continuous surveillance. Moreover, the Coast Guard had approved the disembarking of a pilot short of Bligh Reef where the accident occurred. After the spill, the agency found that its containment and cleanup fund was depleted and not refreshed from penalty fines so that contractors couldn't be hired on the spot to limit damage.

The State of Alaska had anticipated the possibility of the *Exxon Valdez* type of accident but their environmental watchdogs neither barked nor bit. An accident of this scale had not happened during the 12 years of shipping oil, complacency had set in, and legislators under pressure from Alyeska had eased contingency safety requirements.

From this snapshot, several lessons emerge. When serious consequences follow acts of nature or of human failures, the mind becomes aware of the large number of constituents and stakeholders in the TDS and their complex linkages. Paradoxically, many functions were installed for redundancy in navigation to prevent such grounding. .

This leads to the surprise concept of “organizational error,” a pathology identified by Sociologist Charles Perrow in 1985. He characterized oil delivery systems as error-inducing rather than safety-promoting. This idiosyncrasy accompanies organizational cultures that implicitly accept untoward levels of risk in conscious tradeoffs. Such organizations are not the direct source of accident but they set the stage for human error to occur at lower levels. Indeed, 80 percent of accidents are found due to human factors, most attributed to organizational culture. Research confirms that the imperative of safety begins at an organization's top management with explicit or implicit penalties of reward and punishment for subordinates.

Even when top management signals priority for safety, other subtle influences undermine the delivery system. TDS's entail so many components that functional coherence is destroyed by complexity. Moreover, in the chain of command, each level is expected to make choices that unfortunately may prove to be parochial and short term, indifferent to conflicts with a master policy

or plan, and focused on shielding higher authority. Financial considerations rule, and public relations are used to minimize corporate liability rather than risk to the public. In 1989, the oil transportation industry suffered more than most delivery systems from all these deficiencies.

The Alaska Commission filed 58 recommendations to reduce risks of a spill and enhance containment and cleanup response. The 15 most relevant are summarized below:

- Prevention of oil spills must be the keystone policy of all in oil shipping.
- Because many individuals and communities are at risk, citizens should be involved in oversight. This echoes the notions that safety is a social judgment, that those exposed to risk should have a say on protection.
- The nation and states need strong, alert, and fully funded regulatory authorities.
- Top management of private oil transportation must be committed to safety.
- Citizens in a democracy have a role in all aspects of risk management.
- Federal technical standards and safety requirements should not preclude more stringent measures by states for prevention and spill response.
- Double hulls and other advances in tanker design should be required at an accelerated time table.
- Traffic control systems should be mandatory, not voluntary.
- Crew levels should reflect the need to avoid fatigue and additional crew required by emergency conditions.
- The role of insurance companies to reduce risk should be revisited.
- Corporations transporting hazardous materials should be required by the SEC to file safety reports along with the fiscal data of quarterly reports.
- A report should be prepared annually by federal authorities to track progress.
- The state should empower itself to take over response to a spill in the absence of swift and effective federal action (again, redundancy).
- An available funding mechanism is needed to facilitate immediate response.
- The state should fund a system of emergency economic assistance to fill holes in citizen safety nets.

Some of these recommendations were swiftly adopted, especially those aimed at state responsibility. Based on the Commission report, the State of Alaska instituted stricter safety measures, including the requirement for each loaded tanker to be escorted by two large tugs, thus providing more assured redundancy in navigation and power to intercept a disabled tanker swiftly.

Similar recommendations were made by the author in a 1982 study of tanker safety in Puget Sound and were initially ignored. In 1990, however, the federal government acted; but under pressure from the oil industry, Congress extended the date to replace single hull tankers with double hulls. Some companies, however, acted immediately, especially with the success of liability suits against Exxon by native populations whose businesses were injured by the spill.

Corporate response has been spotty, with litigation over damages on the order of one billion dollars long in the courts. Other observations can be sifted from the Commission report. With engineering improvements in machinery and electronics, the proportion of accidents attributed to human factors has increased; the Norwegian safety authority for shipping states up to 80 percent of the total. The Intergovernmental Maritime Organization of the U.N. emphasizes that corporate commitment to safety begins at the top. Accidents often expose corporate cultures that bond staff

and management to a common set of values that conflict with those of society as a whole. Implications are treated later on social responsibility of the firm

This anatomy of an accident illustrates in a modern, interconnected society that an error by a single individual led to damages of over \$3 billion. Other examples have been widely cited such as the failure of a chemical plant in Bhopal, India, and the nuclear power station at Chernobyl. In retrospect, most long-term and persistent dangers arise from weaknesses in people and in their institutions.

On a personal note, for this author being appointed to the *Exxon Valdez* Commission was a depressing irony. In a sense, I was there at the beginning. In 1967, I was in England when the *Torry Canyon* went on the rocks at Land's End as a result of human error. It was the first major spill by a supertanker. On return to my post at the White House, I instituted an Executive Order for President Johnson of a national contingency plan of containment and cleanup.

When I moved to Seattle in 1970, I witnessed the vulnerability of Puget Sound that would serve as a port for oil to be shipped by pipeline and tanker from the Prudhoe Bay, Alaska. Although an environmental impact statement had been required for safety of the pipeline, the filing ignored the hazards of spills along both the Alaskan and Washington coasts. At a hearing in Washington, D.C., I delivered a risk analysis to amend the EIS. The second version nodded at maritime hazards but was weak enough to justify publication of a second alarm, this time in a journal of the ASCE. In 1975, I chaired a study committee for the state legislature that led to federal regulations for Puget Sound requiring a tug escort and limits to tanker size. In 1982, a comprehensive report on navigation safety was published with additional analysis of risks with tanker traffic and the need to strengthen Coast Guard surveillance.

With the appointment to the Alaska Commission, I felt like the fabled tar baby, stuck forever to studies of tanker accidents.

Deficits of Foresight, Vigilance, Contingency Resources, Political Will, and Trust

Contemplating their survival leads most citizens to feel secure when risks are known and convincingly held to acceptable limits. While that accomplishment may be an impossible dream, the human family has advanced in comprehending that threats to survival are not inescapable whims of fate. While many believe, like the ancient Greeks and Romans, that the gods punish human transgressions with disasters, society presently believes risks can and must be controlled.

This protection is especially demanded with risks of human origin. Thus, society has bootstrapped its understanding of cause-and-effect so as to prevent many malignant consequences or at least to act defensively to contain the degree of harm.

Within that abstraction is a chain of understandings, some with ancient roots. The time is long past for people anywhere to achieve the desired security as individuals. For better or worse, each of us is imbedded in a distinctive culture and subculture on which we must depend to be alive and free. The most critical element of that society is trust.

The problem with trust is its undependability, notwithstanding its prominent role in a democracy. Connections between trust, lying, and ethics have earned attention as far back as Aristotle. The subject has gained distinguished analysis ever since, recently in the book on "Lying" by Sissela Bok and sermons by Solzhenitzen. Consider the following headlines in the New York Times for a single day, January 4, 2006:

- Lobbyist Abramoff Accepts Plea Deal in a Corruption Case
- Bribery Investigation to Reach into Congress(Rep. Nye and others)
- The National Security Agency(NSA) first Acted on its Own to Broaden Spying
- on the Subject of Leaks (on domestic spying)
- U.S. not Told of 2 Deaths during Study of Heart Drug (Johnson and Johnson)
- 6 Ex-Putnam Officials Accused of Fraud
- Judge Orders Ex-HealthSouth Chief to Repay \$48 Million
- Windows Patch not Ready (Microsoft vulnerability)

That same day, a tragedy unfolded in West Virginia with the deaths of 12 men in a mine that had been cited with over 200 safety violations in the last two years. The coal company bears responsibility, but so does the federal government which discovered the violations but failed to act. Pressures on members of Congress and the Bush White House led to reduced budgets for mine inspectors and allowed dangerous mines to remain open.

A week earlier, the headlines exposed fraud in scientific results announced by a stem-cell scientist in South Korea. In four books published between 1979 and 1999, I listed similar breeches with examples of Boeing (bribing contract officials), General Motors (hiding dangers of the rear engine *Corvair*), Ford (concealing a vulnerable fuel tank on the *Pinto*), and the super scandals of ENRON and World Com.

These observations lead to the melancholy conclusion, that key organizations are as lacking in moral principles as are individuals whose human nature has uncorrected flaws. Compared with that of individuals, however, the scale of corporate malfeasance is far greater.

Experience reveals that it takes a spectacular accident or crisis to so agitate a quietly humming TDS as to expose the institutions involved, their communications networks as well as their life style.

Some organizations demonstrate solid integrity, revealed by a concern for safety, doctrinal foresight, a tolerance for dissent, alacrity in damage control, self discipline, and acceptance of responsibility. Many do not. They engage in cover-ups, deflection of blame, and substitution of public relations for problem solving.

The pathologies of ethics are not limited to the private sector. We still remember the Watergate and Iran-Contra scandals germinating in the White House. Much more recently, these negative and positive aspects were conspicuous in newspaper accounts of the Macondo well blowout development and aftermath.

Public and private organizations differ, however, regarding their attitudes toward ethical lapses. The public expects a high level of moral vision in public servants, and so feels more justified in publicizing their weaknesses as in the case of President Clinton and Monica Lewinsky than with private enterprise.

The public cherishes privacy and, given the corporations' legal status in protection of its officers from liability, is more inclined to accept the secret life of corporate officers and boards. Compared to fifty years ago, consider how obscure names of corporate officers have become.

To explain, organizations have personalities, cultural attributes, and values similar to those of individuals. When public safety is at stake, the public has a right to expect the same standards of values for corporate officers as they do for officials of government. These personal qualities include

intelligence, integrity, respect for the law, common sense and compassion, capacity to listen and learn, emotional stability under stress, and deep understanding of the social contract of America.

President Calvin Coolidge tried to epitomize that focus with the statement, “The business of America is business.” In terms of function, a more appropriate term would be, “The business of America is technology.” If technology was defined as the social process mapped by the TDS, the significance of values would be clear in their shaping ethical qualities of all system components.

The earlier headlines make clear that our society has serious gaps in the practice of ethics. It follows that every brand of risk is intensified where integrity is compromised; instead, it should be the keystone of every organization’s culture.

Not all news is bad. There are striking examples of courageous integrity. After completion of New York’s City Service skyscraper, design engineers found that the specifications for strength of structural steel were in error and not reported until after completion. Apart from bruised pride, the admission opened the hazard of powerful lawsuits. Yet the social responsibility to protect the public prevailed; additional structural elements were installed. There is heroic power in doing the right thing.

Attention to ethics has not been sufficiently emphasized in our schools of business, and this is reflected in the behavior of graduates. Most believe that evidence of sound management lies in external rewards through rise in stock prices, and internal kudos for maintaining tight control. Here is where fault lines appear in our basic values.

Missing is an awareness that human organizations are organisms and not mechanisms. With mechanisms, cause and effect are coupled predictably. Not so with organisms. Their behaviors are less certain, cause and effect blurred. External influences such as terrorism, intense global competition, or occulted fate undermine certainty,

One thing, however, is fairly certain—whoever controls technology controls the future. No wonder Orwell’s speculations regarding the corporate state have been resurrected. That reality would be less likely in a society that honors diversity rather than central control. Diversity works only with a shared set of values that nurture trust. Without trust, the system of governance works only by coercion.

The nation’s founders surely recognized that truth but did not incorporate their moral vision in the Constitution. Some elements were added by amendments, the Bill of Rights.. History reveals, however a strong moral climate was suffused in the population through religious doctrines. They may have assumed that such discipline would be permanent despite acknowledging that democracy was an unproven experiment.

In the aftermath of the Deepwater Horizon failures, it is clear that systemic shortages other than in ethics were present and these are being dissected by the media. Shortfalls include the effects of human and organizational errors, of shortages in foresight, in vigilance to detect early warnings of danger, in contingency resources to limit damage and then to repair what’s broken, and finally a shortage of political will to exercise the leverage of power to get the right things done and done urgently, and then to do these things right. Today, most failures do not involve hard-edged technology but rather human-ware.

Here lies another contradiction. In our democracy that underlines egalitarianism, power is thought of as suspect and even malign. There are, however, benign purposes for the exercise of power, and these need honoring in the human ambition for survival.

To be emphasized is the imperative role of citizens as a part of government. They should be part of the power structure as suggested in the TDS. Only then will those who govern do so with the informed consent of the governed. This was the perspective of the nation’s founders and it could be lost amidst the buzz of intricate social processes, especially cases of unprincipled advocacy by society’s powerful economic interests. The antidote to the disproportionate influence by special interests starts with more transparency of policy affairs.

One way to understand the web of influences on risk management is to think of our high-tech society as steered by three sets of IT operating instructions. One set is the free hand of the economic market place. A second is public policy, much of it regulation to manage risk. The third set is values that animate the moral parameters of the other two. Underpinning these arguments is an implicit assumption that citizens realize government is not the only machinery of governance. We, the people, have a critical role. Most urgent is to meet the deficiencies exposed by the case studies—the lack of foresight, vigilance, contingency resources, time, political will, and trust.

Most essential is foresight. Government officials and citizens can then focus on emerging issues of security, seek the facts, compare remedial alternatives, and unintended consequences of each. With information and trust, citizens could make their views known on acceptable levels of risk in the spirit of catastrophe avoidance. Officials should recognize this citizen role in a participatory democracy and welcome an informed and concerned electorate.

7. Thinking about the Future

Evaluating Social Choice by Outcomes for the Children

For many centuries, philosophers have taught that the quality of a civilization can be judged by how it treats its children. With that rationale, the quality of decisions made today for managing risk can be judged by consequences observed tomorrow as outcomes for our children. In other words, today’s decisions on acceptable risk can best be judged by results observed 10 to 20 years hence. These results become legacies for future generations—social, political, economic, and ecological. With such criteria for success, those responsible for risk assessment must look ahead in order to make operational the questions, “What might happen, if?” or “What might happen, unless?”

Imaginative analysts might nominate answers, but trouble may still occur when the issue requires a policy decision that spins winners and losers. Assuming that all stakeholders are represented at a bargaining session, it is likely that compromises are reached among different advocates. Almost all will argue from their short term advantage, with no advocate for hypothetical children. The short term triumphs because society chooses to lock its barn door too late.

This vulnerability in public policy was sketched for the U.S. Congress in 1965 by its CRS Science Policy Research group, leading to creation of the Office of Technology Assessment in 1972. Requests from members and committees led to roughly 50 reports a year until the agency was zero budgeted by House speaker Newt Gingrich in 1995. The OTA left a valuable library of risk assessments that permit comparison of different methodologies. All were endowed with a futures perspective.

That resource also demonstrates the importance of values in every society.. For example, studies reveal a paradigm shift in the 1970’s regarding technology’s wrenching of social norms. The question asked with pride about potent innovation, “Can we do it?” shifted to the question of “Should we?” In simple terms, this requires a look at the medical mandate to “do no harm.”

If my earlier contention is true that whoever controls technology controls the future, and if we judge the acceptability of a technological development (or its misguided absence) by the effects on the children, we can conclude that whoever controls technology in effect is raising our children. That shocking characterization of shifts in our values may already be happening..

That prospect can be a useful wedge to understand the impact of values on today's decisions and thus on the future for our progeny. This leads to an inescapable question on which values dominate our culture and that of the deciders who extract from our circumstances answers to "How safe is safe?"

In America's diverse population, one size answer doesn't fit us all. Each brand of risk and its stadium of different interests is likely to generate a different outcome. Therein lies another level of perplexity in dealing with risk. There is no standard pattern. Today's solutions are unlikely to be suitable tomorrow. Living with risk isn't easy.

Foresight as an Imperative in Risk Management

Safety and security depend on fantasy, on imagining what might happen and then how to prevent harm or at least minimize the event's impact. Risk management demands a mind set of looking ahead, practicing a doctrine of anticipation. That notion can be sampled in a series of books on Science Policy by the most frequent citations in the indices. It is also possible to track changes in what one author (Wenk) emphasized as important over a span of 22 years, 1979 to 1999, in connecting technology and the future to people and to politics:

- a) *Margins for Survival: Overcoming Political Limits in Steering Technology*, 1979.
- b) *Tradeoffs: Imperatives of Choice in a High-Tech World*, 1986.
- c) *Making Waves: Engineering, Politics and the Social Management of Technology*, 1995.
- d) *The Double Helix: Technology and Democracy in the American Future*, 1999.

For each book, the most often cited index terms were:

Margins for Survival, 1979: Anticipation, [Foresight, Early Warning, Future, Long-term,] Behavior of political leaders, Cultural values, Decision processes, Government, Information, Nuclear hazards, Technology and Society, Threat and response, Time.

Tradeoffs, 1986: Citizen Participation, Congress, Decision processes, Ethics, Foresight [Anticipation, Future, Long range,] Government, Industry, Information, Media, Political processes, Risk assessment, Technology.

Making Waves, 1995: Accidents, Business, Coordination, Economics, Engineering, Ethics, Foresight, Government [Congress, President, Policy,] Organizational behavior, Risk, Technology, Values.

The Double Helix, 1999: Business, Economics, Ethics, Foresight, Government, Information, Media, Safety and Risk, Technology, Time.

A fast scan of these citations unlocks two paradoxes. The featured topics sound more like books in the behavioral sciences than in engineering. That slant was rationalized in a 1995 paper, "Teaching Engineering as a Social Science," published by the American Society for Engineering Education. Its thesis was simple, that everything engineers do is to meet needs and wants of people. That suggests learning about human nature as well as laws of nature.

The second enigma was the power of some topics to command attention over a long period when the interaction of technology and society was in flux. The concept of *foresight* deserves special attention.

Many people meet this concept as children when taught to pass a football to where the receiver is perceived to be when the ball arrives. Boy Scouts are engraved with the motto, “Be Prepared.” Many young people encounter the future pragmatically in the quest for a college scholarship that depends heavily on high school grades and recognition of leadership earned years before. Those studies, incidentally, seldom focused on the way ahead; History and English Lit necessarily looked backward. Students met futurist Jules Verne through their vicarious curiosity to explore both the geographical and the scientific frontiers. A series of world’s fairs were held in North America beginning in 1933, speculating on the future in exhibits and programs: in Chicago, Cleveland, New York, Seattle, Montreal, Spokane, and Vancouver. Not until the October 4, 1957, Soviet space spectacular did the entire nation engage the future as the meshing of technology with society and public policy for safety and survival.

It bears repeating that the importance of foresight follows from a reality that all technologies have unintended consequences, some potentially lethal. Shrinking these risks is the core of social responsibility of professional engineers. Practice entailed two different strategies. One is to corral information as to what might happen (in the future), if, or unless. Skillful probing should then lead to stages of care in design to reduce risks. The second strategy was to take precautions against a range of uncertainties by over-design, the use of safety margins.

Both strategies, however, encounter potholes, tradeoffs with other design parameters such as cost, reliability, weight or delivery schedules, and thus with performance. Both strategies stumble for yet another reason. By our culture and possibly by our genes, modern humans have difficulty looking ahead. Anthropologists assert that humans are the only mammals even capable of imagining the future. Seasonal migrations of birds and animals seem spun by instinct, not fantasy. Moreover, early humans were compelled to satisfy immediate needs of food, water, and safety so that the longer range perspectives were irrelevant.

Modern humans still suffer from pathologies of the short run. The monograph, *Margins for Survival*, lists sixteen, all dealing with human behavior. That discovery should teach that managing risk crashes into a type of sound barrier that challenges a way of thinking beyond equations and number crunching. Practicing foresight depends on individual and group behavior, what we call social process. Only with this far horizon can risk managers accommodate and compensate for individual and organizational error and its siblings. The three operating instructions for the process were mentioned earlier. Foresight has one other critical product. It instructs us on how to achieve our greatest challenge, making the world a better and safer place for our progeny. Indeed, how a society treats its children is a measure of civilization. In policy terms, that idea stretches back to drafting of the American Constitution.

With the dilemmas of our time, it would be tempting to draft a cook book on foresight, a universal method of forecasting what might happen, if. That quest is fruitless because every case is different. Some dangers, however, repeat themselves such that projections of the future follow trajectories of the past. We learn from failures.

That aphorism puts a premium on history, not just a chronology of key events but also an understanding of different layers of individual and organizational functions, responsibilities, leadership patterns, institutional cultures, communications, resources available, etc.

The past can be prologue.

Pathologies of the Short Run

All risks and measures to enhance safety embody dimensions of time. These intervals range from nanoseconds in computer chips to decades of human longevity, to centuries of tectonic movements. In the context of risk management, the most crucial interval lies ahead, in the immediate future and the distant. Survival is the imperative of the future, both short and long term. Common sense dictates looking ahead, but we are so conditioned to seek immediate gratification that short term goals and strategies trump the longer term, regardless of how much more significant they are. The culture seems indifferent to future penalties of current choice.

This exercise of foresight should be distinguished from prediction, the attempt to satisfy human curiosity about tomorrow's weather, the longevity of a family member, and the performance of the stock market. Daily newspapers still carry horoscopes and astrologers still practice an ancient art that extends back to pre-Biblical times. The sagacity of foresight lies in asking questions about alternative, conditional futures—what might happen, if or unless, in relation to acts of nature or acts of people.

There are many pathologies of the short run. Consider the reward structure in commerce. In their narrow self-interest, CEO's are torn between boosting long-term performance of a firm against winning the Wall Street beauty contest next Monday. Shareholders lack patience; so do money managers of mutual funds. Executives also lack incentives for long term strategies because they expect to move on and prudent foresight may bring credit to their successors.

The reward structure in politics is similar. Incumbents sense what earns voter esteem and promise rewards in the next election. Shorter term issues, especially if paraded in headlines, are more rewarding. Seldom are elected officials bold enough to inform an electorate of the distinction between the long and the short run consequences.

To be sure, the future is clouded with uncertainty. In our technological era, we are confounded with complexity of both machines and social processes. Linkages of effect with cause are frustrated because human systems do not have the fixed properties of mechanisms. They are organisms.

In smaller communities of the past, everyone shared information about how their local TDS worked. The social contract was more transparent. Now in large and complex communities, early warnings may be weak. Fretting over the unknown carries emotional burdens eased by ignoring the future. That pattern can explain the unwitting storage of radioactive waste 50 years ago at a weapons factory where it is leaking. Residents knew of the danger since it began, but good jobs drowned out a faint and sporadic protest until very recently.

In general, the public seems indifferent to these longer term issues, partly out of feelings of incompetence and powerlessness. The perceived loss in control leads to weary acceptance of political decisions that are "piecemeal, provisional, parochial, uncoordinated, insubstantial, and lacking in prophetic moral vision."

Organizations are known for their resistance to change, for their aging in such a way as to lose alacrity in response to threats. Energies are directed to self preservation by combating forces uncongenial to well entrenched beliefs. Change can be threatening when dilemmas lack clear solutions, it is more comfortable to avoid action or change in direction. Leaders find bliss by selective ignorance. Such escapes are irresponsible but they are especially attractive when the queue

of problems is relentless and new ones erupt before earlier ones have been resolved. Avoiding the future also reduces the risk that a look ahead may uncover mistakes of the past.

In this inventory of pathologies, there is also a perceived shortage of time. That seems anomalous in an era when technology promised to save time and permit mulling over options in the decision theater. Yet the tyranny of a backlog and the frenetic atmosphere of policy making blocks both rational choice and conflict resolution.

Caught in the crossfire, leaders get nervous and either react with impetuosity to seek immediate relief or are paralyzed by a commitment to the past. Under stress, once again the short term wins. Society leans to a conservative stance because it has lost confidence in itself to manage technology.

This catalogue of pathologies should sound familiar. It exposes how inimical they are to democratic process. Nominating and comparing options takes time, as does an honest debate on who wins and who loses. With unsettled issues accumulating, none receive adequate attention in the policy theater, even less in the media to help inform citizenry to do their duty. When these issues are covered, the media demand instant accountability, live on TV, leaving no time to deal with complexity and context.

When debates are held, advocates argue from their parochial, short term perspectives. No one in the decision pyramid has the patience or energy to look through the mists ahead to practice prophylaxis or take collision avoidance action.

Add problems of information overload, stress of uncertainty, imperatives of reelection, and new crises world-wide, many beyond remediation. Loss in virtues of foresight and character can lead to exhaustion of stamina and to impetuous judgment.

The operating directions I proposed almost a half century ago came from an innovative concept of technology assessment. Simply put, TA is a method for looking ahead. The OTA's organic legislation spelled out these paraphrased details:

- Define the TDS, its purposes, its stakeholders, its organizational components, and information links.
- Define the technical, social, economic, political and ecological context, and the estimated behavior of different system participants.
- Establish a base of hard facts and of uncertainties.
- Forecast what is foreseeable about impacts and about evolution of hardware, software, and social ware.
- Generate alternatives of policy and implementation plans including doing nothing, and trace consequences, both desired and unwanted.
- Identify impacted parties, including future generations and effects on each.
- By asking, "What might happen, if, to whom, and when?" Incidentally, this methodology has a mirror image in environmental impact analysis.

Imagine the prize of successful performance of public policies if all initiatives were subject to this mode of analysis.

Early Warning of Close Encounters.

Early risk management drew on common sense, imagination, familiarity with human nature, and with contemporary cultures rather than science. Now it also draws on science and engineering and

on learning from failure. For threats that recur frequently, impact statistics are a great help. For threats that occur rarely and especially those with extreme consequences, data are too sparse to extract probabilities for numerical risk analysis as defined previously. That condition springs a paradox.

Admitting there are limits to available information, foresight is still essential. Beyond infrequent accidents or natural catastrophes, we learn from incidents, “close encounters.” These events would be similar in patterns of cause and effect to those having severe impact, but in these cases the trajectory to tragedy was arrested either by the lucky tapering of circumstances or by timely and effective accident avoidance maneuvers..

Everyone lives with dangers. Repeated close shaves, however, serve as early warning of a hazardous environment, a hazardous situation or our own impaired judgment. Projected to the future, this store of experience is a survival tool. It doesn’t work with slow learners or fools. It does work, however, on an institutional basis where data on close shaves are collected and analyzed in real time in the spirit of prevention or damage control.

The collective benefit of that monitoring is dramatically illustrated by the case of airline safety. For several decades, the FAA has required operating personnel to report close shaves. Analysis of events that were often repeated served as early warning of danger. Participants included pilots, traffic controllers, maintenance inspectors, and occasionally passengers.

Because the FAA has authority to punish violators of rules, it was aware that those committing errors might be reluctant to report themselves. As a precaution, FAA contracted with a neutral government agency, NASA, to collect and analyze data, preserving their anonymity but reporting the “hot spot” patterns that deserve immediate risk reduction measures. As a result, accidents on the nation’s airways have been conspicuously limited over a period when air traffic sharply increased.

The same reporting system was proposed by the author in a 1982 report on navigation safety in Puget Sound where newly operating tankers carrying crude oil posed a serious environmental hazard.. The Department of Transportation adopted the proposal, issued reporting rules and forms, and selected its laboratory in Cambridge, Massachusetts as the neutral, data collection agent rather than the U.S. Coast Guard which has regulatory authority. Communication of this risk management technique to ship operators was so poor, however, that few reports were filed and the DOT abandoned the system.

The virtue of close encounter reporting remains and has been adopted in other risky situations. Operators of nuclear power plants are required by the Nuclear Regulatory Commission to file such reports, even using telephony to warn operators of similar plants of similar vulnerabilities.

The public is well aware of product recalls mandated by various agencies where intervention is based on the frequency of identical hazards, some creating accidents, some only incidents, the close shaves. Broader applications are obvious.

8. The Anatomy of Risk - A Summary

In virtually all human affairs, some risk is normal. The consequences of neglect may be grave, if not now then in the future. There follows a distillation of points raised earlier on how to think about the risk situation as a prelude to risk management.

- Risk is a highly complex condition, especially challenging because it combines abstruse technical factors with diverse and uncertain elements of societal behavior; and because the consequences may cause great harm.

- Three frontiers of risk pose threats, extremes of nature, weaknesses in human nature, and the unintended consequences of technology.
- All technologies spawn side effects, most unwanted by some sector of the population, now or in the future.
- Each risk condition is unique, but two theorems for analysis have found wide application to facilitate understanding:
 - The first is based on the notion that what you can't model you can't manage.
 - This leads to a generic framework to structure intertwined laws of nature and of human nature, what is termed a Technological Delivery System, a TDS.
 - The second tool is based on the notion that risk does not yield to rigorous technical analysis because acceptable risk is a social judgment.
- Risk analysis using a TDS depends on three premises of governance.
 - The first is that those exposed to involuntary risk should have a say in their intensity of risk exposure.
 - The second is that when economics of the free market, existing laws and local governments fail to meet that level of safety, the federal government is charged to assume responsibility to lower the threshold of threat to levels that citizens demand.
 - That achievement, however, has both direct and indirect costs, so that significant tradeoffs are necessary between safety and expense.
 - Because of cultural diversity in America, achieving consensus on acceptable risk releases a fog of conflict and uncertainty.
 - Bargaining develops among stakeholders; lobbying becomes endemic.
 - Typically, each argues from their immediate, short-term self-interest such that little attention is paid to long-term effects, including on future generations.
 - The third precept is that the federal government not just serve as umpire, but balance long- with short-term factors, thus serving as a surrogate for progeny.
- In this chain of argument, a question arises as to whether the public that is to be consulted as to risk tolerance has adequate factual information and grasp of the risk equation so as to render not just consent but informed consent.
 - Two TDS elements help with that illumination: (a) the print and electronic media and (b) past or recent events. These so agitate a TDS that the full cast of stakeholders is revealed, their roles in posing a threat in preventing or limiting the damage, or in their capture as victims.
 - Study of past and recent events offers a rich opportunity to learn from failure. Most of these failures can be traced to human and organizational errors.
 - Those lessons should tutor emergency preparedness through the self-conscious exercise of foresight, to limit impacts to choice and not chance.

- Potent levers of foresight are the questions, “What, if or unless; when and to whom.” This is the spine of technology assessment that was institutionalized in 1972 for Congress as radar for the ship of state. That capability was lost in 1995. Perhaps it needs rethinking for both branches of government.
- Engineering practice treats uncertainties by over-design with safety margins.
 - How these are set and by whom are critical.
- The role and performance of the federal government can be evaluated to ascertain effectiveness of regulation for risk reduction and damage control.
- Dissection of these events should reveal the strength and weaknesses of existing legislative authority, the match between appropriations and need, the identification of leadership to integrate and activate emergency preparedness and crisis response among federal and lower authorities.
- A customized TDS should help illuminate who is responsible for what among organizational components, but a critical element is the quality of communications to assure that basic information is shared and that otherwise piecemeal actions are synchronized to assure systemic functioning..
- As to federal involvement, the President becomes the nation’s uncertified systems manager because: (a) all agencies responsible for citizen safety and security report to the Chief Executive, (b) he is held to account for their satisfactory performance and must initiate new public policies if authority or performance is weak, (c) many dangerous natural phenomena entail common property of air, land or water, and (d) in extreme cases the military arm of which he is Commander in Chief must be mustered.
 - Ultimately, the President is responsible for protection from terrorism, extremes of nature, from dangers of technology’s side effects and from human frailties of ignorance, error, blunder, folly, mischief, greed and hubris.
 - This burden must be processed with foresight to exercise political power and political will, especially to meet shortages of vigilance, resources and trust.
- Government is both mandated and constrained by public policies, and these are rooted in values that differ widely among stakeholders.
- One source of conflict arises between industry and government because there are sharp differences between these entities in goals and in tactics based on their internal values. Industry honors efficiency and measures success by profit and generation of wealth. Government honors sustainability and measures success by economic and social justice.
 - Some tension between these two power centers is healthy but excessive tension can be corrosive.
- The quality of social and political choice is revealed by the heritage each generation leaves its children.
- Citizens need to realize that government is “We, the People!” that democracy is not a spectator sport and that each citizen has responsibility for risk management through public policies and citizen watchdogs.
- The risk management process depends critically on mutual trust of all parties.

9. Applying These Concepts to the Offshore Oil and Gas Industry

This treatise was prepared for this study of the Deepwater Horizon Macondo well failures and disaster. The diagnosis of causes for the calamity demanded a sifting of the foregoing issues for steps to meet the federal government's responsibilities and accountability to anticipate threats and to prevent and to mitigate losses of life and property.

Three measures emerged from the most salient lessons and the most potent interventions to avert a repetition of the flooding disaster:

- a) To enhance the management of all modes of risk, the responsibilities for vigilance and decision making at the tip of the authority structure should be clarified and strengthened, perhaps with a new unit in the Executive Office of the President.
- b) To buttress the legislative responsibilities of the Congress, additional technical staff should be appointed to assure adequate revenues to manage risk and to monitor performance of the Executive Branch in its duties of care.
- c) To reflect that citizens at risk are entitled to information regarding their exposure and opportunities to participate in governance, new processes should be authorized at a local level to foster informed consent and dissent and to function early warning in disaster-prone areas.

Such measures have great promise in the spirit of preventing another lethal flood in New Orleans. They present opportunities to deal with a much broader array of threats—to life, peace, justice, health, liberty, private and common property

These cardinal recommendations arise from Constitutional law and from a history of public policies that establish the Federal Government as the most senior authority for providing safety and security. Moreover, the technological engines of the last century have added to natural causes a new class of dangers arising from human and organizational errors and from unintended consequences of technologies switched on for their benefits.

This double helix of technology and governance leads to awareness that the President is the nation's uncertified systems manager. Responsibilities accrue from the President being the Chief Executive supervising all federal departments and agencies and responsible for their disaster preparedness, their exercise of foresight, and for adequacy of their funding. As Commander in Chief of the armed services, he has direct and immediate access to potent physical and human resources both to prepare for emergencies and to offer rescue and salvage assistance after a disaster.

The age of electronic communications has heavily affected the functioning of the White House in its connections to the outside world. Events anywhere have repercussions everywhere. Message traffic is more complex, demands faster analysis and response, and entails a denser web of possibly differing participants.

One psychological effect is to force attention to immediate issues rather than the important. The pressures from the unremitting queue of short-term dilemmas squeeze out any attention to focus on longer-term challenges. The future is neglected, thus seeding an enormous penalty for future generations, including the burden of public debt.

Decision making in every White House has other impediments. Apart from the standard approach of framing issues and options, the incumbent has to assess the impact of choice on political power and political will. Each quandary imposes stresses on political capital. With a press

intent on not becoming a sycophant and losing their role as the fourth estate, that Greek chorus is noisy and distracting, and in a democracy, not centrally controlled. So the President must be aware of the public perception of issues at hand and their intertwining with unresolved preceding issues.

That latter condition is reflected in a new reality of government organization. There was a time when the missions and roles of individual departments were highly specialized and compartmented. Today, issues leak well beyond the province of single agency. This imposes a more intense requirement at the top for coordination and integration of functions of several agencies. Only the President and the Vice President have the authority of being elected and occupy a central position of leadership of all departments and agencies.

In a nutshell, the President needs help of a special cadre of advisors experienced in and focused on catastrophic risks of all kinds. Organizationally, they should not become a layer between him and agency heads. This staff should be mandated to look ahead, to think in the future tense, to adopt a stance of being proactive in the sense of preventative medicine rather than reactive, and to balance long- with short-range factors free of partisan politics.

The staff director should have direct access to the President at all times to offer early warnings such as intelligence agencies do for military security, to share urgent information without its filtering in the White House chain of command. In addition, the director should have the authority to convene emergency sessions of appropriate cabinet officers to gain their inputs and cooperation when circumstances demand immediate collaboration and to serve as a monitor of disparate and incoherent responses.

This new capability could be a Council for Catastrophic Risk Management in the Executive Office of the President. The interim Council on Marine Resources and Engineering Development, PL89-454, could be a model.

The Congress needs a symmetrical capability, especially in its orientation to the future. Such a resource existed between 1973 and 1995 in its Office of Technology Assessment. That organic legislation should be revisited to see if its engines need restarting but with a more specific focus on risk management.

Finally, there is a major and unprecedented role for citizens who should be considered part of governance in the spirit that those who govern do so at the informed consent of the governed. This is the population exposed to risk. Authorities for risk management should make sure that those vulnerable have information regarding their condition and a reciprocal ability to respond to requests for their informed consent especially regarding tradeoffs, say safety for cost.

In addition they could function as watchdogs to serve as early warning on the ground of disasters waiting to happen as well as monitors of agencies charged with prevention, containment and remediation. This function was deemed essential to help protect Prince William Sound from another disastrous oil spill.

One central purpose should animate all three of these entities, separately and in tandem. They should address the question, “How Safe is Safe?” That investigation demands foresight in the spirit of the injunction, “Without vision, the people perish.”