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Technological nightmares: Frederick S. Pardee distinguished lecture, October 2003

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TECHNOLOGICAL NIGHTMARES

By Paul Streefen

FREDERICK S. PARDEE
DISTINGUISHED LECTURE

October 2003

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Frederick S. Pardee

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By Paul Streeten

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PAUL STREETEN



Dr. Streeten is the founder and chairman of the board of World Development, a consultant to the United Nations Development Program and to the United Nations Educational, Scientific and Cultural Organization (UNESCO). He has worked for several UN bodies. Among other institutions, he has played a major role in the Institute of Commonwealth Studies and the Institute of Development Studies in Sussex. He is a principal thinker behind the Human Development paradigm and has been intensely involved in the writing of all the United Nations Human Development Reports, either as a part of the team of authors or as an advisor. Dr. Streeten has participated in numerous conferences and conventions worldwide. Many of his earlier lectures have been published in the book *Thinking About Development* (Cambridge University Press, 1997).

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TECHNOLOGICAL NIGHTMARES

Never prophesy, especially about the future.

—Sam Goldwyn

Introduction

I am not a Luddite. Like most reasonable people, I welcome technical progress. As Stephen Marglin has reminded us, “It is worth remembering that the followers of the original General Ludd, whose name became synonymous with irrational resistance to progress, did not oppose the spinning jenny but jennies in factories. Luddite resistance was not to technical progress but to the application of progress in ways which would destroy the birthright of ordinary folk to labor in their own cottages.”¹ Ned Ludd, or King Ludd, was a mysterious and mythical figure. He was an English laborer who was supposed to have destroyed weaving machinery around 1779. His followers, the Luddites, destroyed power looms between 1811 and 1816. The movement shook the North of England in 1811 and 1812. Hand weavers and combers rose up against the new machines that were displacing them. They smashed power looms and burned down textile mills. The authorities made the destruc-

1. Stephen Marglin, “Towards the Decolonization of the Mind,” *Dominating Knowledge*, edited by Federique Apffel Marglin and Stephen A. Marglin (Oxford Clarendon Press, 1990), p. 25.

tion of machinery a capital crime. By 1813, 24 of the Luddites had been hanged.

Luddites are still with us. In the 1970s there existed in Cambridge, England, a society called the George Corrie Society. Its purpose was to put obstacles in the way of technical progress. And in the USA the Unabomber had pathological objections to technical progress.

The indictment of the opponents of technical progress consisted not only in pointing to technological unemployment but also to the depersonalization and regimentation of work, the despoliation of nature, and the indiscriminate slaughter of total war. Since the 1970s this indictment has been widened to encompass the technologies of information and of life, including the cutting edge of computer science and molecular biology. Technology is blamed not only for its dramatic disasters—such as Three Mile Island, Chernobyl, Bhopal, and *Exxon Valdez*—but also for the insidious, alienating replacement of conversation and community by television watching and net surfing.

The ancient Maya creation epic, the *Popol Vuh* contains a “Rebellion of the Tools” in which people are attacked by their farm implements and held over the fire by their pots and pans. The story can be regarded as an early warning of the threat of machines.² Samuel Butler’s *Erewhon* (1872) pictures a society in which a Luddite revolution had overthrown technology. Parties called the machinists and the anti-machinists fought each other and the latter won. The objection, Butler emphasizes repeatedly, was not so much to the machines as to the rapid speed at which they were evolving.

One person’s technological outrage is another’s miraculous salvation. Stripped of the gauzy romanticism of myth, the pre-industrial village was for most people a place for exhausting and unremitting subsistence labor, harnessing men, women, and children to the mind-numbing tasks of farm and household.

I am fully aware of the great benefits technical progress has brought. It has raised productivity and wages and has not necessarily caused long-term unemployment. New and improved goods and services have replaced older ones and have created new employment opportunities. Half the things we spend our money on were not available in 1870, from air travel to zip fasteners. The reduction in household drudgery greatly benefited working class women. But technology has brought not only

2. Ronald Wright, “All hooked up to monkey brains,” *Times Literary Supplement*, May 16, 2003, p. 19.

higher productivity and incomes, but also better education and the enjoyment of a longer life in good health.

I do not believe that technical progress inevitably leads to more pollution, greater raw material exhaustion, degradation of the environment, or generally gloom and doom. Cassandras like Paul Ehrlich have been shown to be false prophets of doom. But I do have some concerns or worries. They are not those commonly discussed by the prophets of gloom. I shall discuss them below after some introductory remarks.

I shall not be concerned here with the hair-raising stories by journalists that attempt to make our flesh creep. The first Club of Rome report entitled *Limits to Growth* (1972) was shown to be entirely wrong. Neither the fears about predicted excess pollution, nor about raw material exhaustion, nor population growth turned out to be justified.

There may well be dangers from global greenhouse warming (the result of the burning of fossil fuels), though some have predicted a new ice age. There may be an ozone threat resulting from ultraviolet radiation. It causes skin cancer, cataracts, and other health problems. A hole in the ozone layer is caused by chlorofluorocarbons. Deforestation in the Himalayas increases flooding in Bangladesh. Forty to fifty million acres of tropical forest disappear every year. Deforestation proceeds at the rate of the destruction of one football field every second, or one Tennessee every year. Soil erosion and desertification are widespread. Ultraviolet radiation may lower the harvest of soybeans, the world's leading protein crop. The destruction of living species such as whales and dolphins and the over-fishing in the Pacific proceed unchecked. More than half of the now-living species may disappear within our lifetimes; besieged creatures include the beluga whale, the eastern spinner dolphin, and the Steller sea lion. The red squirrel, the snail darter, the northern spotted owl, and the dusky seaside sparrow are all endangered. The search for ivory will make elephants extinct in 20 years at the present rate of killing of 200–300 per day. The international trade ban on rhino horn drove up its price and increased the killing.

Chemical waste seeps downward to poison groundwater and upward to destroy the atmosphere's delicate balance; acid rain ruins forests; incinerator ships burn toxic wastes; DDT, though banned in the USA, is found in the mud of Lake Siskiwit near Lake Superior. There are three forms of air pollution. First, there is acid rain. Twenty million tons of sulfur dioxide are emitted from coal-fired power plants. Second, there is smog caused by barbecues, dry cleaners, petrochemical plants, and motor cars. Third, there are toxic chemicals. Paper that is chlorine bleached contains dioxin and other organochlorines, which are among the most

hazardous substances in the world. Seven hundred million pounds are released each year.

These are much-discussed problems, although I shall not talk about them. Vice President Al Gore compared them to *Kristallnacht*. But economic progress does not have to take the form of pollution and raw material exhaustion. Some people have sought the solution in zero-growth. But this is nonsense. If sustainable growth is interpreted as maintaining all ingredients of growth, including the total stock of exhaustible raw materials, what is sometimes called “hard sustainability,” zero growth is not the solution. Capital would have to be maintained by replacement, which calls for the raw materials. It would merely postpone the day of reckoning. We would have to opt for zero consumption. But zero consumption means the extinction of the human race.

We have four options. First, we can opt for less growth, with fewer goods and services, and therefore fewer “bads.” Second, we can opt for the production of more anti-bads (such as scrubbers) made with the resources reallocated. Whether this is counted as more or less growth depends on our accounting conventions: whether the anti-bads are counted as necessary inputs for goods or as final products. Third, we can choose even more goods and faster growth, to compensate for the growing amount of bads. Finally, we can produce different kinds of goods, with fewer of the characteristics causing bads: for example slower, less polluting cars such as hydrogen fuel cell-driven or bioethanol driven cars. This fourth option would be my preferred one.

It is sometimes forgotten that much technical progress can be and has been entirely benign. There are many entirely innocuous innovations that neither exhaust raw materials nor pollute. They represent a switch from energy-intensive to knowledge-intensive innovations. The first Club of Rome Report was entitled “Limits to Growth”; a later Club of Rome Report was called “No Limits to Learning.”

The most dramatic engine of current economic growth—information technology—is environmentally benign. One could draw up a long list of innovations that have none or few of the detrimental effects usually attributed to technology such as pollution. There is a long list of such benign innovations, among them micro-electro-mechanical systems (MEMS), the technology of the first decade of the 21st century (as it was microprocessors in the 1980s and lasers in the 1990s) which constructs buildings to adjust to earthquakes and biomedical testing; heart bypass surgery; anti-polio vaccine; painless dentistry; valium; prozac; Smith-Kline Beckman’s anti-ulcer drug Tagament; the compact disk; microchips; HYVs of wheat and rice; CAT scan; Magnetic Resonance Imaging (MRI); Ultrasound; Sony’s Walkman; EMI’s body scanner;

Federal Express overnight delivery; the word processor; TV, cable and VCRs; Kurzweil's voice system (in which you dictate to a machine that types); *in vitro* fertilization; the fax machine; high definition TV; the fuel cell; and many others.

Conditions that carried a death sentence only thirty years ago, such as leukemia, are now routinely treatable with a mixture of high-tech drugs and surgery. Cochlear implants now allow the deaf to hear; retinal transplants restore sight to the blind; new anti-inflammatory drugs allow the lame to walk; and sophisticated tests can find a cancer in the body even when only a few cells have gone awry.

Nanotechnology

Some innovations have given rise to controversy. Nanotubes were discovered in 1991. The word nanotechnology was invented in the early 1980s. It comes from nanometer, a billionth of a meter, which is a measure of the size of atoms and molecules. Soot is made of carbon. When carbon is vaporized in an inert gas such as helium and allowed to cool slowly, it forms what is called a buckyball. A new form of carbon was discovered in 1985, called carbon-60 or buckyball (or fullerenes), so named because its structure resembles the geodesic dome invented by Richard Buckminster Fuller. It is incredibly strong, chemically inert, and conductive. Buckytubes, or nanotubes, add millions of extra sets of hexagons of carbon atoms to the middle of the soccer ball molecule. They can function as semiconductors and replace silicon.

In September 2003 there was a conference in Santa Fe, New Mexico, on constructing a 60,000-mile-high elevator to carry cargo into space. It would use nanotubes, which have many times the strength of steel. The science fiction writer Arthur Clark gave the keynote address from Sri Lanka via satellite. His 1978 novel *The Fountains of Paradise* predicted such a space elevator.

Haifa's Technion-Institute of Technology has developed a new pump device which will allow diabetics to inject themselves painlessly and easily with insulin and which will also assist in the injection of additional medications and immunizations. The Nanopump is a tiny silicon array of dozens to hundreds of micro-needles hardly detectable to the human eye, which, when placed on the skin, deliver medication via a pump.

In Michael Crichton's 2002 novel *Prey*, minute "nanobots" (nanorobots) invade and take control of human bodies. Nanotechnology can, according to some, be dangerous to the environment and to human

health. Nanotubes—cylindrical, carbon-based molecules—are nanotechnology’s favorite building block. Bill Joy, the chief scientist at Sun Microsystems (which he has left), published an article in *Wired* in 2000, “Why the Future Doesn’t Need Us,” with the subtitle “Our most powerful 21st century technologies—robotics, genetic engineering, and nanotechnology—are threatening to make humans an endangered species. They are so powerful they can spawn whole new classes of accidents and abuses.” They are something a little like life and a little like a computer program. They create the “gray goo problem.” The gray goo would be a phalanx of nanomachines programmed to create yet more nanomachines until they run out of raw material—and, for raw material, read planet.

The applicable folktale for those who fear the effects of nanotechnology is “The Sorcerer’s Apprentice”: you get the process started, but the self-replicating nanobot escapes, and you cannot turn the thing off.

The message of *Prey* is that biotechnology in the 21st century is as dangerous as nuclear technology was in the 20th. (Its horrors were vividly described in Nevil Shute’s *On the Beach*.) The dangers arise from knowledge, from our inexorably growing understanding of the basic processes of life. The message is that biological knowledge irresponsibly applied means death.

Dr. K. Eric Drexler (*Engines of Creation*) fears that nanotechnology could lead to a future in which self-assembling and self-replicating nanobots are in control, that they could reduce the biosphere to “gray goo.” Bill Joy thinks nanotechnology is so dangerous that it should be abandoned. The small but vocal Canadian Action Group on Erosion, Technology and Concentration has called for a complete moratorium on the use of synthetic nanoparticles. Its concerns were picked up by the Prince of Wales, who is worried by a report of a “gray goo” threat, a nightmare vision in which molecule-sized robots keep replicating themselves until they crowd out all life on the planet.

All these fears may be absurd. Dr. Richard E. Smalley, a passionate advocate of nanotechnology who believes that nanobots are impossible, said to Bill Joy: “I say get up and turn on the lights, Bill, because this nanobot future is just a silly nightmare.”

Nevertheless, nanoparticles may have toxicological risks. If inhaled, they could become lodged in the lungs and move to the blood and the brain.

There are three types of technology. The first is frightening from the start. When the first atom bomb was detonated at Alamogordo, New Mexico, in 1945, everybody knew about its terrible potential for destruction. There is a clear need for government regulation. The sec-

ond, such as information technology (IT), is much more benign. It has its drawbacks such as the digital divide (the great inequality of access to IT), and it presents threats to privacy. A minimum of regulation is indicated. The third, like biotechnology or nanotechnology, is in between. It has promises and dangers. For example, one of the products of nanotechnology could be cheap and efficient photovoltaic materials, which are used to generate electricity from sunlight. There are numerous other potential uses of great promise, including the prolongation of our life span. People are divided about the degree of control needed.

Terror and Error

Once I organized a conference in Sri Lanka for the Society for International Development. I had invited Ivan Illich and Arthur Clark. After Arthur Clark had described in glowing terms his technical utopia in which everything is done by robots, Illich, who then was an ordained priest of the Catholic Church, said, "I would not like to make love to a robot." Since then, I have read a chapter by Howard Rheingold on "virtual reality and teledildonics" predicting that we shall be literally "embracing technology."

Martin Rees, Britain's Astronomer Royal, a professor at Cambridge University, has bet \$1,000 that an instance of bioterror or bioerror will take a million lives before the year 2020. He gives humanity's survival in the 21st century a 50:50 chance. His book is called *Our Final Century* in Britain and *Our Final Hour* in the USA. He wanted a question mark after the title of his book but his publishers had ruled it out to gain a wider audience.³

I do not want to scare anybody. It is important to distinguish between the role of a prophet and that of a forecaster. The prophet Jonah did not know the difference. He predicted the destruction of Nineveh because its people did not behave themselves. They took his warnings seriously and mended their ways. God spared them. Jonah was furious with God. He mistook the function of a prophet for that of a forecaster. He mistook a warning for a prediction. On the other hand, prophets of doom cannot be wrong. If their forecasts turn out to be true, they can always say, "I

3. Martin Rees, *Our Final Hour; A Scientist's Warning: How Terror, Error and Environmental Disaster Threaten Humankind's Future in This Century—on Earth and Beyond* (New York: Basic Books, 2003).

told you so”; if not, they can say that people heeded their warnings and mended their ways.

There are technological accidents (errors, not terror) from the *Titanic* in 1912 to the *Challenger* in 1986 to the shuttle *Columbia* in 2003. The nuclear accident at Three Mile Island in 1979, the fire at the Chernobyl nuclear plant in Ukraine in 1986, the explosion of a chemical factory in Toulouse in 2001, the sunken tanker *Prestige* off Spain in 2002 with the resulting oil spill are examples of errors. In the past disasters inflicted by environmental forces (floods, earthquakes, volcanoes, and hurricanes) were not uncommon. The obverse of technology’s immense prospects is an escalating variety of potential disasters, not just from malevolent intent but also from innocent inadvertence. Now we witness also those inflicted by human agency.

We are often blind to the manifestations of technological discoveries. Ernest Rutherford, the greatest nuclear physicist of his time, dismissed as “moonshine” the practical relevance of nuclear energy. The pioneers of radio regarded wireless transmission as a substitute for the telegraph (used mainly for ship-to-shore communication) rather than as a means for broadcasting entertainment to a wide public. According to Rees, neither the great mathematician John von Neumann nor the IBM founder Thomas J. Watson envisaged the need for more than a few computers in the entire country.

Suffering from Success

The unpredictability of the consequences of our invention can lead to what may be called suffering from success or second-generation problems. These are often wrongly attributed to faulty design or vested interests. But many difficulties are the result of the successful solution of previous problems. Scientific confidence asserts that there is a solution to every problem. Experience teaches us that there is a problem to every solution, and often more than one. Let me give a few examples.

The early emphasis on industrialization in the developing countries showed up agriculture as the slow coach. It was the unexpected success of urban industrial growth that drew the policy-makers’ attention to the rural sector. The Green Revolution, in turn, spawned new difficulties relating to plant diseases, inequality, unemployment, and other second-generation problems. The reduction in mortality rates through cheap and efficient methods of modern death control, itself a welcome phenomenon, without correspondingly cheap and effective methods of birth con-

trol, produced the problems arising from rapid population growth. We witnessed modern death rates, while still being stuck with traditional birth rates. When family planning became successful, it produced the problems of aging societies: the social and psychological problems of a world in which for many people their only kinsmen and kinswomen would be their ancestors. It would be a world with more lonely people, without siblings, uncles, aunts, cousins, children, or grandchildren. Unemployment is partly the result of high productivity growth. Jobless growth (or jobless recovery) is surely to be welcomed, but only if it is combined with more leisure and an equal distribution of job opportunities.

Education raises the aspirations of the educated and leads to movement to the cities. If there are not enough jobs there, we get educated unemployment. Higher education contributes to the brain drain, to the emigration of skilled and professional manpower. Successful urban development has shown up the need to accelerate rural development. Successful outward-looking trade policies were built on the infrastructure and the industrial and technological base of previously inward-looking policies.

Edward Tenner has written about the revenge effects of technology. In his 1996 book *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*, he lists repeating, recomplicating, recongesting, regenerating, and rearranging. Repeating means that when the task is easier, it is demanded more often. Spreadsheets would be an example. Recomplicating occurs when we need a telephone number, an access code, a credit card number, plus voice mail to make a call. Recongesting occurs when an invention like the motor car, intended to get us more quickly from here to there, slows us down. Ivan Illich estimated that the average American spends 1,600 hours driving or working to support transport costs to cover a year total of 6,000 miles, at 4 miles per hour. This is as fast as pedestrians and slower than bicycles. Regenerating occurs when pest control regenerates pests. Heptachlor and Mirex killed predators of fire ants. DDT devastated wasps, the predators of Malaysian caterpillars, which caused devastation. Rearranging I can illustrate from a personal experience. Once I traveled from Massachusetts to North Carolina by rail in the middle of a summer heat wave. The air-conditioning in the train broke down. The windows, secured in order to make the air-conditioning effective, could not be opened and people started to faint.

Disaster control encourages people to occupy unsafe areas. Medicine has helped to cure acute illnesses and injury, but chronic diseases are more common as a result; miracle crops and new animals let loose in strange habitats have run wild; forest fires have been reduced, but the

unburned growth that collects makes fires worse when they do occur. Suppressing forest fires builds up combustible materials for larger conflagrations. Safer cars and sports equipment make people more reckless. The invention of a safer football helmet actually led to more injuries because the new helmets increased the game's aggressive possibilities. The telegraph, it was believed, would create stronger communal bonds; instead, it permitted greater dispersion. The airplane, it was guessed, would make the world smaller, leading to a new era of peace: instead, it became an instrument of war. "The railway was predicted to spark the dictatorship of the proletariat, the telegraph to engender world peace and the television to revolutionize education," writes Charles Kenny in "The Internet and Economic Growth in Less-developed Countries: A Case of Managing Expectations?"⁴

Vacuum cleaners and washing machines were intended to free housewives' time. They did so for working class women but not for middle-class housewives. Previously they had sent their dirty clothes to a laundry; now they had to do their washing at home. The British economist Roy Harrod wrote a pamphlet after World War II entitled "Are these Hardships Necessary?" It was written from the point of view of the middle and upper classes, pointing out the difficulties of getting cheap and efficient home help. He ignored that the reverse side of these hardships was that the working classes had better options for work and higher incomes.

It is noteworthy that the safest part of the New Jersey Turnpike is the crowded metropolitan portion north of New Brunswick. The more rural South Jersey section has twice its accident rate. Congestion compels vigilance.

Rivers get their own back on those who try to tame them. Dams silt up. River embankments encourage faster flows and more violent floods. Irrigation projects are plagued by bilharzia and by salinity (as the water flushes harmful mineral salts to the surface of the soil, where they destroy its fertility). The Principle of Opposite Effect states that most new policies contain something unexpected in them that tends to offset the original intention. Computers are not immune from it.

The Internet also follows the law of unintended consequences. The Net was originally an effort by the Defense Advanced Research Projects Agency (ARPA) at the Pentagon to find a way for users of computers in one place to communicate with computers in other places. (It is the same agency that proposed futures markets in terrorism. Mr. Poindexter of

4. *Oxford Development Studies*, vol. 31, Number 1, March 2003, p. 108.

Watergate fame was the head of it.) The initiative, under President Dwight D. Eisenhower, was one of many by the United States after the Russians put Sputnik into orbit in 1957 and gave rise to the feeling, half true and half panic, that suddenly the Soviet Union was ahead of us in science.⁵

There are technologies that are counterproductive in terms of their own aims. The troubles arise not from side effects, as in the case of nuclear energy, but the very purpose of the invention is negated. It is rather like the prohibition of an obscene book leading to increased sales.

I already mentioned cars that produce congestion and lead to a slow-down in traffic jams. Medicine and hospitals cause iatrogenic illnesses. There was a recent article entitled "How to prevent the hospital from making you sicker." Schools and universities make us stupid; schools produce illiterate students. George Orwell wrote about "the sort of thing that you could learn only at the university." Prisons produce criminals. Sixty-three percent of freed prisoners are jailed within three years for serious crimes; prisons make for more prisoners and spread AIDS; there are more recidivists than cured criminals. Agriculture ruins the soil; irrigation produces salination. Fertilizer and irrigation lead to soil erosion, contaminate the water, and later poison human communities. Sanitation systems pollute. Filters for water purification turn out to be breeding grounds for bacteria and cause cancer. Helmets and other protective gear have made football more dangerous than rugby. Neck and spine injuries have tripled after the debut of football helmets. Antibiotics have removed the horror of some of the 19th century's most feared infections, but have also promoted the spread of even more virulent bacteria. They led to the development of drug-resistant strains. Laparoscopy (where an instrument is inserted into the abdominal wall) can mean post-surgical complications. Weapons that are intended to protect us destroy. Insurance companies that insisted on second opinions before surgery in order to reduce surgeries, found that more surgery was required. Speed limits and compulsory seat belts make drivers more reckless. Devaluation of the exchange rate can worsen the balance of payments. Tourism kills tourism. The barrier coral reefs in the Caribbean have been destroyed as a result of effluent; beaches in Thailand and many other places have become unsafe for bathing; skiing in the Alps has led to the destruction of trees. Voice mail, intended to save time, doubles the time to complete a telephone call. Airplane seats are getting smaller as planes get larger. Sun-

5. See Katie Hafner and Matthew Lyon, *Where Wizards Stay Up; The Origins of the Internet*, Simon & Schuster, 1996.

tan lotions can cause skin cancer. Cushioned running shoes, designed to protect the knees, do so at the expense of increasing stress on the hips.

In 1965 Paul Jennings wrote about Resistentialism (intended as a parody of existentialism). *Les choses sont contre nous*. He argued that “man’s increase in [an] illusionary domination over Things has been matched, *pari passu*, by the increasing hostility (and greater force) of the Things arrayed against him.”

Six Concerns

After this somewhat lengthy introduction let me now turn to my six worries or concerns.

1. The need for a cultural revolution

My first concern is about the impact of information technology on employment and income distribution. Skills and aptitudes are much stressed in the economics literature, but attitudes tend to be neglected. This is probably so because they are not easily measured. Compare eight ditch diggers with a computer operator in a bank. The former can be supervised, so that if anyone slacks, the supervisor admonishes him. Not so with the computer operator. He has to be responsible. If there were a supervisor, he might just as well do the work himself. A different culture is needed.

Advanced technology often means that a smaller number of skilled people supply their services over a wider range, producing a “winner-take-all” effect, where only the best do well, and these lucky few command enormous incomes. We witness this in sports, business, and entertainment. The invention of the phonograph did this for singers, and the invention of the motion picture did it for actors. Proliferating communications and information technology may do the same for many other occupations.

What is the impact on employment and unemployment? Many predict growing unemployment of low-skilled workers. But education, leisure activities, and caring for the needy provide new job opportunities. Some of these can perhaps be replaced by electronic teaching, monitoring, etc. But if attitudes and commitment are more important than skills, a cultural change is needed.

Are those with low skills no longer wanted? It is not at all clear that our society cannot use plenty of health workers, nurses, child care workers, special-education teachers, home health-care aides, manicurists, gar-

deners, plumbers, sweepers, protectors and restorers of the environment, valet parking attendants, janitors, cleaners, waiters, salesmen, physical training instructors, musicians, designers, and other service workers who do not need the high and scarce skills demanded by modern technology and whose services cannot be replaced by either computers or imported low-cost goods from low-income countries (though imported low-cost labor from poor countries should be welcomed). In fact, it is precisely for these jobs which cannot be replaced by computers that the demand is likely to increase in the future. The Bureau of Labor Statistics considers many of these jobs as likely to be the fastest growing over the next decade. Many of these jobs are, however, in the currently despised and neglected public sector and may call for even more despised higher taxation. They are also often ill-paid and not recognized as valuable. We need to change our valuation of such work and should guarantee minimum standards of reward for them.

Kurt Vonnegut, in his novel *Player Piano*, describes a future nightmare society (a dystopia or, as Jeremy Bentham called it, a cacotopia) in which “the divine right of machines,” efficiency and organization, has triumphed, and the large underclass of unemployed are handed out, by a small group of affluent managers, plenty of goodies, but lack what John Rawls regards as “perhaps the most important primary good,” which is self-respect. Unemployment means loss of dignity, which is at least as important as income. Vonnegut’s unemployed eventually revolt.

What deprived the underclass of self-respect was the fact that it was an “equality of opportunity” society. IQ tests decided who became a manager, and it took a manager to lead the revolt. Were you to allocate jobs by a lottery or the accident of birth, there would be no problem with self-respect.

The concern in the advanced countries has become jobless growth or, more recently, jobless recovery. In fact, economic growth, whether measured in terms of overall productivity or productivity in manufacturing, has been considerably slower since 1981 than in the 1960s, when growth was not accompanied by unemployment. Since the growth of productivity has been less than the growth of demand, one would have expected jobs to be created rather than destroyed.

Is it luck in the genetic lottery (nature) or family and other environmental factors (nurture) that determines our success or failure in life? Is inequality of income, wealth, and dignity due to genes? Ronald Dore says we should reward effort, not the genetically “bright and beautiful.”

Some comfort for those concerned about growing inequality can be found in the words of Dr. Tina Cary. She writes: “For those of us who are not Luddites, another question arises: will changes in information

technology necessarily widen the gap in wages between the haves and have-nots? Given that some computer programs available today make medical diagnoses identical to those of qualified physicians, we may find that computers can also lower wages for skilled work, not only for unskilled work. If computers take on such work as accounting and law, the result might be a lessening in the gap in wages! Another aspect of this is that information technology allows jobs to move more freely, so that the programmer or data entry person can live anywhere.”⁶

2. *The electronic nightmare*

We now have at our disposal cheap, super-efficient means of surveillance. Electronically stored information is more difficult to keep under lock and key than paper that is stored. Hence the *means* for more totalitarian control are at hand. There has been a dispute between the FBI and civil liberties groups and it has been proposed to widen the scope of the National Crime Information Center. It could contain inaccurate or subjective data, raise security problems, and lead to false leads. It violates the right to privacy in the interest of greater security.

Information is power. Tiny microphones are now capable of recording whispered conversations from across the street. Conversations can even be monitored from the normally imperceptible vibrations of window glass. Cameras the size of large wasps can be flown into a room and record everything. Fortunately, the same technology that is destroying privacy also makes it easier to discover terrorists, trap stalkers, detect fraud, prosecute criminals, and hold the government to account.

There are bound to be trade-offs between privacy on the one hand and security, efficiency, convenience, and liberty on the other. “Each benefit—more security against terrorists or criminals, better government services, higher productivity at work, better medical care, a wider selection of products, more convenience, more entertainment—will seem worth the surrender of a bit more personal information, or a marginal increase in monitoring. Yet the cumulative effect of these bargains, each seemingly attractive on its own, will be the relentless destruction of privacy.”⁷ Both the government and the private sector are hungry for more information.

David Brin, the American physicist and science fiction writer, proposes full transparency and the complete abolition of privacy. In his 1998

6. Dr. Tina Cary, President, American Society of Photogrammetry and Remote Sensing, Bethesda, Maryland, USA.

7. *The Economist*, January 25, 2003.

book *The Transparent Society* he says, “Light is going to shine into nearly every corner of our lives.” Attempts to protect privacy usually benefit only the rich and powerful or the government. Let everyone have access to databases, peer through CCTV (closed circuit television) cameras, and listen in on conversations. “Mutually assured surveillance,” Brin argues, would see to it that most people would not abuse their access to information. He argues for complete openness, for “reciprocal transparency.” If police cameras watch us, we should be able to watch them. The biggest threat to freedom is that surveillance technology will be used by too few, not by too many. Citizens should have the power to watch the watchers.

His position is supported by economists who attribute many inefficiencies to asymmetric information flows. If the flow could be symmetric, a general improvement in which everyone gains would follow. Examples of the inefficiencies that arise from asymmetric information are wars that are caused by one side guessing wrong about the other’s power or determination; going to trial; the collapse of mutually beneficial negotiations when one party is afraid that someone else knows something it does not, and if they agree to a proposal it must be because it favors them in some way we have not realized.

But most people are unwilling to open up completely. In the film *The Truman Show* the hero abandons the only life he knows to evade the pitiless gaze of the cameras, having discovered that he has been the subject of a reality-TV show since birth.

More recently, however, as a result of the spread of mobile telephones, digital cameras, and the Internet, surveillance technology has become widely available. Bruce Schneider, a security expert, has written that “surveillance abilities that used to be limited to governments are now, or soon will be, in the hands of everyone.”⁸ There are, however, drawbacks to the wide spread of surveillance. It has led to the invasion of hidden cameras in bedrooms, showers, lavatories, and locker rooms. Industrial espionage is another danger. Surveillance technology can also be used for identity theft. As *The Economist* concludes its discussion, “Increasingly, it is not just Big Brother who is watching—but lots of little brothers, too.”⁹

8. Quoted in *The Economist Technology Quarterly*, December 4, 2004, p. 31.

9. *Ibid.*, p. 34.

3. *The Frankenstein nightmare*

Mary Shelley's *Frankenstein* (1818) is perhaps the most influential piece of science fiction ever written. People then thought that God created life. Shelley's doctor apes the action of divine creation and fails. The book's subtitle is "The Modern Prometheus." Prometheus stole fire from heaven and gave it to mankind. He was punished because he gave mankind power and with it choice. Biotechnology will have the power to manipulate human life.¹⁰

Should biotechnologists be allowed to mess around with the genetic structure of human beings? Should pharmacologists be free to change the psychological make-up? There can be no objection if it helps in eliminating genetic diseases. But how are human rights and human integrity affected by the ability to shape the structure of humans? The dangers from nuclear energy are obvious. They call for regulation. But not so those from biotechnology. The promise of a longer life, of freedom from depression and a guarantee of happiness (Prozac is like soma in Aldous Huxley's *Brave New World*) and social control (Ritalin is used for hyperactive children) are temptations. But the costs are less obvious. Are these psychotropic drugs forerunners of pharmacologically altered states of mind?

We are nearer to pharmacological changes than to genetic ones. In 1944 Oswald Avery, Colin MacLeod and Maclyn McCarthy of Rockefeller University determined that DNA (deoxyribose nucleic acid) carried the hereditary blueprint. In 1953 Crick and Watson discovered the double helix. In the 1960s tadpoles were cloned in Britain. In 1970 scientists developed proteins that cut DNA in precise locations. In 1973 Stanley Cohen and Herbert Boyer of Stanford University and the University of California at San Francisco snipped a piece of genetic code out of one bacterium and inserted it into another. The result was a rust-colored pig in Beltsville, Maryland, with the genes of a cow.

In 1981 mice were the first transgenic animals. In 1986 it was decided that not only microbes but also higher life forms can be patented. In 1988 Harvard patented a mouse. In 1997 Ian Wilmut cloned a sheep called Dolly. (Dolly died in March 2003.) In 2000 a pig was cloned with organ harvesting as the goal. In 2002 Clonaid, a company founded by the Raëlian religious movement, claimed the first cloned baby, Eve. The cult is named after its founder and spiritual leader, Raël, a French journalist formerly known as Claude Vorilhon. Dr. Brigitte Bosselier is the

10. See *The Economist*, "Survey of Biotechnology," March 29, 2003.

company's chief executive. In 2003 a mule was cloned in Idaho. In February 2004 South Korean scientists created human embryos through cloning and extracted embryonic stem cells that hold great promise for medical research. The work was led by Dr. Woo Suk Hwang and Dr. Shin Yong Moon of Seoul National University. The purpose, according to the scientists, is not to clone human beings but to advance understanding of the causes and treatment of disease. In 2004 Dr. Gerald Schatten of the University of Pittsburgh School of Medicine said he will be able to clone a monkey very soon.

In cloning, or somatic cell nuclear transfer (SCNT) as cloning is called, a cell from an adult animal is placed inside an egg that has had its own genetic material removed. The DNA of the donor cell can then take control, eventually forming an embryo. Fears are expressed that it would lead to birth defects or alternatively to an era of "designer babies." Some believe that children should not be designed in advance, that newborns should be truly new, without the burden of genetic identity already lived; that a society in which cloning is easy (requiring few cells from anywhere in the body) means anyone could be cloned without knowledge or consent; and that replacing lost ones with "copies" is an insult to the ones lost, since it denies the uniqueness and sacredness of their existence.¹¹ Cloning carries high risks of bodily harm to the cloned child. It threatens the dignity of human procreation, giving one generation unprecedented genetic control over the next. It is the first step toward a eugenic world in which children become objects of manipulation and products of will.

The opposition to cloning relies, however, on the ambiguous distinction between natural and unnatural. Is cloning different from the introduction of antibodies, vaccination, efficient agriculture, or the abolition of slavery?

What if cloners present a healthy child? The *Star Wars* films featured an army of clones derived from the genes of an aggressive bounty hunter, modified to ensure willingness to follow military orders. The image of a horde of unthinking, cloned attackers is a classic science-fiction nightmare. But producing such an army with today's techniques would require a huge number of women to supply the eggs and bear the fetal clones to term, a problem that is often glossed over in horror stories.

Cloning, practiced widely, might eliminate the need for men (women could bear children asexually), or it might lead in cultures that revere

11. See Eric Cohen and William Kristol, "No, It's a Moral Monstrosity," *Wall Street Journal*, December 5, 2001.

males to an excess of men; and it might reduce the genetic diversity that comes from mingling genes in sexual reproduction.

Critics fear that cloning could usher in a new eugenics. The Council of Europe and the United Nations have declared human reproductive cloning a violation of human rights. The President's Council on Bioethics (in 2002) worried that cloning to produce children could disrupt the normal relationship between generations and within families, could turn children into manufactured products rather than independent beings and could put undue pressure on a cloned child living in the shadow of a genetically identical adult.¹² But like the war on drugs, bans on supply will not cut off the demand.

Problems arise from the vehicles to get foreign genes into the body. The most popular vehicle is the retrovirus that can stitch genes into human DNA. Scientists "disarm" the retrovirus but something could still go wrong. The possibility exists of a pandemic holocaust in which the disarmed viruses could turn into active ones and damage all humankind. Pharmaceutical regulation is driven by horror stories like the sulfanilamide elixir and thalidomide. The regulation of cloning may have to await the birth of a horribly deformed baby.

Many embrace the power to clone under the banner of human freedom. Freedom of parents to choose the kind of children they have, freedom of scientists to pursue research, and freedom of entrepreneurs to make use of technology to create wealth. Francis Fukuyama in his book *Our Posthuman Future* argues that this posthuman world could be one that is far more hierarchical and competitive than the current one and full of social conflict. Human genes will have been mixed with those of many other species and our shared humanity would be lost. People would live to be 200 years old. Or alternatively the world could be one of soft tyranny like that envisaged in Huxley's *Brave New World*.

"'Geneism' could eclipse racism as the most destructive force on the planet," says George Annas, professor of health law at Boston University. Once some of us are enhanced genetically, "won't we see other people as subhuman, and enslave or slaughter them?"¹³ Only the rich can afford genetic modification. Humanity would be spilt into hereditary castes. The success of the successful would seem "deserved."

McKibben regards the genetically engineered genius as a robot. It is an uncomfortable thought but one may ask: why prefer the unintentionally

12. Philip Boffey, "Fearing the Worst Should Anyone Produce a Cloned Baby," *New York Times*, January 5, 2003.

13. Bill McKibben, *Enough: Staying Human in an Engineered Age* (Times Books, 2003), p. 37.

mixed genes to planned ones? We believe that a person who has been programmed to make certain choices is not truly free. But our own haphazard genetic endowment, upbringing, and education determine us in exactly the same way. Why are planned reactions worse than those caused by chance?

Will the posthuman world be free, equal, prosperous, caring, compassionate, with better health care, longer lives, and more intelligence than today's? Or will it be more hierarchical and competitive, full of social conflict? Or will it resemble Huxley's *Brave New World*, a soft tyranny in which everyone is healthy and happy but has forgotten the meaning of hope, fear, or struggle.¹⁴

There is the possibility that biotechnology will permit the emergence of new genetically elite classes. But the opposite is also possible. In democratic societies people will not tolerate the stratification. It may lead to fights. The demand will be for raising the bottom genetically. It would be the opposite of the old eugenics that prevented the subnormal from having children. Here the state would enhance the abilities of their children. We can envisage a state of affairs with "genetic alteration or gene splicing, whereby parents who are five feet tall and bald can give birth to a six-footer with long blond hair."¹⁵ Biogenetic interventions will blur the borderline between the made and the spontaneous and thus affect the way we understand ourselves. "For an adolescent to learn that his 'spontaneous' (say, aggressive or peaceful) disposition is the result of a deliberate external intervention into his genetic code will undermine the heart of his identity, putting paid to the notion that we develop our moral being through *Bildung*, the painful struggle to educate our natural dispositions. Such interventions will give rise to asymmetrical relations between those who are 'spontaneously' human and those whose characters have been manipulated: some individuals will be the privileged 'creators' of others."¹⁶ It is possible to rear genetically improved children who will show horrible effects only after 20 years.

C. S. Lewis in *The Abolition of Man* was considering what "Man's power over Nature" must always and essentially be: "Each new power won by man is a power *over* man as well." "The final stage is come when Man by eugenics, by pre-natal conditioning, and by an education and

14. Francis Fukuyama, *Our Posthuman Future. Consequences of the Biotechnology Revolution* (New York: Farrar, Straus and Giroux, 2002.)

15. Margaret Atwood, "Arguing Against Ice Cream," review of *Enough: Staying Human in an Engineered Age* by Bill McKibben, *The New York Review of Books*, volume L, Number 10, June 12, 2003, pp. 6–10.

16. Slavoj Žižek, "Bring Me My Philips Mental Jacket," *London Review of Books*, May 22, 2003, p. 3.

propaganda based on a perfect applied psychology, has obtained full control over himself...The battle will indeed be won. But who, precisely, will have won it? For the power of Man to make himself what he pleases means...the power of some men to make other men what *they* please.”¹⁷

Stem cell research to treat diseases like Parkinson’s, Alzheimer’s, and diabetes is generally approved. Excess embryos from *in vitro* fertilization are used for this research. Some would argue that the creation of embryos by cloning is similar.

Perhaps more worrisome than genetics is neuroscience and operating on the brain. In an attempt to treat depression, neuroscientists once carried out a simple experiment. Using electrodes, they stimulated the brains of women in ways that caused pleasurable feelings. The subjects came to no harm—indeed their symptoms seemed to evaporate, at least temporarily—but they quickly fell in love with their experimenters. This may be a greater threat to human dignity and human autonomy than cloning.¹⁸

These methods are also capable of “enhancing” human beings. Some worry that society will be turned into a homogeneous mass. Others are worried by the opposite: that society will be divided into the privileged and the unenhanced, reminiscent of Huxley’s alphas, betas, gammas, and epsilons. Drugs to combat shyness, forgetfulness, sleepiness, and stress are now close to clinical trials.

How is free will affected by these possibilities? The same question arises that was raised earlier: what is the difference between random, unintentional conditioning and intentional conditioning? We tend to condemn the second, but praise the first. Hard work and natural talent are considered “part of me,” while using a drug is “artificial” enhancement because it is a form of external manipulation.¹⁹

Social control can be used not only by the state but also by parents, teachers, school systems and others with vested interests in how people behave. The fear has been expressed that biotechnology will cause us to lose our humanity. The picture has been painted of brainless hominoids whose organs will be harvested as spare parts. Using stem cells to grow a replacement organ is already an acceptable alternative to transplant surgery.

17. C. S. Lewis, *The Abolition of Man* (Oxford University Press London: Humphrey Milford, 1944), Chapter 3.

18. *The Economist*, March 25, 2002, p. 14.

19. Zizek, *op. cit.*, p. 5.

In May 2002 scientists at New York University attached a computer chip directly to a rat's brain, making it possible to steer the rat by means of a mechanism similar to that in a remote-controlled toy car.

In 2004 the electronics giant Philips planned to market a phone-cum-CD-player woven into the material of a jacket. The Philips jacket represents a quasi-organic prosthesis, less an external apparatus with which we interact than part of our self-experience as a living organism.

There are some who predict the extension of life without maintaining the quality of life. There will be more and more dependants at a growing cost to society. Aubrey de Grey of Cambridge University predicts life expectancy in 2100 will be five thousand years. None of us will be around to check whether he is right.²⁰ Odysseus was offered immortality by the goddess Calypso, but turned her down to grow old and die with his wife Penelope.

Ability to predict the sex of a fetus and abort girls has led to unbalanced sex ratios and a surplus of men in societies such as India. Amniocentesis, cheap sonograms, and easy access to abortion have led to unbalanced sex ratios in parts of Asia. Amartya Sen estimated that 100,000 women are missing in Asia. An excess of men leads to crime and aggression.

The threat of atomic apocalypse has been replaced by the fear of an environmental catastrophe, unstoppable human-engineered viruses, rampaging mutant genes, and neurologically altered posthuman beings.

4. The terrorist's atom bomb in the suitcase

Technical developments have greatly amplified the damage terrorists can do. Nuclear power plants can be sabotaged; there is the danger of terrorists' attack and of the proliferation of nuclear weapon capability. The prophets of the benefits of nuclear power overlooked the problems of the disposal of nuclear waste.

In order to prevent these hazards, is our freedom threatened? When I served on the British Royal Commission on the Environment in the early 1970s, we were worried that in order to prevent attacks on nuclear power stations, our freedom and civil rights and liberties might be threatened. We are seeing this now. We must ask, how much should a democratic society risk in order to preserve the freedom of unharassed dissent? I think it was Walter Laqueur in his book *The New Terrorism* who predicted some time ago that Washington's global interventionism has magnified the chances that a US city will become the target of mega-

20. Nicholas D. Kristof, op. ed., *The New York Times*, August 12, 2003.

terrorism. The pervading fear of an attack, even without its taking place, multiplies greatly the damage done by an actual attack.

The threat comes not from nations but from sub-national groups. Technical developments amplify the damage terrorists can do. To make an atom bomb, a terrorist or would-be proliferator would need to get hold of only 5 kg of weapon-grade plutonium or 15 kg of weapon-grade uranium, less than you would need to fill a fruit bowl. At present the world probably contains about 250 metric tons of this sort of plutonium and 1,500 metric tons of uranium. To lose one bomb's worth from this stock is the equivalent of losing a single word from one of three copies of *The Economist*.²¹ General Alexander Lebed said that the Soviet Union, before its collapse, had produced suitcase-sized nuclear weapons, easily transported anywhere. "Loose nukes" can easily find their way into the hands of Al Qaeda or any other terrorist group.

A nuclear explosion at the World Trade Center, involving two grapefruit-sized lumps of enriched uranium, would have devastated three square miles of southern Manhattan, including the whole of Wall Street. It would kill hundreds of thousands if it went off during working hours. Martin Rees, Britain's Astronomer Royal, writes that the collapse of the Soviet Union has left the world awash in enough raw materials—enriched uranium and plutonium—for some 70,000 bombs.²²

If the terrorists (or freedom fighters, as they consider themselves) are not afraid to die, indeed court death, for their cause and the greater glory of Allah, what use is the threat of counterattacks? It will just mean that more of them are martyred and go to Allah's heaven where 30 black-eyed virgins are waiting for each of them. We shall have to remove the cause of their hostility if we want lasting peace. But this is a very slow process if we don't want to give up our own principles.

Susan Sontag wrote concerning the 9/11 perpetrators, "In the matter of courage (a morally neutral virtue): whatever may be said of the perpetrators of Tuesday's slaughter, they were not cowards." There has been a lot of public criticism of her. She has been called "morally obtuse" and a prime example of the hate-American crowd. These criticisms are unjustified. I agree with her, except that there are no morally neutral virtues. Courage is an instrumental virtue and is therefore judged partly by the ends it serves. A virtue is by definition good, not neutral, and courage is in itself good, though, if combined with other qualities and if serving evil ends, it can be bad or lead to deplorable results.

21. *The Economist*, June 5, 1993, p. 15.

22. Rees, op. cit.

Chemical and biological weapons such as anthrax or smallpox threaten millions, not hundreds or thousands. Knowledge about them and the techniques of their use are dispersed among hospital laboratories, agricultural research institutes, and peaceful factories everywhere.

5. *Cyber-terror and cyber-error*

There was at first considerable suspicion that the largest blackout in US history on August 14–15, 2003, was caused by terrorists or sabotage. It would have been very easy. Cell phones, municipal water systems, and the Internet operate on similar principles.

Imagine terrorists breaking into computers that control the water supply of a large American city, open and close valves to contaminate the water with untreated sewage or toxic chemicals, and then release it in a devastating flood. As the emergency services struggle to respond, the terrorists strike again, shutting down the telephone network and electrical power grid with just a few mouse clicks. Businesses are paralyzed, hospitals are overwhelmed, and roads are gridlocked as people try to flee.

Lamar Smith, a Texas congressman, told a judiciary committee in February 2002: “A mouse can be just as dangerous as a bullet or a bomb.” But control systems are usually kept entirely separate from other systems. A simulation carried out in August 2002 by the United States Naval War College in conjunction with Garter, a consultancy firm, concluded that an “electronic Pearl Harbor” attack on America’s critical infrastructure could indeed cause serious disruption, but would first need five years of preparation and \$200 million of funding.²³

6. *Our “final” experiment?*

Physicists attempt to accelerate atoms close to the speed of light and then crash them together. Some physicists raise the possibility that these experiments could start a chain reaction that might destroy the Earth or even, by tearing the fabric of space, the universe. Imagine a very tiny risk of an utterly calamitous outcome—a low-probability, high-cost catastrophe. An asteroid colliding with the earth could cause the extinction of mankind. Although such events deserve the same attention as higher-probability, lower-cost disasters, they do not get it. The reasons are partly that politicians have short time horizons and partly that any one country hopes to take a free ride on others taking action in disasters that affect several countries.

23. *The Economist*, October 26, 2002.

Society has become more dependent on big, complicated entities like the grid, the Web, and the air-traffic control system. Professor Charles Perrow, author of the 1984 book *Normal Accidents: Living with High-Risk Technologies*, predicts that the next accident will be in air-traffic control. The trend has been to hire managers who have training in soft skills like human relations but who lack technical understanding that is vital in running complex systems. These are regarded as dull chores.

Three different disaster scenarios from collision with a high concentration of energy can be envisaged.

1. A black hole may be created that sucks in everything around it.
2. The quarks (each proton and neutron consists of three quarks) reassemble themselves into a compressed object called a strangelet. By contagion, it transforms everything it encounters into a strange new form of matter. (Kurt Vonnegut's novel *Cat's Cradle* envisaged such a form in "ice-nine.") A strangelet disaster could transform the entire planet Earth into an inert, hyperdense sphere about one hundred meters across.
3. A catastrophe occurs that engulfs space itself. When particles crash together, this could trigger a "phase transition" that would rip the fabric of space itself, affecting the entire galaxy and beyond.

Arthur Koestler wrote in his 1949 *Insight and Outlook* that man had now acquired the means to destroy the planet. Evolution had granted him a technological capacity far in excess of his spiritual capabilities. "Thus within the foreseeable future, man will either destroy himself or take off for the stars."

Accountability of Representatives

As technology becomes more arcane and specialized, political decisions require training and understanding confined to very small circles. Questions such as "what is the correct missile system?" or "how much should the exchange rate be varied (or left to market forces)?" are highly technical. Must then technocracy replace democracy? If so, how can technocrats be made socially sensitive and politically accountable? Or are we to be delivered into the band of what C. Wright Mills called "technological crackpots?"

Should Prometheus be Restrained?

The motto of our times is “If it can be done, we should do it.” Yet we may ask ourselves whether we should try to halt or slow down or police technical change to avoid some of its dangers. If a country is dependent on international trade, it is necessary for it to be at the frontiers of technical knowledge. Defense is another imperative. But assume these two necessities are removed. Assume that we have a system of global control of arms. Would we then choose to halt or slow down the production of technical knowledge? Or is the Promethean instinct too strong? We apply cost-benefit analysis in other fields; why not here? Our progress can have a harmful impact on the exports of the developing countries. We could apply the Promethean instinct to beauty and artistic creation. Yet, there is much less money spent on the theater, on architecture, and on painting.

There are two questions: can technological progress be controlled? And should it be controlled? In spite of opinions to the contrary, it surely can. The current mood is against government control, but the speed and scope of technological development can surely be controlled. Even in the present mood, nuclear weapons and nuclear power, ballistic missiles, biological and chemical warfare agents, replacement of human body parts, and neuropharmacological drugs cannot be freely developed or traded internationally. They may call for international controls.

The US Office of Technology Assessment (OTA), which rendered useful services, was closed down in 1995. France and Holland have imitated such an agency, and Britain has rejected it.

There are three principal criteria for allocating resources to technological research: collective greed (trade), collective fear (arms), and collective pride (Nobel Prizes); but there are also more civilized criteria such as to relieve suffering, to maintain ecological balance, and to conduct basic research across the spectrum of human knowledge.

Note on the “Precautionary Principle”

There are two points of view when we face risk and uncertainties in our research. One is based on the precautionary principle. The precautionary principle says that when there is any risk of a major disaster, no action should be permitted that increases the risk. If, as so often happens, an

action promises to bring substantial benefits together with some risk of a major disaster, no balancing of benefits against risks is to be allowed. Any action carrying a risk of a major disaster must be prohibited, regardless of the costs of prohibition.

The opposing point of view holds that risks are unavoidable, that no possible course of action or inaction will eliminate risks, and that a prudent course of action must be based on a balancing of risks against benefits and costs. In particular, when any prohibition of dangerous science and technology is contemplated, one of the costs that must be considered is the cost to human freedom. Freeman Dyson calls the first point of view precautionary, the second libertarian.

Wilfred Beckerman summarizes the precautionary principle in the following way: "It is asserted that faced with a possibility, however remote, of some catastrophic development, prudent policy demands that whatever action is required to prevent it be taken." This implies that the required action has to be taken, however high the costs. He uses the following illustration. When we buy a padlock to prevent our bicycle from being stolen, we compare the value of the bicycle with the chances of theft and the cost of the padlock. If the bicycle is worthless and the cost of the padlock is very high, we don't buy it.

To apply the precautionary principle means that irrespective of the chances of future loss, the scale of the loss, and the costs of preventing it, one must incur these costs. We have the choice between (1) accepting some remote and unquantifiable possibility of severe effects and (2) certain catastrophe if draconian policies are adopted to avoid it. The economic costs of avoiding all conceivable possibilities of a catastrophe could be astronomic. Pascal's wager is an extreme version of the precautionary principle.



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