CHAPTER 1

Hedgehogs or Foxes?

> The mature individual is the individual who can hold conflicting world views together at the same time, and act, and live and that his or her life is enriched by that capability—not weakened by it . . . To be able to see the world globally, which you are going to have to be able to do, and to see it as a world of unique individuals . . . That is complexity, that is really complexity!
>
> C. W. Churchman

> The test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function . . . One should, for example, be able to see that things are hopeless and yet be determined to make them otherwise.
>
> F. Scott Fitzgerald

We begin our exploration with two vignettes, one looking back and the other looking ahead.

MIDNIGHT AT BLIGH REEF

At 12:04 A.M. on March 24, 1989, in calm seas, the tanker *Exxon Valdez* struck Bligh Reef in Prince William Sound, Alaska. Eight of the eleven cargo tanks were punctured, and the result was the largest oil spill in U.S. history. Of the 53 million gallons (or 1.26 million barrels) of crude oil carried, 21 percent spilled (10.8 million gallons). Almost all of the spill (10.1 million gallons) occurred in the first five hours after the accident. The oil spread over 3,000 square miles in Prince William Sound and the Gulf of Alaska. The ship was under the command of Captain Joseph Hazelwood. A sobriety test was given to him ten hours after the accident and showed a .06 percent blood alcohol level, above the USCG limit of .04 percent, but below the state's .10 percent limit.

Built in San Diego in 1986, the *Exxon Valdez* is 987 feet long and has a deadweight of 213,755 tons. The spill was by no means the largest in the world to date. In 1967 the *Torrey Canyon* dumped three times as much (30 million gallons) off the British coast and in 1978 the *Amoco Cadiz* spilled six times as much crude oil off Brittany (68 million gallons).

Captain Hazelwood notified the Coast Guard 22 minutes after the grounding. The on-scene coordinator (USCG) notified the National Response Center, the State of Alaska, and Alyeska, the petroleum service company responsible for pipeline and Valdez port operations, within one hour of the accident. Alyeska's response was delayed more than twelve hours after notification—far beyond the five hours stipulated in its contingency plan. Within twenty-four hours, the *Exxon Baton Rouge* was positioned alongside the *Exxon Valdez* to transfer the nearly 80 percent of oil still in the tanks of the grounded ship. On the second day Exxon Shipping Company assumed responsibility for the cleanup. Estimates of the shoreline contaminated by oil ranged from 730 to 1245 miles. Figures for sea bird deaths climbed from 28,000 in 1989 to 90,000–270,000 in 1990 to 580,000 in 1991. Estimates of sea otter casualties ranged from 872 in 1989 to 5,500 in 1991. There was a loss of at least $12 million in herring fishery, while 30 percent of the salmon spawning grounds were threatened. Three years after the accident, the governmental Exxon Valdez Oil Spill Trustee Council reported continuing damage as the oil worked itself through the fish-spawning and animal breeding cycles. Hydrocarbons have accumulated in the bile and blood of river otters, which eat mussels that are still contaminated with oil in the Sound. Bird nesting sites continue to be disrupted by oil, high abnormality rates in fish eggs have been observed, and the social structure of killer whale pods is breaking down. Even the migrations of salmon and birds have been affected.[1]

The cost of the spill to Exxon from March 1989 through September 1990 was $2.2 billion.[2] This figure may be compared to the $1.3 billion cost of the Three Mile Island nuclear accident. *In neither case were there any human fatalities.** At the end of the

*It is interesting to note that the Bhopal, India, chemical accident at the Union Carbide plant, with estimates of 2,500 to 4,000 fatalities and possibly 200,000 non-fatal injuries (many of them severe), was settled by the company for only $470 million in damages paid to victims. However, this settlement was subsequently disputed.

1989 cleanup effort, Exxon executives said it was time to celebrate the successful "treatment" of the shoreline. Otto Harrison, the company's cleanup chief, pronounced the entire shoreline of the Sound to be "environmentally stable," almost free of oil, and posing no further danger to fish and wildlife. However, Exxon announced that it would have a 450-person crew in the area after the pullout to monitor and to study developments. Alaska's Governor Cowper disagreed with Exxon's assessment: "Obviously the beaches are not clean, and we are not satisfied with the condition of the beaches and the water." The Coast Guard's Admiral Yost observed that the results of Exxon's laudable summer cleanup project did not measure up to the efforts. It was evident that the corporation, already faced with more than 140 law suits, was likely to be billed for additional cleanup work that the state would perform.

A year after the spill, in March 1990, many wildlife species, such as otters, porpoises, and bald eagles had returned to Prince William Sound. But tarry oil layers were still found on some beaches, and oil washed out from the beaches was found to have been redeposited. Early estimates of oil removed in Prince William Sound were 4–12 percent by man and 30 percent by natural marine processes.[3] Subsequently, the National Oceanic and Atmospheric Administration (NOAA) sampled 600 sites and claimed that the ferocious waves of winter had removed 50 percent of the oil buried along the shores and up to 75 percent of the surface oil. But one hundred miles of beaches remained tainted, oil could be seen on the water surface, dead sea otters were still occasionally washed up on shore, and Eleanor Island waters were too dirty to fish for shrimp.[4]

Exxon returned in April 1990 for more cleanup with up to 150 workers. There was no more massive high–pressure steam cleaning of rocks as in the first summer. Instead, specific spots of heavy oil were tilled, washed, or dug up. Nitrogen and phosphorus fertilizer were sprayed to promote the growth of microorganisms that can break down oil.[5] By the end of the second summer the heavily oiled beaches were down to four miles, but oil was still buried in gravel and sand at about 800 sites. A NOAA survey during the summer concluded that oil could remain a decade or more before disappearing, noting that "the same forces that buried it can unbury it."[6] The oil spill coordinator for the state of Alaska estimated that 60 percent of the oil remained in Prince

William Sound two years after the accident. However, by 1993, both government and Exxon scientists agreed that the remaining oil appears to pose no significant environmental threat.[7]

Environmental damage assessment was hindered for three years by legal maneuvers to block the release of data relevant to pending law suits. Much uncertainty remains as to the long-term effects of the original spill. The full biological, ecological, and social impacts are still unknown. There was a record catch of pink salmon in the sound in 1990, but studies have raised concerns about their long-term reproductive vitality.[8] A 1992 overall assessment of Alaska's wildlife by federal and state agencies indicated that the total population of sea otters was 250,000, "healthy and increasing," that of bald eagles was above 35,000 and healthy. Large land mammal and bird populations were stable or increasing, as were those of some sea mammals, such as sea otters, beluga whales, and ringed and ice seals. However, other sea mammals—steller sea lions, harbor and northern fur seals, and humpback whales—were declining precipitously. Four years after the spill, there is still sharp disagreement between government and Exxon scientists about the fate of sea birds, specifically murres, and wild pink salmon.[9] In August 1993, the local fishermen staged a demonstration by blockading the Valdez Narrows to protest their continuing low catch of pink salmon and Exxon's refusal to meet with them.

As a postscript, it should be noted that, in October 1992, another oil tanker, the British Petroleum-chartered *Kenai*, carrying 35 million gallons of Alaskan crude, developed steering trouble 16 miles from Bligh Reef and came perilously close to running aground on Middle Rock in Prince William Sound. Recent disastrous tanker accidents off the coasts of Spain, Scotland, and Sumatra underscore the global nature of the pattern. As of March 1993, five of the world's fifteen largest oil spills have occurred in the four years since the *Exxon Valdez* incident.[10]

TWO FORCES THAT ARE TRANSFORMING OUR WORLD

As we speed toward the 21st century, there is much talk about "a new world order." The cold war is over and the "knowledge society" is beckoning. The two factors that undoubtedly will have a decisive impact on life in the next quarter-century are population and technology. The impact of their explosive growth will be pervasive and affect all passengers on spaceship Earth in obvious and subtle ways, raising unprecedented challenges to system management capability.

Population

While the earth's land area has remained virtually fixed, population is multiplying as never before. At the time of Christ, the global population was only about 200 million. By 1950 it reached 2.5 billion, and this figure doubled to 5 billion in 1987. In 1900, there were 16 cities with more than 1 million inhabitants; in 1990, there were 276. The World Health Organization estimates that there are 100 million acts of sexual intercourse every day, with 910,000 conceptions.[11] With 40 percent to 60 percent of all pregnancies unplanned in the U.S., the global rate is undoubtedly even higher.[12] From 1987 to 2000, 1.3 billion additional human beings will rub elbows with one another, raising the world's population to 6.3 billion. The net annual population growth currently is 92 million. In the year 2000, there will be at least 21 cities with 10 million or more population; 18 of these will be in the developing countries.

The projected 2025 total of 8.5 billion* means that the population has multiplied by a factor of more than forty in two millenia. More than 62 percent of the people will live in crowded urban areas. In 2025, China and India together will have a population of 3.2 billion, equal to the entire world population in 1940.** While the developed countries in 1990 averaged 1.8 children per woman, the figure for Africa was 6.1. In Rwanda, the number of births per woman in 1989 was 8.5. Women bear many children to improve their status. As a Rwandan women's advocate observed, "The more children you have, the more stable the marriage. The children become your strength against your husband—they will fight for you if he tries to hurt you."[13]

By 2020, Kenya's population will have jumped from 23 million to 79 million; Nigeria's, from 112 million to 274 million.

*Based on past forecast accuracies, a range between 7.2 and 9.8 billion reflects the uncertainty.

**The Chinese government has recognized the severity of the problem and instituted Draconian family planning measures to reverse its disastrous population growth. It claims that the expected number of children per woman has declined from 2.5 to 1.9 in the period 1988 to 1992.

Even if birth control were to be practiced widely, the status of women in the Third World raised significantly, and old-age security provided, the impact would not be apparent for a long time. United Nations population estimates for 2050 range from a low of 8.5 billion to a high of 12.5 billion.[14] The pressure on the natural environment and resources as well as on social institutions of the global population growth is crushing. In 1992, 60 percent of the world's people are living in coastal areas; in fact, 65 percent of all cities with 2.5 million or more population are on coasts. The pressure on the marine environment is obvious.

There is a growing gap between rich and poor. The fastest population growth is occurring in the poorest, the slowest in the wealthiest nations. While the population in the wealthy areas is aging, that in the poor areas is becoming younger. In 2000, one-third of the world will be teen-agers, mostly in Asia, Africa, and Latin America. This growth pattern hardly seems to be touched by the simultaneous death due to malnutrition and disease of 35,000 children daily (the estimate of the United Nations). Within the United States we observe a similar pattern. The income of the top 5 percent of the population has risen in the last decade from 15 times to 22.5 times that of those at the poverty level.[15] The family income of the wealthiest 5 percent rose 23 percent while that of the poorest 25 percent declined 6 percent.

The U.S. population has increased from 151 million in 1950 to 250 million in 1990. About one million immigrants arrive each year, with 300,000 of them estimated to be illegal (90 percent of the illegals being Mexican). One estimate anticipates at least 15 million immigrants, legal and illegal, arriving during the 1990s, with another 30 million by 2020.[16] By 2030, three minorities—Hispanic, Black, and Asian—will jointly constitute the majority population. In the fast-growing Hispanic population, only 26 percent are fluent in English and only half complete high school.[17] One example:

> At age 32 [Andre] Sherman [of Baltimore] acknowledges six children whose ages range from 8 to 16 years. They were born to four different women, none of whom he married . . . Each of the mothers receives welfare payments to help raise the children, whom Mr. Sherman now says he fathered impulsively and recklessly. He learned at age 16 that he had first impregnated a girl . . . In rapid succession [he] fathered more children. At one point 12 years ago, three women were simultaneously pregnant

> with his children. "I was wild like all kids," he offered by way of explanation.[18]

For poor teenage girls in grim ghettos, pregnancy gives their seemingly hopeless lives purpose and meaning.

Technology

The overarching technology of our time is that of information—its gathering, processing, storing, movement, and display. Major advances are occurring at a dizzying pace in areas such as microelectronics, optoelectronics, artificial intelligence, computer architecture, and networking. From computerized medical diagnosis to learning games, from professional work stations to desktop publishing, from computer-integrated manufacturing to environmental simulation, from simple robots to intelligent machines that move, sense, and respond to environmental changes, new applications are propelling us deeper and deeper into the information age. Even genetic engineering can be considered in the context of information technology, as it deals with biological levels of information.

Nineteenth century technology gave us machines that were extensions of the human limbs so that we could move faster and lift larger loads; information technology creates extensions of the human brain, nervous system, eyes, ears, and mouth. Indeed, the distinction between living and nonliving systems is becoming blurred, as shown by the current evolution of biochips and genetic manipulation.

Information differs strikingly from matter and energy. If we give you physical goods, you gain them and we lose them. If we give you information, you gain it but we do not lose it. The production of information uses very little energy in comparison with the production of material. Matter and energy are bounded on a finite earth; information is not. Thus the focus on information appears uniquely suited to the future on this planet.

Progress is accelerating in other fields as well. Trains moving at 250 MPH to 300 MPH, as well as new supersonic aircraft, are on the horizon. The creation of new materials (composites, ceramics, design at the atomic and molecular scale) and energy conversion systems (photovoltaics, fuel cells, nuclear fusion) should provide substitutes for problematic resources. Planetary engineering projects will become feasible: routine terrestrial mapping using satellites, education systems for Third World areas involving satellite transmission, and possibly even large-scale amelioration of adverse environmental changes.

The Interaction

The combination of population growth and technology is shrinking the earth to a kind of global megalopolis. Economies, enterprises, television-borne culture, starvation, and environmental concerns transcend national boundaries. Information technology brings distant events into our living rooms instantaneously. Perhaps the most striking example is the Apollo manned lunar landing seen "live" on home television screens. Air transportation brings people and goods easily and quickly from one continent to another. The synergism resulting from striking advances in both information and transportation technologies truly transforms the relation between the human being and territory in an anthropological sense. The world becomes one's neighborhood.

At the same time, the very same combination of more people and more technology is creating unprecedented waste, a stinking mess that befouls air, land, and sea. Both rich and poor are degrading the environment: the rich by overproduction and overconsumption, the poor by overpopulation (even in the face of underconsumption). The impact of industrial processes, such as chemical effluents (as in the Rhine River) and nuclear radiation (as in Chernobyl), moves effortlessly from one country to another. The burning of fossil fuels produces massive amounts of carbon dioxide that create the global greenhouse effect, which may raise the surface temperature and sea level significantly in the 21st century. The use of chlorofluorocarbons destroys the stratospheric ozone layer protecting life on the earth. Humans are decimating forests from the United States and the Amazon Basin to Borneo and Nepal.

The rapidly expanding global demand for energy and materials is inexorably increasing the possibilities for catastrophic accidents. The proliferation of biological, chemical, and nuclear weapons and high-tech delivery systems is increasing the opportunities for terrorist leaders and "crazy states" to cause human catastrophes on an unprecedented scale. The frustrated and seething masses in the poor world are easily inflamed by tribal feuds or fundamentalist crusades into fanatic engines of destruction. *For* *the first time in history, human-induced crises such as modern wars and environmental disasters have the potential to rival natural disasters in their scope and magnitude.*

So many new products are created that we cannot keep up with studying them to determine their toxic effects. Of 48,000 chemicals listed by the EPA, little is known about the toxic effects of 38,000 and fewer than 1,000 have been tested for acute effects.[19] A 1984 National Academy of Sciences study found that adequate information on potential health hazards existed for only 18 percent of the 1,815 pharmaceuticals studied, 10 percent of the 3,350 pesticide ingredients, and 11 percent of the other commercial chemicals considered.[20]

Often the impacts of a technology are not apparent for decades. The building of the Welland Canal to connect the St. Lawrence River to the Great Lakes in 1829 made it possible for lampreys to bypass the natural barrier of Niagara Falls and gain entry into Lake Erie. It took 110 years for them to decimate fishing in the upper Great Lakes. Fortunately, by 1955 a selective chemical poison was found that killed the larvae of lampreys, and by 1962 the threat was overcome.[21] There is always the hope that new knowledge will reverse environmental threats. But it is just as possible that we may face devastation before the threat is effectively countered, or perhaps before it is even widely recognized. The time factor also comes into play with population growth. If the world's population is to be stabilized, how many decades (or centuries) will it take?

Of most concern is the threat to freedom posed by the combination of exploding population and technology. Consider Los Angeles as a primary example. It has been rapidly transformed from a "laid-back," decentralized community to a traffic-gridlocked metropolis. Initially, traffic lights sprouted, then "freeways" mushroomed. Today, clogged streets and freeways often create a nightmare of immobility. Two freedoms appear to conflict: It is difficult to imagine the accommodation of the freedom of growth without increasing the need for controls and thus reducing the freedom of the individual. How can democracy continue to spread and offer prized freedom to individuals?

The combination of population and technology is giving rise to new forces, which will impact everyone in the crowded global megalopolis of the 21st century. Technology now permits unprecedented centralization *and* decentralization simultaneously. It is creating a single global system while at the same time, through networking, permitting greater local autonomy.

Must we redefine terms like *security, freedom,* and *democracy*? Is a reformulation of the concept of 'growth' in order? Will islands of wealth continue to be surrounded by a roiling sea of poverty? Will the wealthy rely on technology to protect themselves from being swamped by the waves of restless poor, the "barbarians at the gate"? Or are we smart enough to exploit it to enhance the quality of life for all?

NEW CENTURY—NEW THINKING

The two problems we have considered seem very different. One is local, the other global; one deals with the past, the other with the future. But they have vital aspects in common. Both draw in human beings as well as technology; both are complex. It is the thrust of this book that such problems must be viewed from several perspectives. No one way of "seeing" them suffices to give an adequate understanding.

In aerial reconnaissance we often find that a puzzling object on the ground can be identified from the air once we have a sequence of photos, each taken from a different position. Looking at one picture, we cannot identify the building. But several photos from distinct angles enable us to see the shadows thrown by the building and provide vital added information. We can do even better by stereoscopic photography, that is, calling on the human ability to "see" in three dimensions. Our two eyes do not merely see slightly different images; the difference between the two enables the brain to compute dimensions invisible to both eyes. The total is more than the sum of its two parts.

In this book, we shall use three very different kinds of perspective to illuminate complex systems: the technical or analytic (T), the organizational or institutional (O), and the personal or individual (P). Each views a system through a different lens. Most importantly, each perspective provides insights not obtainable with the others. Together, they give us a deeper understanding of complexity. Once again, the total is more than the sum of its parts.

A prime example of the importance of using multiple perspectives is the case of human-caused crises. In virtually every major crisis, there has been simultaneous interaction or breakdown of technology, organizations, *and* individuals.

The idea of using several perspectives in examining a problem or concept is very old. Indeed, one finds a curious preference for three perspectives throughout human history. In Egypt, Ra, Amon, and Ptah form three aspects of one supreme and triune (three-in-one) deity. In Judaism, God is viewed as nature (Malhuyot), as history (Zihronot), and as revelation (Shoferot). In Christianity we have the Holy Trinity: God the Father, God the Son Jesus, and God the Holy Ghost.

Historians have also found multiple perspectives valuable. The distinguished French historian Fernand Braudel divided his work on *The Mediterranean and the Mediterranean World in the Age of Philip II* into three parts:

1. the timeless history of humans and their interactions with the physical, inanimate environment
2. the social history of groups and groupings that generate forces leading, for example, to wars
3. history on the scale of individuals

Correspondingly, he saw historical time as "geographical time, social time, and individual time."[22]

We want to make very clear, however, that viewing the past from different perspectives in no way means denial of the actuality of the past, as has been done by certain "revisionist" historians, for example, those who deny the Holocaust ever occurred.

Max Weber, the great German sociologist, proposed three kinds of legitimacy: rational, traditional, and charismatic. Sigmund Freud used three quasi-archeological layers in order to understand human complexity: the professional, the political, and the personal. He found the first to be the most current and accessible, the third to be the deepest, least current, and least accessible. Jürgen Habermas saw man in three relationships: man to outer nature (or technical), man to man (or societal), and man to inner nature (or the self).

In 1959 C. P. Snow gave a lecture at Cambridge University entitled "The Two Cultures." In this widely discussed talk, he decried the gulf of misunderstanding between the scientific and nonscientific cultures. He saw this polarization as "a sheer loss to us all." He also drew a distinction between the individual and the social "condition," noting that the individual becomes fully human only in the context of a social setting.[23]

Political scientist Graham T. Allison is the most immediate link to the concept used in this book.[24] He introduced three "models" to examine the Cuban missile crisis: (1) the rational actor, (2) the organizational process, and (3) the bureaucratic politics. Allison's models were subsequently used by historians James W. Davidson and Mark H. Lytle to examine the decision to drop the atomic bomb in their 1982 book *After the Fact: The Art of Historical Detection.*[25]

Archilochus, a Greek poet, said, "The fox knows many things, the hedgehog knows one big thing." In his book *The Hedgehog and the Fox* Isaiah Berlin used this quotation as the basis for his examination of the fundamental difference between the single- and multiple perspective modes of thinking.

> There exists a great chasm between those, on one side, who relate everything to a single central vision, one system less or more coherent or articulate, in terms of which they understand, think and feel—a single universal organizing principle in terms of which alone all that they are and say has significance—and, on the other side, those who pursue many ends . . . ; these last lead lives, perform acts, and entertain ideas that are centrifugal rather than centripetal . . . moving on many levels . . . The first belongs to the hedgehogs, the second to the foxes.[26]

For complex systems we want the foxes rather than the hedgehogs. It is our hope that the reader will come to feel at ease with multiple perspectives and recognize their usefulness in dealing effectively with his and her own challenges.

In part 2, we shall use the technical, organizational, and personal perspectives to view the Alaska oil spill. The anatomy of this case is instructive because it is indicative of technology management challenges that we will confront around the globe with increasing frequency.

As noted in the Preface, the box in the top right-hand corner will serve to remind the reader which perspective or perspective linkage is under discussion.