Organizations and the Production of Systemic Risk

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Abstract

Organizations and Systemic Risks

Systemic risks are those threatening multiple parts of an organizations, or other organizations and systems in its environment. Interdependencies abound in our highly technological world and can be unexpected, and in the case of global warming—largely an organizational failure—dire. An 80% reduction in the assets of oil, gas, and coal companies is required to reduce warming but is not anticipated. So-called "natural" disasters are shown to be enhanced or even caused by organizations. The organizational roots of the 2008 economic meltdown, Fukushima, and chemical plant accidents are examined with regard to regulations, profits, and system interdependencies. With economic systems favoring short-run concerns, and shareholder rather than stakeholder values, there is little evidence of emerging long-run visions that could protect future generations.

INTRODUCTION

Organizations are bound to have failures since nothing can be perfect, so they are always running risks. Most of what industrial societies do is done by organizations, and some are responsible for the production of "systemic risk." Most risks affect just a part of the organization and little of the environment. They hardly have catastrophic consequences. In contrast we use the vague term "systemic risks" to refer, first, to those that involve many parts of the organization, as when failures propagate throughout the organizations, and second, when these impact other organizations as well as people and its natural environment. Systemic failures of the second sort are particularly important when our "critical infrastructure" is involved. "Infrastructure" is shorthand for interdependencies (the "infra") among "structures"—the organizations. "Critical" refers to things that we cannot do without such as communications, transportation, energy, health care, food and water,

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and the police and the military. Take out any one of them and rest cannot function. Critical infrastructures are vital.

For example, the computer operating system used by over 90% of personal computers—Microsoft Windows—is poorly constructed and thus subject to attacks upon computers and their connections. It is feared that an attack could lead to bank failures, train or aircraft accidents, conventional wars, nuclear plant meltdowns, or even nuclear wars. Microsoft, in this view, generates major systemic risks.

So far industrialized nations—the ones with the most interdependencies in their critical infrastructures—have not experienced any major death dealing catastrophes because of system-wide failures of infrastructures, though fears of this are widespread. But they do have financial crashes produced by organizational systems, as well as health crises and wars. Think, then, of systemic risks as involving multiple interdependencies with widespread consequences.

INTERDEPENDENCIES

It is widely recognized that the modern world is full of complex interdependencies and this magnifies the impact of risky organizational behavior. When the financial meltdown in 2008 occurred, it turned out that the stock market and bond market, supposedly separate, were quite tightly coupled, and because much of finance is now global, the disturbance almost instantly spread through nations, precipitating seemingly unrelated crises.

Interdependencies can be subtle and surprising. In the 1970s congress held hearings on the desirability of requiring colleges and universities to eliminate the summer break and run full out all year. Take a second to guess who testified against this efficiency argument. Most people say college teachers and administrators, but most of those endorsed the idea. The opposition came from the travel industry that was dependent on temporary, largely college-going, help during the summer when most adults had a week or two of vacation, and from the airlines, which flew them to the resorts. One does not normally expect airlines, resorts, and colleges to be so tightly linked, but it was tight enough to defeat the efficiency legislation.

Nor would one expect an earthquake in Taiwan to cut the world output of electronics by 7% for 1 month. The 1999 earthquake in Taiwan stalled shipments from a key factory because of a week-long break in the island's electrical and transportation systems. Vital components for factories around the world had this factory as their sole source because it was the cheapest supplier. While hardly a disaster, it illustrates the vulnerability of global supply chains searching for the cheapest supplier.

GLOBAL WARMING AND ORGANIZATIONS

The biggest risk society faces is that of increasing emissions of greenhouse gases (GHGs). Most of these pollutants come from fossil fuels used in transportation, heating, and electrical generation—oil, gas and coal. Most of these resources are owned by nations, such as Saudi Arabia. But whether the resources are in private hands—Exxon-Mobile—or public hands—nationalized oil, gas and coal companies—they are a source of profits. For private companies, these proven resources handsomely support stock prices, produce profits as they are exploited, and are the basis for low cost loans from investors. However, scientists have concluded that to prevent global warming from going above 2°C (already a hazardous temperature rise) we can only put roughly 565 more gigatons of carbon dioxide into the atmosphere by midcentury and still have some reasonable hope of staying below a 2° increase in temperature. And we're already three-quarters of the way to that target. Study after study predicts that carbon emissions will keep growing by roughly 3% a year—and at that rate, we'll go through our 565-gigaton allowance in just 16 years. We have 2795 gigatons of carbon in the proven coal and oil and gas reserves of the private and state-owned fossil-fuel companies. This is the fossil fuel we're currently planning to burn.

This means we have *five times* as much oil and coal and gas on the books as climate scientists think is safe to burn. This investment is what the market uses to set the stock prices of Peabody Coal and Exxon-Mobile and Chesapeake Gas. Their market value would have to drop by 80% if we kept 80% of those reserves locked away underground to avoid going beyond 2° of warming. Saudi Arabia would have to cut its national budget by a similar amount. Millions of Chinese would return to the dire poverty from which they have so recently emerged, since China now is the leading polluter among nations. (The United States leads in per capita GHG emissions.) Oil, gas, and coal companies, whether private in the West or state-owned in the East, are not about to stop generating systemic risks.

In the United States the private companies responsible for polluting the atmosphere became worried about a government restriction on emissions after international organizations and scientific bodies sounded louder alarms in the early 1990s. By 1995 they had a well-financed "denier" campaign going, denying that the earth was warming, or that if it was, that humans were responsible.

In 1997 the difference between self-identified Democrat and Republican respondents to a Gallup poll asking whether global warming was happening was only four percentage points: 52% of Democrats and 48% of Republicans thought it was happening. By 2008 the four-point difference had increased to

34%. Concern with global warming among Republicans has actually *declined* over the past decade, and their belief that it was being exaggerated rose from 37% to 59%.

The denier campaign was one of the most successful social movements in recent US history; in just over a decade a significant proportion of the electorate changed from accepting scientific findings to rejecting them. The conservative political base was successfully mobilized through a variety of tactics. They made sure climate change skeptics repeatedly testified before congressional committees. The American Enterprise Institute offered a bounty of $10,000 to authors for each skeptical paper they published in reputable journals. The industry entertained TV weather announcers; organized citizens groups and demonstrations; and flooded the nation with TV and print ads denying that humans caused warming. Eighty percent of their capital was at risk.

NATURE AND ORGANIZATIONS

Nature is the author of countless disasters, but organizations figure in these indirectly. An earthquake, followed less than an hour later by a tsunami, destroyed four nuclear power plants in the Fukushima complex in Japan in March 2011. To what extent were organizations involved in this natural disaster? Heavily, it turns out, since there were urgent warnings from experts both within the organization that built and ran the plants, and from without, warning that the protections against tsunamis and even the more common earthquakes and were quite inadequate. While the tsunami was unusually large (but not unprecedented), the earthquake was in the predictable range. Radiation from at least one of the reactors was detected immediately after the earthquake and before the arrival of the tsunami made things worse. (Tsunamis are rare; earthquakes are not, so the fact that the earthquake alone could have destroyed four plants is important.) The company had been warned that they were not prepared.

Or take the flooding of New Orleans in 2005, clearly a natural disaster. But a few years before, a canal had been built to provide cargo ships with direct access from the Gulf of Mexico to the lake that boarders the city. Environmentalists and others vigorously objected to the canal (the MRGO) because it would destroy adjacent areas of trees and vegetation that buffered the city from storms, and would continually widen and need constant dredging because of the porous soil, and finally, a hurricane coming in the right direction would be channeled directly into the heart of the city by the canal. But real estate and construction interests succeeded in getting the federal funds to build it. Hardly any ships used it once it opened, but Katrina did. Organizations, taking systemic risks, enlarged this "natural"

disaster: the Chamber of Commerce, major real-estate firms, construction firms, and local political parties.

More tenuously, we can see organizations behind such very natural disasters such as plagues and epidemics of all sorts. Global warming, largely a result of the fossil fuel industries, allows viruses to multiply in jungles, and commercial exploitation of jungle products allows them to hitchhike on people that the transportation industry moves about the world. Or take the epidemic of obesity. Sugar and salt are tasty. Most of sweets in the United States come from corn syrup, which is heavily subsidized by the Department of Agriculture at the behest of giant food producers. The sweet drinks and foods, and the salty snacks, are kept very cheap with the corn and petroleum subsidies, so the poor buy them because of their tempting taste and as a cheap source of protein, and they get fat. Powerful food organizations use heavy advertisement and clever marketing to keep this epidemic going.

INDIVIDUAL BEHAVIOR AND RISKS

Note that I am avoiding the usual explanation for living dangerously: individual choices. This explanation is certainly a viable one; we often have choices and make the wrong ones. A cultural explanation is another powerful one. Some cultures minimize risky behavior; others maximize them, through socialization from birth onwards. But there is still an organizational component.

Take two people, otherwise identical in their "risk tolerance," and one gets a job in the commercial side of a large bank and the other in the investment side. They soon are likely to diverge in their tolerance of risk because of different organizational structures. The structure of rewards and penalties, the structure of authority, communication lines, and tasks will lead the people in the investment side to take large risks with the bank's money and generate large (short run) profits, or they will be replaced. Those in the commercial side will take care and focus upon long-term profits, and be judged by their contribution to the firm as a whole rather than an investment portfolio. If they take large risks they will be replaced. Both individuals are likely to carry some of this organizationally produced orientation over to their personal lives. A psychologist who tests each of them will attribute their personal choices to their "character" or personal traits. A sociologist will agree, but add that their character is markedly, though not completely, shaped by the structure of the organizational demands they must meet.

In financial institutions it was once a law that these different orientations had to be separated into different organizations: investment banking and commercial banking. Financial firms doing both were thought to be a main

cause of the 1929 financial crash and the Great Depression because the commercial side took up the risks that the investment side thrived upon. By 1999 that law (the 1933 Glass–Steagall Act) had been first evaded and then repealed; banks could engage in both activities. The part of the banks that emphasized risk and immediate profits invaded the more cautious commercial side, developing new products like derivatives and credit default swaps, perhaps to the horror of our fictitious employee on the commercial side. We now have the setting that produced the economic meltdown of 2008. Because the banks were becoming fewer and much bigger because of mergers, the system was also more "tightly coupled"—more intensely interactive—and the dangers cascaded through more of the financial system than just the banks. Fraudulent behavior became easier to perform because of the complex instruments being invented, and focus upon immediate profits encouraged such behavior. Some organizational structures invite fraudulent behavior by individuals; others discourage it. It is to organizations that we should primarily look, rather than putting individual behavior first.

SETTING THE ORGANIZATIONAL STAGE

But what accounts for *organizational* behavior? For this we have to turn to governments and political processes. (These are influenced by organizations as well; it is a reciprocal relation.) The 2008 economic meltdown shows how governments and political leaders sometimes choreograph the risks that organizations undertake.

We can start with China. It can be plausibly argued that China caused our meltdown. China does not have a strong social security program, wherein individuals are forced to pay into a fund that will help them through medical emergencies, unemployment, and most importantly, their living costs when they get old and retire; an ageing population is a condition that all nations are increasingly saddled with. So it has been up to individual Chinese citizens to save money on their own, putting it in state banks. With millions of citizens doing this, the banks accumulated a great deal of wealth. Where to invest it? The United States has been the investment of choice for foreign nations for many decades and that is where it went. This made capital cheap for US organizations, and at the same time the US government could please its own citizens by making it easier for them to purchase their own homes—long a favored policy of politicians in the United States.

Banks, using money loaned from China, made borrowing easier and cheaper, and in the short run profited immensely from these transactions. With government benignly looking on, credit standards and financial oversight declined, and we had the housing bubble. The new financial instruments the banks invented, such as securitization and credit default

swaps, ran amok while financial institutions, banks, investment banks, hedge funds, insurance companies and so on saw their profits soar. There were plenty of warnings; it was not something that could not be foreseen. The warnings came from people in government—legislators, regulators, and the White House itself—and many economists in think tanks and universities, and risk officers in the banks themselves, to no avail. As a few firms failed, the interconnectedness of ever larger and fewer financial institutions allowed the failures to spread widely, affecting not just banks but insurance firms and the bond market, and other nations.

Of course, China is not to blame for lending us money cheaply; by definition systemic risks and failures have many fathers. The US government should have seen the effect of easy money and reigned in the prodigal banks. The banks, in their own long term self interest, should have ask for strong regulations that would damp down the fire they were enjoying so much. But the deregulation movement that gained increasing strength since the 1980s was so profitable that no one dared damp it down. "When the music is playing, we all have to dance" said one hedge fund manager. Deregulation of the industry allowed organizational structures and practices to emerge that tolerated high risks and encouraged malfeasance.

This means there is a lot of blame to go around—the political advantage of cheap money and mortgages for the party controlling the White House, and the congress that brought about deregulation. But a good portion of it resides in the failure of financial institutions to manage their affairs properly so that their clients, their own organizations (some big ones just collapsed), and the public at large would not be harmed. Top officers of financial firms ignored their own risk officers, hired to appraise systemic risks. Because financial firms are now too big to fail, the costs of the disaster have shifted from the risk-taking firms to the government, and thus to taxpayers.

THE NUCLEAR RISK AND GOVERNMENT

The US government has set the stage for a quite different catastrophe, the continuing one of four nuclear power plants in Fukushima, Japan.

Nuclear power plants contain the highest concentration of hazardous substances we have been able to assemble; have a history punctuated with near misses and regulatory slack; and have had two major disasters in the short history of only about 400 plants, worldwide.

After the atomic bombs had blown up good parts of Hiroshima and Nagasaki in Japan in 1945, the US government had a problem: there was world wide outrage over the use of such deadly weapons, and as President Eisenhower and his cabinet members said in 1953, the "taboo that surrounds the use of atomic weapons must be destroyed." Secretary of State John

Foster Dulles admitted we could not use an A-bomb given public opinion. Therefore "we should make every effort to dissipate this feeling." One way was the "friendly atom" program, the peaceful use of atomic energy through subsidizing nuclear power plants in the United States and other friendly nations such as Japan. As an official at the US Department of Defense put it in 1953, "The atomic bomb will be accepted far more readily if at the same time atomic energy is being used for constructive ends."

The daughter of the atomic weapons program was thus the nuclear power plant, but it has turned out to be its "bad seed." The United States sponsored or encouraged the construction of nuclear plants in many nations, but was particularly generous and insistent with Japan. In the United States, with huge subsidies and virtually no liability if mistakes were made, nuclear power plants—104 of them at present and four more under construction—experienced repeated near misses and one nearly disastrous accident at the Three Mile Island (TMI) plant in Pennsylvania in 1979. The cumbersome regulations of the Nuclear Regulatory Commission were more effective than those in Japan, but still appear to be ineffective in reducing risky events, as are the tiny fines imposed for violations.

Cancer rates and especially incidents of childhood leukemia rose in the wake of the plumes of radioactive materials released at TMI, but effects on health were blamed on psychological factors—the stress that followed the accident. (Some scientists held that the level of radiation was so low that it could do no harm, so the disease and early deaths that appeared must have been from stress.) Stress and life styles were blamed for the sharp drops in life expectancy in Belarus, Ukraine and Russia after the Chernobyl disaster in 1987. The US Department of Energy, with 70% of its budget spent on things nuclear, still holds that low level radiation is not harmful, as, apparently, does the government of Japan after their Fukushima disaster in 2011. Biological scientists know better; they say all radiation is harmful.

The Japanese government, the US government, and the International Atomic Energy Association insist that the consequences of radiation received, and still being received, from the four failed Fukushima plants are negligible. But other scientific sources show alarming fallout damage on people, plants, animals, wildlife, and the earth itself. US officials argue that the level of radioactive fallout is so low that there is no point in studying its effect upon the exposed population, despite contrary evidence.

The Unit Number 4 Fukushima reactor illustrates both the immediate danger and the problem of nuclear waste storage. There are thousands of spent fuel rods stored 100 feet up in a damage building, vulnerable to even moderate sized earthquakes to which the area is prone. Its collapse would require the evacuation of Tokyo, and perhaps prevent the continuous cooling require

for safe storage of a much larger amount of spent fuel rods from all six reactors in the tightly coupled nuclear facility, just 100 yards away.

The feeble safety measures of the utility is the organizational tag we can place on this danger, but the box that contains many such tags is the "Property of the US Government"—its Department of Defense and the policies of a succession of Presidents promoting nuclear power and nuclear weapons.

CHEMICAL PLANTS

Our landscape is littered with "weapons of mass destruction" that can be triggered by accidents, as well as by nature or terrorists, and most of these involve chemical plants. The industry is highly concentrated and so are its dangerous substances. Consider the example of vapor cloud explosions. The government reports that there are 123 locations in the country where the explosion of a cloud or asphyxiation from toxic vapors could endanger over *one million* people.

The Chemical Safety Board examined chemical plant incidents for the period 1987–1996 and found there were more than 60,000 incidents and 260 deaths per year in the 10-year period. (Surveys like this rarely appear for the years after 9/11; the Department of Homeland Security says they would aid terrorists.) A single railcar of chlorine, if vaporized near Los Angeles, could poison four million people. Four million people could be harmed by the release of 400,000 pounds of hydrogen fluoride that a refinery near Philadelphia was keeping on hand. A chlorine railcar release near Detroit would put three million at risk. (The railcar releases we have had so far have been in rural areas with few deaths.) Union Carbide's Institute, West Virginia, plant near Charleston stored 200,000 pounds of methyl isocyanate—the chemical that did so much damage in Bhopal—which would threaten 60,000 people. (The plant is now owned by Bayer.) And close by New York City, a plant in New Jersey had, and may still have, 180,000 pounds of chlorine and sulfur dioxide, which could create a toxic cloud that would put 12 million people at risk. According to government records, nearly 1000 tons of deadly chlorine gas is stored in the "toxic mile" where the New Jersey plant sits, next to an interstate highway.

The Occupational Health and Safety Administration is plaintive in their reports of non-compliance by industry and how they are only able to level trivial fines. The forceful testimony by an OSHA official recently indicted the whole refining industry. He found that the petrochemical industry was repeating the same glaring mistakes despite their losses and despite the fines they receive. He gives several instances of ignored warnings; is concerned with worker harassment; and cites the inadequacy of measuring safety with "hard hat" requirements and holding on to railings. He notes a 20-year-long

effort by OSHA to get companies to focus on process safety rather than just individual safety. BP had won an award for individual safety measures days before the Gulf of Mexico blowout, but investigations showed it had flunked process safety, which includes inspections, testing, training and quality materials and supplies. It is not a case of a few bad apples, even if BP is the industries worst. The report finds the same violations committed by multiple refineries, a characteristic of the industry. OSHA has its faults, but so does the chemical industry.

DO WE LEARN FROM ACCIDENTS?

While catastrophes are rare—only one Bhopal so far, only Chernobyl and Fukushima in the 60 plus years we have been living with a few hundred nuclear power plants—they are increasing. Despite the mantra "in our accident is our salvation," meaning that we learn from mistakes and make the systems safe, we do not seem to be learning much, and what we learn is so incremental as to be quite inadequate. Take TMI: from that accident we learned that in the containment building a zirconium-water reaction consumes oxygen and frees hydrogen, which is explosive. Fortunately, accumulation at TMI was small and the explosion not serious. Since it could have been large, the US Nuclear Regulatory Agency (NRC) required that there be a vent in containment buildings to release hydrogen gas in case it built up. (Venting would also release radioactive particles, but that would be safer than an explosion that could damage the reactor further.) In the Fukushima disaster the hydrogen built up, but the lack of electric power meant that the vents did not open; workers tried to get to them in order to open them manually, but the radiation level was so high they would have died before they could get there. There were three hydrogen explosions that made matters much worse and released a lot of radioactive gasses. What we learned from Fukushima was pretty obvious, and should have been already obvious: the NRC now requires US plants to also have manual devices for opening the vents if power failed. This is the rate of our progress.

REGULATIONS: WHO IS FAILING?

"Regulatory failure" is the term that is often used to characterize the regulatory apparatus that oversees risky systems. Even the Japanese government acknowledges its failure in the case of nuclear power plants, where regulators moved to and fro between the industry and the government in a cozy culture of looking the other way. In the United States, the NRC has always been accused of favoring the industry they are supposed to regulate, and

many officials and staffs of the agency come from the Department of Energy, which favors nuclear power.

As ample as the failures of the NRC are, they and other regulatory agencies have an additional problem. With their budgets controlled by Congress, and with regulated industries supplying large campaign funds to congress people, there are limits upon what they can do. For example, in 1997, as a result of a number of near misses and violations of standards at the nation's nuclear power plants, the NRC increased the number of investigations. Republican senator Pete Domenici headed the committee that approved the agency's budget. He called in the top officials of the NRC, and threatened to cut their budget in half if the number of investigations was not cut back. It was cut back.

DEREGULATION AND PROFITS

Why does industry take such risks, almost always known ones? Accidents, and especially catastrophic ones, cost companies money (or the state, when it owns them). Insurance covers much of the losses in capitalist societies. (In what is referred to as "socializing the risk" the cost of insurance is included in the price of goods and thus spread to all customers.) In addition, expensive accidents are rare. As we will see, it is hard to have a really serious, expensive accident. It is, however, easy to get steady profits by such things as working employees close to their physical limits (production pressures), hiring cheap temporary or part-time workers who have little training, cutting back on inspections and maintenance, reducing the number of safety personnel, and buying cheap parts and materials. (Even fines do not deter firms; they are almost always trivial compared to company profits and are tax deductible.) There are very few disasters where subsequent inquiry by independent sources has not disclosed some or most of these, almost prosaic and routine, causes of disasters. While there are fancy theories for accidents (normal accident theory and high reliability theory are two prominent ones), we hardly need them for most accidents.

Seeking profits by cutting corners raises the question of whether there are any alternatives, and the answer is that some economic structures minimize risky profit-seeking behavior, while others maximize it. Unfortunately, the deregulation movement has favored maximizing such behavior. With the White House, under Democrats and Republicans alike, allowing more mergers of competitive firms, industries had fewer but bigger firms. That meant more political power to resist regulations, and, in the case of those with hazardous materials, larger concentrations of hazmats. It allowed consolidation of markets, with buy-outs and mergers increasing the concentrations of hazardous materials and thus the severity of the accidents. Moreover,

financial deregulation allowed the importance of "shareholder value" to increase at the expense of "stakeholder value"—the interests of workers, communities, industry stability, and societal benefits. The shareholder value movement meant that stock prices and short-term profits came to be valued. Investors, such as pension funds, hedge funds and large stockholders focused upon current profitability and stock values rather than internally generated growth and viability in the long term. Corporate officers were now rewarded, through bonuses and stock options, for maximizing short run profits, even if it meant risking long-term corporate survival.

A case in point is the Chief Executive Officer of the chemical firm, BP. He engaged in an aggressive expansion program, taking over other large firms such as Standard Oil, Arco and Amoco, and in 2000 started an ambitious cost-reduction program, ordering 25% cuts in the operating costs of their refineries and pipelines. This led to a major accident in Texas City, Texas (15 deaths and 180 injuries) and a major oil spill the next year at a Prudhoe Bay, Alaska, pipeline. Executives at the Texas City refinery repeatedly warned the top management of BP of the risks they were running because of budget cuts, particularly in process safety, and predicted that people would soon die. Regulatory agencies were at best somnambulant. People died in what was a very expensive accident, costing the company $1.5 billion plus fines of $2.1 billion. In spite of this the profits for just the third-quarter of that year were up 34%, to $6.46 billion. The next year, at Prudhoe Bay, there was a huge oil spill of over 200,000 US gallons covering two acres and a lot of wildlife, again despite management warning that lack of maintenance and inspection money would lead to a spill. The company received a fine of a little more than a day's profit, and had another large spill 3 years later in 2009. A year later, in 2010 we have the Gulf of Mexico deepwater well accident. Again there were production pressures, broken warning devices, and warnings. The costs this time have been much greater, but the company continues to prosper, investing in deepwater drilling elsewhere in the world. It is just one of the organizations in the oil and chemical industry that continue to produce systemic risks.

WHY NOT MORE CATASTROPHES?

So far I have been doing with social scientists call "selecting upon the dependent variable," which means I have been trying to explain why accidents happen, the "dependent variable." Not surprisingly, I have concluded that unsafe behavior causes accidents and the vast majority of them are preventable. But what if we selected a different "dependent variable," safe operation rather than accidents, asking what causes risky organizations to actually run safely? We then might list strong regulations, inspections, redundancies, safe practices, strong unions, and so on. In fact, the list of

variables that cause safe operation would be much longer than the list that causes failures; organizations do a great many things to insure safe operations, and considering all the risks I have been saying that we run, why do organizations avoid them almost all the time? Such a shift in the dependent variable allows an important insight: it is very hard to have a really serious accident and even harder to have a catastrophe.

Considering the accident at Bhopal. Chemical plants with highly toxic substances capable of killing thousands have been around for at least 50 years but Bhopal is the only one that has killed more than 500 people. Workers have made mistakes in attaching the wrong hose to a line before, but in this case it happened to be a very consequential mistake; it sent water to a tank with a deadly substance that should not receive it. There should have been nozzle connections of different sizes, and there should have been warning devices. But warning systems are frequently out of service in chemical plants since they are rarely energized or needed, and this was a particularly serious instance where warnings were needed.

Neither the temperature indicator on the MIC tank nor the flare tower for burning off the released MIC was functioning. The water curtain (high-pressure water sprayers) for neutralizing MIC could reach a height of only 10 m whereas MIC leaked from the vent gas line to about 33 m. Alarms had been disabled or were waiting for repairs just when they were needed. The plant staff had been cut back because of business conditions and they were inadequately trained. Management was short of staff and itself lacked experience and training. There were no devices to detect the presence or direction of toxic clouds. Remove any one or two of these nine problems and there probably would not have been a disaster. Catastrophes are highly contingent events; they require a large number of conditions—particularly errors, often small ones interacting unexpectedly—to come together just right.

This is true not only for the chemical plant at Bhopal but for its interactions with the environment; the larger system. A large shantytown had grown up right next to the plant, so many would be at risk. No alarm was sounded so citizens had no warning. (Indeed as people were becoming overcome by the fumes and called the plant, officials said there was no danger.) The wind was just right to send the plume over the shantytown. (Plant workers fled upwind.) It was night and the people were at home and in bed. Because of the climate, walls were flimsy and windows open, so the toxic fumes easily penetrated. All five of these conditions were required to make it a larger system catastrophe. Adding the nine in-plant contingencies makes it more understandable that we have had only one chemical disaster the size of Bhopal.

Contrast the Bhopal event, where everything came together just wrong, with a suburb in Florida that had a explosive cloud 2000 by 1000 by 100 feet

drift over it. But it was night when there was no automobile or truck traffic that could create a spark that would set it off. Explosive clouds from chemical plants have been ignited by sparks, but fortunately most have been in rural areas and the fatalities have been small. Not so with an LPG plant in Mexico City in 1984; the escaped cloud was ignited and set off explosions of other storage vessels, wiping out the huge plant and 500 people.

CONCLUSIONS

In our prosperity lie our risks of disaster. This is a familiar summary of the literature on the "risk society." With prosperity, largely the consequence of cheap electric power, economies concentrate populations, concentrate hazardous material and concentrate the power of firms over our "critical infrastructures," such as communications, transport, financial firms, and such necessities as agriculture and water. This makes us more vulnerable to natural hazards such as weather, earthquakes, viruses, and so on, but also more vulnerable to industrial accidents, deliberate terrorist acts, hackers, and software failures. For poor countries the risks stem largely from nature's fury and vagaries, and the predations of international resource extraction companies, but the rich countries have the added risks of concentrated "hazmats" and the private control of critical infrastructures.

The trend line for emerging disasters is complicated. Concentrations of vulnerable energy and infrastructures will continue under "free market" capitalism and in command economies such as China. Each crisis, such as the 2008 worldwide economic meltdown, produces more concentrated market agents as governments try to cope. We are making only marginal gains in safety with a few laws and regulations that reassure us. Reassurances are dangerous. With safer cars we drive faster, keeping the risk more or less constant. People worldwide are living longer and poverty is declining, further reassuring us. But hidden in the warmth of these advances is more vulnerability.

For example, antibiotics reduce deaths, but kill helpful bacteria as well, and as we get more injections we also get more antibiotics through the meat we eat because giant corporations give pigs and cattle antibiotics to make them grow faster and fatter. The result is a deficit of beneficial bacteria that must be met with more medical injections to ward off previously unheard of threats to our systems.

Most of our extended longevity is because of simple, basic improvements in diets, clean water and sanitation that industrialized countries achieved 100 years ago. But now the industrialized countries must increase life spans with ever more expensive medical procedures such as hip or heart replacements and the very expensive prolongation of life after age 70. This trend,

prolonging marginal existence, will only increase. It is very profitable for organizations in the health sector.

One of our dangerous trends is that we do not see the trends emerging. We consume most of the irreplaceable resource of oil by simply burning it for transport in a burst of profligacy because it is cheap and convenient. It is "bottled sun." But it is also much more. Two percent of our oil goes into manufacturing, where it is essential. It produces a vast variety of petrochemicals such as plastics; 95% of our food products need petroleum. And our store is finite, not replaceable. While we gaily travel freely now, heating the earth to dangerous levels, we ignore the exhaustion of a resource that so much of our prosperity depends upon.

Oil companies look ahead only a few years; governments have to look ahead hundreds or even thousands of years. Given the political power of industry and the short time horizons of citizens who must be forced by banks to even insure their houses, few governments are pressured to expand their time horizons. The Netherlands is an exception; they are building dykes to withstand a 1000-year flood and forcing the relocation of whole villages to provide floodplains for the spillover from overflowing rivers. In New Orleans, St. Louis, and other flood-prone areas of the United States, we raise the dikes a little and put housing developments in previously flooded areas, to be flooded again, with government insurance paid for by all taxpayers.

I see no emerging trend to look ahead to realize what we are doing with nonrenewable resources and with GHGs that create threatening weather extremes and the destruction of our eco-systems.

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Charles Perrow, Professor Emeritus of Sociology at Yale, is an organizational theorist. A past Vice President of the Eastern Sociological Society, he has been a Fellow of the Center for Advanced Study in the Behavorial Sciences (1981–1982, 1999); Fellow of the American Academy for the Advancement of Science; Resident Scholar, Russell Sage Foundation, 1990–1991; Fellow, Shelly Cullom Davis Center for Historical Studies, 1995–1996; Princeton University; Visitor, Institute for Advanced Studies, 1995–1996, Princeton NJ; former member of the Committee on Human Factors, National Academy of Sciences, of the Sociology Panel of the National Science Foundation, and of the editorial boards of several journals.

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