TECHNOLOGY AND VALUES: NEW ETHICAL ISSUES RAISED BY TECHNOLOGICAL PROGRESS

by Harvey Brooks

While a discussion of the origin and evolution of social and ethical values is beyond the scope of this paper, it is impossible to deal with the impact of technology on values without some assumptions as to the social function of values. In this regard I tend to adopt a rather pragmatic approach. I believe that the formation of value systems is an adaptation which enhances the survival of the social entities in which the individual claims membership. In this respect, values are the product of a cultural evolution, and result from natural selection through social and economic processes in much the way that the biological characteristics of species result from natural selection acting on variations in genetic constitution. What makes cultural evolution more complicated is that it is partly conscious and partly unconscious. Values are transmitted culturally, especially in the process of socialization of children, and this process is analogous to genetic inheritance. Different sets of values have different survival value both for the individual in his social milieu and for the social entity of which he is a part. Values change both because the physical environment of the society changes and because of social units in which individuals have partial membership change. The first of these processes of change has an analog in biological evolution, but the second is more unique to cultural evolution. A biological individual belongs to only one species, but a cultural individual belongs to many different social entities simultaneously, and this plurality of membership, plus the size and inclusiveness of the membership group, is characteristic of advanced societies.

For primitive man, the survival of the extended family, or, at most, of the tribe based on kinship, was the determinant of all values, and it was the relation of man to his natural surroundings

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and occasionally his conflicts with other similar groups which governed the values which would emerge with highest priority. Even at this stage, technology played a role in the evolution of values because of its influence on these relations of primitive man.

For modern man, technology plays much more of a role because of its capacity to alter the natural environment and because of the relationships of interdependence which it creates among the various systems of membership to which the individual belongs. According to Mesthene,[1] technology creates values both by creating previously unattainable options and by changing the relative costs of existing options. Social and group relations which seemed a part of the natural order a generation ago now seem within the capacity of man to change by the application of technology, for example, the elimination of poverty. Thus, a choice has been created which places the issue of poverty into the ethical domain.

The concept of the survival and welfare of the social entity is a subtle one, and becomes more complex as intersecting membership groups proliferate in modern industrial societies. The survival of the group may require the self-sacrifice of the individual, and many values relate to the choices which have to be made between the welfare of the more inclusive groups at the expense of the more restricted ones—the welfare of the nation versus that of the family or the welfare of all humanity versus the welfare of the nation-state. Such choices are frequently implicit rather than explicit, dictated by tradition and habit rather than by rational choice. Indeed this is essential, for our span of attention is too limited for us to afford to open up every issue anew every time it is presented to us as a choice. Similarly, the welfare or survival of the group is also an implicit rather than an explicitly articulated notion. As technology increases interdependence, the welfare of the group against its rivals becomes less important than the common welfare of the larger system which includes the rival groups, but it takes a long time for values to adjust to this more inclusive membership and achieve a new balance of choices.

The situation is further complicated by time horizons. To what extent should we choose to sacrifice comfort or well-being today for the very survival or well-being of our posterity? How is the future to be valued in relation to the present? The issue here is not simple to resolve, primarily because we cannot know enough about the future. As I will discuss in more detail below, technology puts us in a position to do many things that effectively commit future generations to courses of action or conditions of existence which they might not like, and which might even be catastrophic if we make some wrong guesses. This has also happened in the past, as for example in the irreversible ruin of agricultural land in the Mediterranean Basin, but it has never been possible on a worldwide basis before.

OVERLINKING OF VALUES TO TECHNOLOGY

Although it is obvious that technological progress has a profound effect on social values, there has been an exaggerated tendency recently to ascribe all such changes to technology. Because technological change has been rapid and highly visible during the past thirty years and changes in social values very rapid during the last decade, it has been tempting to assume a direct causal connection between the two. In an indirect sense this is probably valid. Increasing affluence and interdependence among industrialized nations would have been impossible without technological progress, and these factors have certainly been important in many of our value changes. On the other hand, I share the view of Mesthene[2] that the actual consequences of technological change represent only a small subset of those which were theoretically possible. Technology is not a *deus ex machina* which develops according to its own inherent logic, independent of the values and preferences of the surrounding society. There is such a logic, and each new piece of technology is in a real sense genetically related to what has gone before. But cultural and economic selection strongly intervene to determine which small subset out of the many technical possibilities is actually developed and applied on a socially significant scale. Here again there is an analogy with biological evolution. The biological characteristics represented in each generation are inherent in those of the previous one, but what actually survives is governed by selection which has more to do with the environment. Similarly the totality of technical characteristics of each new generation of technology is determined by the technical logic of its genesis but only what is socially selected survives to govern the technical possibilities of the next generation of technology. Due to the imperfections of human motivation, comprehension, and wisdom, the technology that is socially selected has a large measure of randomness and accident, but it is still under human control.

As one surveys recent history, especially that of the last seven or eight years, one can make a fairly convincing case that our values have been changing much faster than our technology, and that, in fact, much of the current malaise is due to a lag of science and technology as well as institutions behind the expectations which have been generated by the social changes of the last twenty years or so. These expectations, in turn, were the result of the wholly different formative experiences of the present generation now coming to adulthood, as compared with my own generation. To the extent that these formative experiences were determined by television, suburban affluence, and extraordinary expansion of access to education, they may be said to stem from technological change. But the expectations themselves have far outrun the capacity of technology and sociopolitical management to deliver, at least on the time scale of the generational change.

One can, of course, argue endlessly as to whether the quality of life has deteriorated in the last twenty-five years. It is the fashion today to say there is nothing good about American society. But my own belief is that our perception of deterioration is due far more to the escalation of our expectations than to the deterioration of the objective situation of the majority of the American population. If one looks at society as a servomechanism driven by the error signals of the discrepancy between expectation and reality, then indeed the error signals today are of much larger amplitude than they were twenty years ago. From one point of view, that may be all that matters.

I would now like to turn to examples of ways in which technological progress has posed new ethical issues or value choices to our society. These are mostly examples not of where technology has changed our values, but of where, by generating new choices, it has in effect created the possibility of value choices where none existed before. For, as I have already implied, values exist only when there are real choices. Though we may deplore what is inevitable, it is not really good or bad in an ethical sense because we do not have the power to do anything about it.

The Capacity to Save Human Lives

It is really only in the last quarter-century that man has developed the capacity to save human lives on a truly monumental scale. World War II was the first war in history in which death from disease did not exceed death on the battlefield, and the most important single factor in this was the widespread application of DDT, invented at the beginning of the war. It is estimated that upward of half a billion people are alive today who would not be in existence but for the application of DDT in the eradication of malaria, typhus, and other epidemic scourges of the low-income parts of the world. When

American private foundations undertook to launch these public health campaigns in the rest of the world, we thought of this as simply an extension of the ethic underlying the Hippocratic Oath, the obligation to relieve suffering and save a life if it were in our power to do so. Yet, in the application of one of our most deeply cherished humanitarian values, we may have saved one generation to bring greater suffering, poverty, and hopelessness on the next. Should we have witheld public health measures, and particularly the application of DDT, until we could also offer acceptable methods of fertility control?

Massive unemployment of young adults in the underdeveloped world, an unemployment which offers nothing but a lifetime of uselessness and is social dynamite threatening the whole process of economic and political development, is directly traceable to the survival to adulthood of the generation saved by Western humanitarianism.

Even today, with all that we know of the consequences of our humanitarian efforts, it is doubtful whether any ethical man would advocate witholding this power to save lives.

Another example of the paradox created by the values represented by the Hippocratic Oath is the availability of heroic measures to keep the hopelessly ill alive, especially in the case of the elderly. This poses a serious ethical problem in the allocation of medical resources, in respect to care, and in respect to research effort. If resources were not finite, there would be no problem, but, even when society pays the costs, the maintenance of one very ill person may deny medical resources to many less acutely ill who are poor and do not have adequate access either to care or to preventive medicine. A special case of this same problem is, of course, the use of procedures such as kidney dialysis, where it is necessary to choose who shall be permitted to die, and whose life shall be maintained.

One could extrapolate to a day, not too far off, where life-saving procedures could consume the entire GNP if we were prepared to carry the logic of the Hippocratic Oath to its possible application. Yet how shall we choose? When is enough enough? The point is that until very recently we did not have to worry about such choices. The best we could do was so little that we could do it for almost all who needed it, and the resources required were too small to compete seriously with other needs. Our technological capacity to save life or to prolong it has outrun our economic capacity or, at least, willingness to allocate the resources for all who could benefit.

In a larger sense, this may be only a transient situation. The heroic procedures I have referred to are necessary only in cases where palliative rather than curative or preventive measures are available. The classic example of the transition is polio. Until a vaccine was found, the social cost of therapy following polio was enormous, but this virtually disappeared when polio could be prevented. If we knew how to prevent or delay deterioration of the cardiovascular system, work on heart transplanation or artificial hearts would be obselete, and similarly for other organs. But the availability of a "true" solution to the problem some time in the uncertain future does not absolve us from the necessity of difficult choices today. Here is where the logic of technological progress does not coincide with the ethical logic of human needs.

Advances in genetics have made it possible to detect many chromosomal abnormalities in embryo, and to abort the fetus if it is believed that its birth is likely to result in a person who is a burden to the family and to society—an individual not a truly human being, perhaps. While the ethical acceptability of such procedures is still a matter of passionate debate, my guess is that the social benefits are such that there will be an evolution of values which make this elementary form of genetic engineering increasingly acceptable. Yet in an ethical sense how do we distinguish between preventing a birth that would only bring suffering, and, in a poor country, permitting the death of an infant whom we know would grow up to be a marginal man, a burden on his society with no social function?

As techniques improve, it is likely that we will be able to detect more and more genetic characteristics in utero. For example, it may become possible to detect potential allergies or, perhaps, behavioral defects which would render the individual a sufficient social liability to justify abortion. Who is to choose, and where is the trade-off between the sanctity of a human life and the potential liability to family or society? And, above all, who is there whom society would or should trust to take on the awesome responsibility of deciding?

One issue that is involved in the above example is the degree of confidence that can be placed in predictions of what the individual will be like. A high degree of certainty of a quite catastrophic defect would be necessary today, but this is likely to change with time. It would seem also that, in arriving at the balance, the measure in which the "life" destroyed approximates the fully developed human is an important consideration. However, given this and the confidence level of predictions as criteria, could such an argument ever be used to justify infanticide? Presumably, the confidence with which the outcome can be predicted may in many instances increase with the degree of development of the fetus, so that the "optimum" trade-off between the certainty of disaster and the value of life might logically fall after the moment of birth! Under these circumstances, by what rational balancing of values could we rule out the elimination of the defective infant when we are prepared to eliminate the defective fetus? If my hypothesis about the way values develop in a society is correct, it does not seem to me impossible that values may eventually evolve which would condone euthanasia of grossly defective infants, repugnant as that may seem to us now. The problem is, of course, that technology will continue to erode the sharp distinction that defines the moment when a life becomes human.

THE CREATION OF PROBLEMS FOR POSTERITY

Recently, A. Weinberg[3] has pointed out that new technologies require increasingly long social commitments for dealing with their consequences. The striking example he uses is the storage of high-level radioactive wastes resulting from the reprocessing of fuel from nuclear power plants. The activity of these wastes is such that they must be kept out of contact with the biosphere for periods of thousands of years with an extremely high level of confidence. This requires a social commitment to monitoring the integrity of the storage against natural hazards, and a guarantee that some future society will not blunder into the storage area. Some people question whether our generation in fact has a right to commit future generations to this kind of sophisticated vigilance. How can we guarantee the integrity of administrative institutions necessary for this purpose? Weinberg rightly points out that similar social commitments have not been unknown in the past. Classical examples are agricultural irrigation systems, and the dikes of Holland. The latter are of particular interest because the Low Countries are in fact subsiding, so that the dikes not only have to be maintained, but must be built higher. On the other hand, the costs of failure of such systems are readily visible; they do not require sophisticated scientific understanding to appreciate even the existence of a hazard to human life or to the food supply.

Yet the other side of the coin is that there is no potential supply of energy adequate to human needs for more than a century, aside from the energy derivable from nuclear fission, and even this is viable in the long term only with plutonium-U238 or U233-thorium breeders. There are many other possibilities, such as solar energy and controlled fusion, but these are both highly speculative and a long time in the future. There may be better alternatives than committing posterity to the guarding of dangerous radioactive wastes, but can we afford to postpone the development and application of fission energy with the risk that such alternatives will not prove feasible? Here again we have a case where the logical order in which new technology appears does not necessarily conform to human preferences or human necessity.

Another variety of commitment of posterity arises from the increasing possibilities of irreversible damage to the biosphere or to some other aspect of the natural environment, including the depletion of nonrenewable resources. Of course, such irreversible changes have occurred many times in the historical past, but always in a localized way, so that man could shift his civilization elsewhere. Many of the great cultures of the past were based on localized concentrations of mineral resources, such as copper and tin, and once the cream was skimmed off of these the civilization declined or shifted to where another key resource was more abundant. We have all heard of King Solomon's copper mines or the silver mines of Athens. We sometimes forget that the industrial revolution in Britain was based on abundant indigenous metals and fuels. The metals are long since exhausted, and the fuels are less and less accessible, but the wealth created by this skimming the cream of local resources provided the basis for a viable worldwide empire and trading system. Much of the agricultural fertility of the Mediterranean Basin was destroyed through bad agricultural practices, and the forests of North Africa have long since been cut down, never to be restored. Elsewhere throughout the world once-fertile areas have become deserts irreversibly. No doubt some of these disasters were assisted by natural secular changes in climate. But in all these classic examples of man's interference with nature, there were always virgin lands to which he could move, new concentrations of minerals which he could exploit. The natural environment on a global scale was still an apparently inexhaustible reservoir. Even as an increasing number of local concentrations of minerals were exploited, technological progress made it possible to exploit lower and lower concentration ores, using cheap energy, at no increase in net cost, while advances in agricultural and forestry practices made possible self-sustaining exploitation of these renewable resources.

Thus, until the most recent times, man could exploit his planet with relative impunity. The wealth won from the depletion of local resources could be used to develop and apply new technology and to purchase resources from the entire globe. One could truly argue that it was better to exploit resources now because economic growth would enable us to do more and more things in the future. With a discount rate of 7 percent a dollar today is worth thirty dollars fifty years hence. This means we can afford to deplete resources or make changes in the environment today provided we can mine lower concentration ores or restore the environment for not more than thirty times the cost fifty years in the future. This is essentially what the economists tell us. But the argument depends heavily on the assumption that the future expenditure will be technologically feasible, or that there will be a functionally equivalent substitute.

Today discussion of environment and resources refers much more frequently to the metaphor of "spaceship earth," stressing the ultimate finiteness of both the environment and natural resources in relation to the growing demands of man upon them. Geographically there are fewer undiscovered resources, and relatively little unexploited agricultural land. Furthermore, whereas in the past most threats to the environment were localized geographically, we are now beginning to talk global threats—DDT in the oceans, CO_2 in the atmosphere from the burning of fossil fuels, depletion of ozone in the stratosphere, additions to the aerosol layer in the lower stratosphere, addition of nitrates from the fixation of atmospheric nitrogen to groundwater, depletion of available phosphates which are irreplaceable in agriculture, loss of genetic diversity in the major food plants. None of these threats is certain, but none can be ruled out with full confidence either. In the face of such uncertainty, what responsibility do we have to our descendants?

Let me take just two examples, CO_2 and phosphorus. There is no question that the CO_2 concentration in the atmosphere is increasing, and this is largely due to the burning of fossil fuels. As a matter of fact, only one-half to one-third as much is appearing as is being generated. We do not know what happens to the rest, what fraction goes into the oceans, and what into an enlarged biomass. What is even more uncertain is the effect of this, if any, on the world's climate. The more the problem is studied, the more complex and uncertain the prediction of the effects of CO_2 becomes. Calculations in the late fifties that indicated the polar ice sheets might melt by the year 2000 and flood our coastal cities are almost certainly wrong, but the uncertainty remains. What obligation does this uncertainty impose on us? If one takes the economists' view, one might argue that we should go on exploiting fossil fuels to the maximum, since with the wealth so produced we could afford to move our coastal cities. We could also accelerate conversion to nuclear energy, although we would be hard put to do without the burning of fossil fuels for transportation. At the very least we have a special obligation to monitor and understand what is happening, even if there is no immediate action that we can take to avoid it.

The complexity of the problem is further illustrated when we bring in the phosphorus cycle. Phosphorus is the one element not in effectively infinite supply which is essential for life. We use it in the form of synthetic fertilizer derived from phosphate rocks, mostly sedimentary. When put on the soil, most of it becomes irreversibly bound to aluminum and iron in a form too dispersed for recovery. Some runs off into lakes and rivers, where it furnishes nutrients which produce eutrophication, usually regarded as a disastrous form of environmental deterioration. But in the process of eutrophication, CO_2 from the atmosphere becomes bound in biomass which settles to the bottom of lakes and estuaries. It has been estimated that one inch of organic sediment deposited at the bottom of all the Great Lakes in a year would be sufficient to remove from the atmosphere all the excess CO_2 produced by the burning of fossil fuels in the United States.[4] Thus there are complicated interactions between the various types of damage man does to the environment. The depletion of the world's supply of phosphorus may thus be contributing to the alleviation of the CO_2 problem. It may be that many of these tend to cancel each other out, and it will certainly be a long time before we can know for sure. But all of these processes are generating commitments or problems for future generations whose magnitude we cannot estimate. This represents a new kind of ethical responsibility that we have never had to face before. At the very least it requires us to find out and understand as accurately as possible exactly what we are doing to our environment. It also argues for much more serious weighing of the present human benefits of each of man's activities against the possible risks and costs to posterity. Such a weighing involves a complicated intermixture of scientific and moral issues which are not easily separable into technical and value judgments. The ability of our descendants to cope with the mess we have bequeathed to them will also depend on the intellectual tools that we pass on to them, and the wealth derived from today's technology that they may use to reverse its side effects.

LOW-LEVEL TOXIC MATERIALS

The human organism is adapted to a host of natural products that have always existed in his environment. But today we are adding thousands of synthetic compounds that nature never knew, and dispersing metallic and mineral materials, such as heavy metals and asbestos, which were never part of man's natural environment. Where such materials are demonstrably and acutely toxic, the ethical problem is relatively straightforward. But many of these materials are not known to have any toxic effects at the levels at which they are measured to occur. On the other hand, at these levels it is virtually impossible to determine toxic effects by any reasonable epidemiological procedures, even with experimental animals, let alone uncontrolled human populations. One need only recall the enormous statistical effort required to demonstrate the deleterious health effects of cigarette smoking. The low-level health effects of the thousands of man-made compounds simply cannot be detected by any reasonable empirical tests. Only if we happen to know and understand the physiological and biochemical mechanisms of a compound's effect in the laboratory could we hope to predict its possible low-level toxicity in the environment.

Weinberg gives a striking illustration of the above general discussion for the case of low-level radiation, one of the best understood and accurately measurable environmental hazards. Until recently, the radiation exposure level for the general population was set at 150 millirems (radiation from the natural background). If the relation between dose and genetic damage were assumed to be linear, this level of radiation would be predicted to cause a 0.5 percent increase in genetic damage in mice above the spontaneous rate of genetic defects. But in order to verify such an effect in an actual experiment, it would be necessary to test a genetically homogeneous population of nearly ten billion animals, a totally impractical experiment.

One of the pieces of testimony that led to the defeat of the SST appropriation in the Senate was the prediction that the depletion of ozone in the stratosphere due to the SST exhaust would result in about ten thousand additional cases of skin cancer worldwide owing to increased intensity of solar ultraviolet radiation penetrating the stratosphere. This prediction was made on the basis of a detailed hypothesized mechanism for the whole phenomenon. Yet, if no such mechanism had been thought of theoretically, five hundred SSTs could have been operational for years, and it would have been virtually impossible to detect any effects on human health on the basis of statistical studies of the incidence of skin cancer, since the postulated effect is tiny compared with natural variations in incidence due to varying habits, skin pigmentation, latitude, and other factors.

In the case of radioactivity, tolerances are computed on the assumption that the effect is proportional to dose down to indefinitely low doses. With most chemical contaminants in the atmosphere it is assumed that there is a threshold concentration below which no effect occurs. Yet there is little scientific justification for the assumption in either of these cases. For chemical contaminants, the linear assumption would predict the occurrence of many illnesses or even deaths in a large population for concentrations well below the nominal tolerance thresholds used in computing air purity standards. But it would be difficult or impossible to detect such effects by any epidemiological methods. Even today, deleterious health effects of urban air quality cannot be said to have been unequivocally proven, though most experts now believe there are such effects. Most of the environmental health hazards that are causing so much concern today could have existed fifty years ago without ever being detected. They would have been lost in the "noise" of bacterial infections and occupational hazards. In other words, they would have been in the domain of "nature" rather than of human choice, and thus outside the domain of ethical consideration. Here is a case, then, where not only does technology create new choices and new values, but increasing scientific knowledge reveals value choices that were not known to exist before.

The value question raised by the discharge of trace chemicals into the environment relates to the balance between benefits and risks of the various activities which are the source of these activities. Up until very recently, the practice has been to permit the unrestricted diffusion and application of technology until definite evidence accumulated of substantial harm to human health. There was relatively little systematic effort to seek out potentially harmful effects, and most have been discovered either by accident or as a by-product of basic research in physiology or in the environmental sciences. In other words, technology was presumed innocent until proved guilty, and the burden of proof was on the prosecutor. More precisely, the presumption was that the risks of harm were small whereas the benefits were visible and demonstrated by the capacity to apply the product or the process at an economic profit. During an era in which harmful effects were scattered and sporadic, and the total size of man's activities was small in comparison with the cycling of materials in natural processes, this may have been a reasonable presumption. But it is clear that these values are now changing, partly as a result of higher human aspirations, partly as a consequence of the relative total magnitude of man's activities, and partly because of our growing capacity to detect trace amounts of materials and measure small biological changes. It is no longer sufficient to consider contaminants one by one, and assume that their effects are simply additive. A growing number of interactions between contaminants are being discovered, and many more subtle ones doubtless remain to be found. Some such effects may even be mutually cancelling. For example, DDT appears to inhibit the bacterial conversion of inorganic mercury to the much more poisonous methyl mercury.

There will be more and more questions raised about introducing new chemicals into the environment except when real, nontrivial, and widely spread social benefits can be demonstrated.

Even more subtle ethical questions are raised by the existence of large variations among individuals in sensitivity to nonnatural substances in the environment. Such variations in the case of beryllium were the cause of a long delay in the discovery of its extraordinary toxicity. But it is possible that there are many similar virtually undiscoverable sensitivities in the population to other materials. In addition to individual idiosyncracies there is the question of sensitivities of particular defined groups such as the very old, the very young, pregnant women, or people with cardiovascular disease. It might well be argued that increasing the concentration of almost any chemical above natural background in the environment will affect some particularly sensitive individuals in the population. In the regulation of environmental contamination, then, to what extent should society take into account these special sensitivities? This is an especially difficult problem if the material in question results from a process or activity which provides benefits to a large segment of the population and adversely affects only a small minority. The judgment, of course, cannot be made without consideration of what technological alternatives there are or might be in the future for achieving similar benefits with less side effects. To what extent would society be justified in requiring or expecting relocation of especially sensitive individuals, or prohibiting exposure of such individuals in other ways? How much of an investment in environmental protection should be required when the percentage of the population that might be benefited or protected thereby is an extremely small minority? One might consider setting standards in terms of an average or representative population, and then treating what happens to the sensitive group as essentially a fact of nature, just as would be the case if the substance in question were a naturally occurring one, such as pollen, to which a few individuals are allergic.

THE INFINITELY DANGEROUS, NEGLIGIBLE-PROBABILITY ACCIDENT

An increasing number of man's activities fall in the category of being normally very safe, but posing unusual hazards if they get out of control. The most dramatic example is probably that of nuclear power plant accidents. The nuclear-power industry is one of the safest there is, and there have been no accidents connected with the generation of nuclear power that have caused injury to the employees of the industry, let alone the general public. Yet we are dealing with a situation where a demonstrated record of safe activity is almost irrelevant. Because of the potential hazards of a major accident, its probability must be made so low that one would not have expected to have had any practical experience with such an accident. Indeed many of the accidents postulated in nuclear reactor safeguard calculations are such that no credible sequence of events has been conceived of which would produce the postulated end result. One nevertheless designs against such events because the human imagination is limited, and the possibilities for human error are greater than any smart group of individuals can dream up. The inventory of radioactive fission products in a power reactor is such that if widely enough dispersed thousands of people could be killed or injured, and whole areas rendered uninhabitable for considerable periods of time. We are dealing essentially with a product of zero times infinity—an infinitely damaging accident of zero probability. And as is well known the product of zero times infinity is an indeterminate number in mathematics; hence, the serious problem of values. The nuclear power example is an especially sensitive one in part because the hazards have been treated much more systematically and scientifically from the beginning than for any other technology. This is in fact a characteristic of science-based as opposed to empirically based technology.

Nevertheless, as one examines man's activities he can identify many similar but less dramatic or lurid examples. A crash of a gigantic aircraft, such as a B-747, in a densely populated area is a catastrophe of comparable proportions to most imaginable nuclear reactor accidents. As the density of air traffic increases and the concentration of urban populations proceeds, the probability of such a disaster inevitably mounts. This probability is undoubtedly considerably greater than that of a hazardous accident to a nuclear power plant, yet it receives very little public discussion because air transportation is a routine, accepted economic activity.

If the passenger fatality rate per passenger mile of air travel remains constant as the percentage of use of giant aircraft increases, it follows that the statistical chance of several hundred passengers being killed in a single crash grows. Conversely, a constant chance of a major disaster implies a declining fatality rate per passenger mile.

As the density and total size of high-density urban settlements increases, the human and material cost of a major natural disaster in such areas also increases. On the other hand, improved construction technology, better communications and warning systems, better public education, and disaster discipline can offset these greater vulnerabilities. In the past, settlements in potential natural disaster area (e.g., earthquakes in California) have been allowed to proceed without social control. There is a serious value question as to what extent we should restrict the freedom of human settlement and land use (and thus invade personal freedom) in order to reduce vulnerability to natural disasters.

Another similar area of concern has to do with the transportation of dangerous chemicals. Every few weeks we read of the evacuation of residents from an area where a toxic or explosive chemical has been accidentally released, usually because of train or truck collision. The situation in this instance is quite different from that which obtains in the field of nuclear energy. In that industry, standards are being set on the basis of an assumed major industry; in other words, the growth in scale has already been taken into account in the calculation of the risks. But in the transport of toxic materials such as chlorine, the standards of containment were set at a time when the industry was much smaller and the volume of material being shipped much less. Thus, the growing scale of activity crept up on us gradually without any systematic reassessment of the risks, while a large capital investment in place made the revision of standards much more difficult.

All of these examples have another element in common. They require an elite group working under enormously exacting social discipline in order to maintain the risks to society at an acceptable level. Aircraft pilots and air-traffic controllers together carry responsibility for millions of human lives daily. The designers and operators of nuclear reactors are subject to an elaborate system of accountability and cross-checking. In all these cases we are dealing with a highly responsible, highly trained, meticulous elite whose normal day-to-day responsibilities are crushingly routine, but who are required to make enormously complex and accurate decisions in an emergency, as well as to recognize promptly a bewildering variety of possible emergencies. We are occasionally reminded of our dependence on such elites when we read of a couple poisoned by *botulinus* toxin from an inadequately processed and inspected production line for canned *vichyssoise* in New Jersey, or of a bribed building inspector in New York. Suppose that many people had consumed poisoned *vichyssoise*, or that the inadequate inspection and control of buildings had applied to a skyscraper instead of a tenement.

Another example of such a special elite, which is even more frightening, is the military men who control our nuclear deterrent, especially the crews of Soviet and American polaris-type submarines. These small numbers of men literally hold the fate of modern civilization in their hands. While the safeguards against accidental or unauthorized launching of thermonuclear missiles are elaborate and multiply redundant, they are designed and operated in secrecy, not subject to review and analysis for risk except by specially cleared people, and not open to public scrutiny and challenge as is the case with civilian reactor safeguards. Even if the American safeguards were more subject to public inspection, the Soviet, Chinese, and French would not likely be. Thus we are handing over our very survival to elites whose selection, standards of training, and discipline we have no control over, and other countries are in the same situation with respect to the United States. The existence of mutual deterrence, of course, provides enormous incentives on each side to avoid mistakes, but the elements of the human situation are similar to the ones described in connection with nuclear power and many other technologies. The normal functions of the responsible elites are even more boring, routine, and lonely than in the case of civilian technologies, while the emergency responsibilities are even more complex, awesome, and dependent on remarkable trust than in the civilian counterparts.

One can well question whether the values that are developing in affluent societies are compatible with the kind of social discipline necessary to manage the enormous technological powers that these same societies command. I am not talking now about sophisticated concepts like "technology assessment" but simply about the routinized control and monitoring of existing technological systems already in place. In the past, military training and upwardly mobile segments of society have been a fruitful source of recruitment for such highly inner-directed and self-disciplined elites. With an increasingly highly educated population and increasing social emphasis on the value of "creative" and spontaneous rather than disciplined and meticulous personality types, will we still be able to find the combined qualities of mind and personality needed to man the ever growing number of such elites required to monitor and control ever more complex and larger scale technologies? Or is there a fundamental incompatibility between the values created by the enjoyment of the fruits of technology and the values required for its responsible operation and control? Already we see in the United States a serious deterioration in the morale of many groups on whom we rely for this kind of responsibility—the military, the police, the engineers, the maintenance mechanics, and others. Will we be able to draw from new segments of the population in the future for this purpose?

VOLUNTARY VERSUS INVOLUNTARY HAZARDS

The United States and every other "civilized" country accepts with equanimity an enormous toll of death and injury from automobile accidents. Implicitly, at least, we value personal mobility and the freedom it brings above the statistical risk to life. Accidents of all kinds are the principal cause of death for the whole population under forty; they are, in fact, the major disease of advanced civilization. We accept this accident toll because exposure is supposed to be voluntary. The individual and his family climb into an automobile in full knowledge of the risks involved. With respect to involuntary environmentally caused risks we adopt a more rigid standard, and for the most part we do not treat place of residence as a voluntary risk. Thus we demand much more protection for the man who buys a house next to a nuclear power plant or an airport than for a man who drives an automobile. However, the distinction between voluntary and involuntary risks is not so clear as it appears on the surface. In most parts of the United States, an automobile is a necessity for earning a living. The decision to drive is only nominally voluntary. It is probably less voluntary than the decision to buy a house near an airport, especially when the hazard or nuisance is already in place.

The risk of disease from the worst urban air pollution is at least ten times smaller (and probably much smaller than that) than the risk from smoking. Yet a high-powered campaign to reduce smoking has been almost totally ineffective, while the public is apparently prepared to accept billions of dollars of extra costs (in electric power rates and the price of an automobile, for example) to eliminate the hazards of air pollution in our cities. Furthermore, the residents of rural areas and small towns are being asked to share equally in the costs of improving air quality in our central cities.

It is believed that at least 50 percent of automobile accidents are attributable to the abuse of alcohol, and yet very little public support can be mobilized for the control of drunken driving or for the cure or control of alcoholism as a disease. The alcohol case is more difficult to understand in terms of voluntary versus involuntary risks, since alcoholic drivers jeopardize not only themselves but the general driving public as well.

Technology increases the number of both the voluntary and involuntary risks to which the individual can be exposed. Thus the value questions involved are much more complex than in a simpler society, in which such risks were primarily imposed by the natural environment, and could be overwhelmingly regarded as "acts of God." The value questions are very subtle. Even in the case of voluntary risks we are ambivalent about whether the individual should be merely told about the risk (as in the case of labeling and advertising of cigarettes) or whether he should be legally prevented from assuming the risk even at considerable extra cost to himself (as in the air bag for auto safety, or in seat belts linked to the ignition). Where the risk is likely to be assumed through ignorance or inattention, as is usually the case with hazardous consumer products, it may be legitimately treated as involuntary, and subject to the standards of involuntary risks. This is the philosophy behind much of the consumer-protection movement. But the question of forcing the consumer to pay an extra price in either money or inconvenience for a less risky product, where only his own risk is involved and where the risk is fully understood and widely known, raises value questions which can still stir up vigorous arguments. In practice, these questions are resolved by political acceptability rather than by any consistent philosophy. The subject is brought up here only as an illustration of how technology imposes new value questions on society.

CONCLUDING REMARKS

The central fact about modern technology is that its powers for both good and evil increase as it evolves, and thus place an ever greater burden on human responsibility and choice. By making possible the realization of previously abstractly stated and generalized ideals, technology confronts us for the first time with the full consequences of our goals, and with the conflicts and inconsistencies between them. Living with technology is like climbing a mountain along a knife-edge which narrows as it nears the summit. With each step we mount higher, but the precipices on either side are steeper and the valley floor farther below. As long as we can keep our footing, we approach our goal, but the risks of a misstep constantly mount. Furthermore, we cannot simply back up, or even cease to move forward. We are irrevocably committed to the peak.

NOTES

1. E. G. Mesthene, *A Final Report,* Harvard University Program on Technology and Society, July 1972 (Cambridge, Mass.: Harvard Information Office, 1972), p. 166.
2. Ibid., p. 203.
3. A. M. Weinberg, "Social Institutions and Nuclear Energy," *Science* 177 (1972): 27-34.
4. Robert Garrels, private communication.