Science and technology in global perspective

Robert S. Cohen

The historical continuum

Science and technology are social phenomena. Like all social phenomena, they arise, develop, change—flourish or languish—even come to an end; and they do so in all continents, throughout all human civilizations at varying times of origin and with differing paces of development. But only tentatively and rarely did technology, with its deep roots in the craftsmanship of the earliest recorded times, or perhaps in the even earlier known techniques of the palaeolithic hunters and artists, reach across barriers of social class occupations to join with science, and then only in periods of particular social requirements: we may think of Chinese pure mathematics and the practical calendars of military and political astrology; of Greek chemistry and the invention of liquid fire for naval defence (a science-technology link but very brief); of European stellar astronomy and practical sailor-navigators of the Renaissance. But the historically unique fusion of craft technology, raised to literacy and a new thoughtfulness in the Italian Renaissance—with its secularized philosophical effort to understand the order of nature, especially in the Galilean adaptation of Platonic mathematical idealism—was the achievement only of post-feudal Western Europe. Despite the immense sophistication of other civilizations and peoples—of the men and women of China, of India, of the high Arab and Persian culture of classical Islam, of Mayan and Aztec and Inca and others of the developed American societies—despite maturity of administration, maturity of the arts, literature, architecture, myths and religion, despite all this, technology and science were mainly apart in social function, and incapable of any thorough mutual fertilization.

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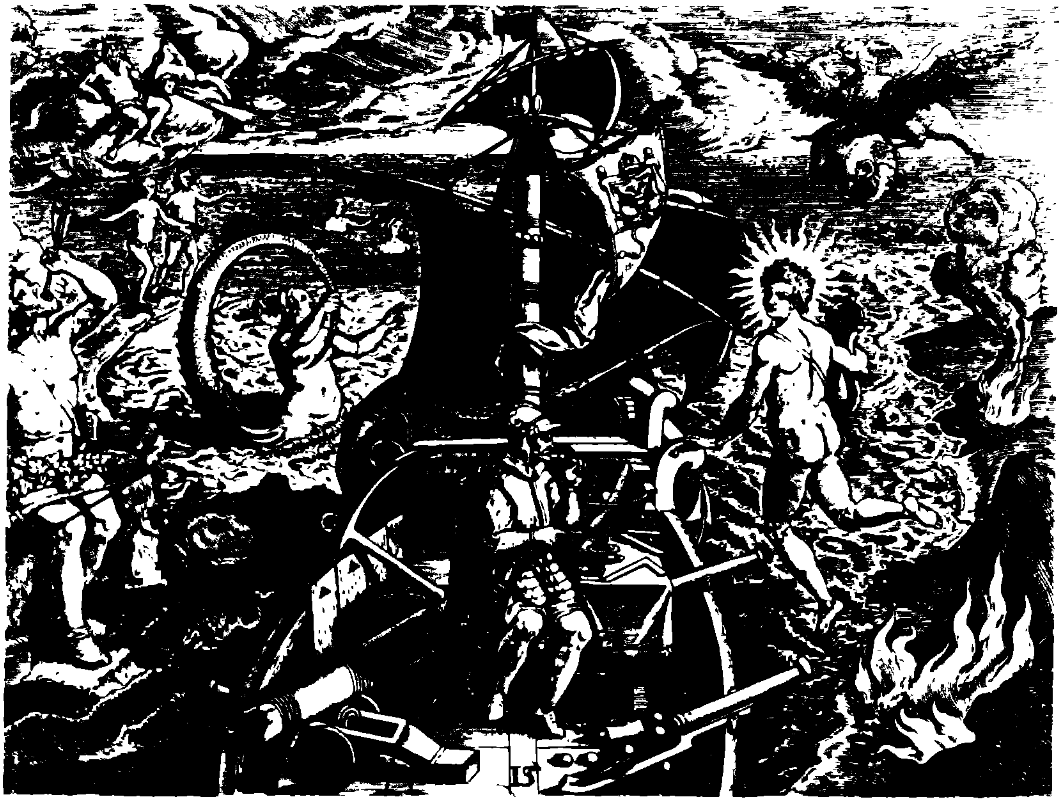
Sooner or later, except for Western Europe, technological power over nature stagnated, along with the societies themselves or, perhaps, first the societies reached a state of saturation: either stable, secure, culturally dull, without innovation and without entrepreneurs, and self-satisfied, without fundamental needs; or saturated but weak, hence ultimately unstable, ultimately based on value-schemes and epistemological ways with nature that were not viable, and hence open to internal decay or foreign conquest. With modern Europe since the late sixteenth century, however, which is to say and to emphasize, with the generation of an entire new class of men with their expanding role as entrepreneurial mercantile capitalists, both science and technology were liberated from their separate traditional constraints of opportunities and conceptions. But the engineers and craftsmen, in one speciality after another during the subsequent four centuries, found progress impossible without science, without fundamental enlargement of their understanding of natural processes, which had to extend far beyond the subtlety of mere enriched skills, and unequivocally beyond the reach of the empiricism of old-fashioned trial-and-error exploration of nature. As the modern world opened, practical life was coming to terms with the explosive value of the new way of decoding nature (Galileo said, 'read the book of Nature in mathematical language'): not by the seeking of more facts but by an imaginative and hypothetical curiosity to comprehend what the facts as such simply do not show. Science, in its modern revolutionary development, i.e. the Copernican revolution (and all the Copernican revolutions after it), mathematatized and mechanized nature, tested and experimented upon nature, pushed and pressed far beyond what nature spontaneously had ever revealed; and with the resulting complex development of this new science, capitalist Europe not only increasingly mastered, but also learned to transform, nature.

The ultimate question for historians of science must be: Why did modern science come into existence when and where it did, and why not where it did not? Was it made possible by this or that cultural quality, or perhaps by a religion whose metaphors of creation seem particularly attuned to explanations by causal laws, whose attitudes toward sexual relations of bodily love are those of domination, so that mathematically formulated laws and drastic experiments upon the eternally feminine 'Nature' might be encouraged, even stimulated, when the socio-economic time was right? And was the time right when the feudal order at last cracked open enough for the long-established but marginal merchants of the feudal towns to begin the march of urban society to social dominance? But then we would have to ask why capitalism came only to the Western Europeans in that dynamic form, or why their traditional religion evolved from its own complex tangle of metaphors and beliefs to the one form of Christianity that functioned so as to help science, in one major way, while hindering science in so many others.

Francis Bacon sensed all these issues when he, a giant among others who shared his views, called for deliberate social support of the scientific revolution by his Elizabethan England. Bacon, for England, initiated science policy; he initiated the social study of the human impact of scientific and technological innovations, and he did so with respect to the material practical realities of economic production and transportation and military power, and also with respect to the reality of a liberation of the human spirit from superstition, dogma, inherited errors of fact and inherited methods of thinking, from what he called 'idols' and what we might call 'idolatry' and 'fetishism'. Bacon was a social optimist about science.

For us, looking at the world today, the matter neither is, nor ever was, altogether as Bacon saw it. Nor as the French nationalist optimists of the eighteenth century believed, as they projected their Utopias that reflected their Voltairean adaptation of the Newtonian mode of thought to all technologies, sciences, educational structure, psychology and plans for a new social order. In the attempt to understand the social impact of scientific technology, we must proceed simultaneously in two ways: first, in a far less sweeping and generalizing manner (is technology good, or is technology evil?) and second, in a far more self-critical and sceptical dialectical analysis (science gives life *and* death). We also should recognize the historical character of our attitude towards the social and human impact of science and technology within our own century: attitudes towards technology will differ depending on whose technology it is, on which specific technological advance we evaluate, on which portion of humankind is speaking or is represented, which class, which race, which tribe, which generation, which sex, at which



'Practical sailor-navigators of the Renaissance'. Magellan on his ship, or science at work amidst mythology, by T. de Bry. Caudoue/Edimages.

cultural place the evaluator stands. And, even more assuredly, attitudes towards technology depend upon which technological advance, specifically, is at issue.

So generalization had best be avoided, or approached cautiously, even though in the end the entire situation of the human race will depend upon decisions regarding scientific technology. We are ourselves, then, in a new dialectic of specificity and universality; and this is due to the species-wide situation we confront, a situation which itself is due to the combined effect of the technology of the past two hundred years and to the worldwide political-economic market domination of the same period (briefly the mastery, so far as it goes, of nature and society by industrial (i.e. technological) capitalism, and its aftermath).

What is all the more puzzling as we try to look over the range of issues that concern the social impact of scientific technology is whether the recent and prospective impact, taken as positive or as negative, taken as that of a single innovation or as that of the cumulative innovative currents of development, is so different from the singular or general impact of earlier strongly innovative technologies. The impact upon displaced rural persons in eighteenth- and nineteenth-century England, who were forced into their rootless, often workless, often criminalized, normally 'gin-soaked', morally anarchic, urban existence, was a drastic shock, a personal and cultural transformation whose details have become clear; the impact upon Japanese peasants under a quite differently arranged urban displacement a century later, was different; and now a third century later, we see vast metropolitan cities of millions who have been technologically displaced; and in this example, while the human misery is undoubted, and the scale of numbers so greatly raised: Is the impact novel? Or the problems unique? This example leads to others that are linked to mass urbanization, and to the entire problem-cluster of a worldwide, mass society that technology has made possible: technologically induced mass unemployment, together with displacement of skills and of social relations, a phenomenon of commodity society, which seems endlessly drifting, or planning such shifts in human situations. Was colonial transformation, even partly without urban shifts, fundamentally different? We must ask whether the invention of mass society, early on, has entailed the continuity of social impacts that appear drastic to each generation, novel to each social observer, and then open to fresh analysis, which unhappily fails to take account of what has already been learned.

Mass war was new, partly a technological achievement, partly a political choice, but at any rate a novel extension of fighting not only to those obligated by the patriotic consciousness and by the legally powerful enforcement of a military draft but also to the civilian population, which itself was understood to be the substance of a country and a military source and resource. The American Civil War was the first to bring the mass-war innovation to reality with an impact upon the United States of nearly unmeasurably disastrous quality. And all major wars since have continued this effect.

To some extent, not quite clear, the social impact of technological innovation follows a continuous pattern, the continuity of innovation after innovation now reflecting, now reinforcing, now amplifying, a continuity of social transformation. Instances of mass population transfer through urbanization and of mass warfare may, of course, require discussion of specific technological advances: thus, city planning from ancient Rome to rebuilt revolutionary Paris, to the city of Washington, to new cities in, say, Siberia and Brazil and post-1945 Hiroshima, would have to be studied with respect to innovations in structural engineering, transport, sanitation, water supply, air pollution and other environmental factors, educational techniques, and the social psychology of work and play, and health care. Are we faced with a radically changed impact today, or have the damaging social effects already (and always) come about wherever mass accumulation has existed?

Even when continuity might be established, the variations may in themselves be quite substantial. When we examine mass culture, we may at first recognize the expansion of everyday consciousness from rural constrictions to the larger community of city and state, to the democratization of mass schooling, popular literacy, widely circulated newspapers and magazines from high-speed printing presses, magnificent and cheap reproductions of art works and musical performances through colour photography and high-fidelity recordings. But then we have also to reflect upon the negative inner development of that impact brought about by a new technology, television, which has profoundly influenced mass consciousness, and must be characterized as a novel shift away from general literacy towards visual homogeneity and a stage of widespread illiteracy so far as the written word is concerned. The problem of this particular social impact—let us say it is that of a passive, spectator culture, a nearly non-participant human practice—may not be new in human history (for we know of Roman circuses 2,000 years ago), but its extraordinarily rapid, and unusually pervasive and existential saturation, in the advanced industrial countries, testifies to an unprecedented and as yet insufficiently understood, technological (and socio-cultural) phenomenon.

When the social impacts of technological innovations are seen in this way, the continuity described in historical studies may be helpful to the social scientist who may hope to recognize parallels of causation, modification, response, as well as parallels of either implicit or explicitly deliberate social policy.

Comparative historical studies, at their best, can shed such illumination upon present problems so that history becomes a heuristic for modern science and technology policy studies and practice. Hence the importance (recognized, but as yet too little integrated within the advanced training of those in public administration and industrial leadership) of differential analysis of modernization across national or regional entities which have exhibited quite varied social responses to their technological modernization; in the United Kingdom, Federal Republic of Germany, the United States, Japan, the USSR and China, for example, they are preceded or accompanied by differences in policy decisions of a social nature (whether of a market sort or of a politically planned socialist nature, or otherwise, needs to be sorted out in each case). The social impact of a technological innovation, then, is underdetermined by technology alone. Although the constraints imposed upon human life by technology are severe at times, the range of possible social control and use of technology (from disaster in large or small ways, to hope and fulfilment) seems still to be open.

Discontinuities and failures

Where the present time nevertheless seems to be fundamentally discontinuous with the past is, we may suppose, marked by two characteristics. First, certain quantitative increases have reached critical points for which, in a familiar phrase, quantity has changed into quality, into a new phase. The explosive power of nuclear bombs, the literally transhuman scale of data mastery in modern information technology, the biologically transformative and creative potential of biochemical genetic engineering, whereby new natural entities can be 'invented', space science engineering, even efficient and accessible birth-control techniques, all testify to the novel social potential of the scientific technology now available. But these technically original inventions and discoveries join the new phase of the impact of the older and continuous technologies suggested above, in what may be a second and vital characteristic of our time in the last quarter of the twentieth century. This is the worldwide scope of social and technological problems; or, as the young Karl Marx might have described it, the 'species nature' of these problems. For at this moment in human history, at last, the human species seems genuinely to be confronted by species-wide dangers and opportunities, superimposed upon and closely integrated with the still urgent issues of a local and regional character.

We may list the worldwide factors:

1. Science and technology, despite their origins embedded within Western political economy and cultural sources, have now become world science and world technology.
2. The production and distribution of goods and services comprise a world market system, despite certain local autonomies and despite the variations of different mixtures of central planning, enterprise planning and competitive mechanisms.
3. Natural resources are abundant or scarce on a planetary accounting, despite local or national variations of the rich or the poor, within nations of both the First and Third Worlds.
4. Population problems are world-threatening, even while they continue to be locally or regionally of an immediate crisis nature.
5. World-scale war, however restricted in specific national participation, is a species-wide ecological and genocidal threat, even while apparently local wars continue to have their own devastating technological and human impacts upon restricted portions of the earth.
6. Religious consciousness, whether in the form of traditional and conservative institutions or linked to anti-modernist and innovative cults, seems to be a world phenomenon, a protective response to the felt, or perceived, threat of general technology and of impersonal mass urban peasant society; to use a phrase of Marx again, a worldwide religious tendency seeks to provide the 'heart of a heartless world'.

These (and perhaps other factors of worldwide scope) may be followed by a list of worldwide failures:

1. The political and economic failure to utilize technology to eliminate poverty, within most of the advanced industrialized countries, and at its most degrading to the human quality of life, within the Third World.
2. Failure of social scientific analysis, both of empirical studies in their historical and their current dynamic aspects, and of the appropriate rigorous methodology of the social sciences for this most practical of scientific tasks.
3. Failure of worldwide education for these problems in particular, and for a healthy and constructive understanding of science and its technology as a part of humanistic education in a scientific age, for the specialists and for the bulk of humankind alike (but especially the specialists' education has been élitist).
4. Failure to solve the continuing need for accumulation of capital from current resources, either by adequate transfer from the capitalist world or socialist sources or by extraction of surplus value from developing countries (oil and certain mineral-rich lands excepted).
5. Failure within scientific and technological élites to transcend their social sources, their élitism, certain heroic exceptions aside (Pugwash and those within the World Health Organization for example) and, in particular, failure to identify and control ideology within science.
6. The fetishism of science matching the popular fetishism of consumer technology.

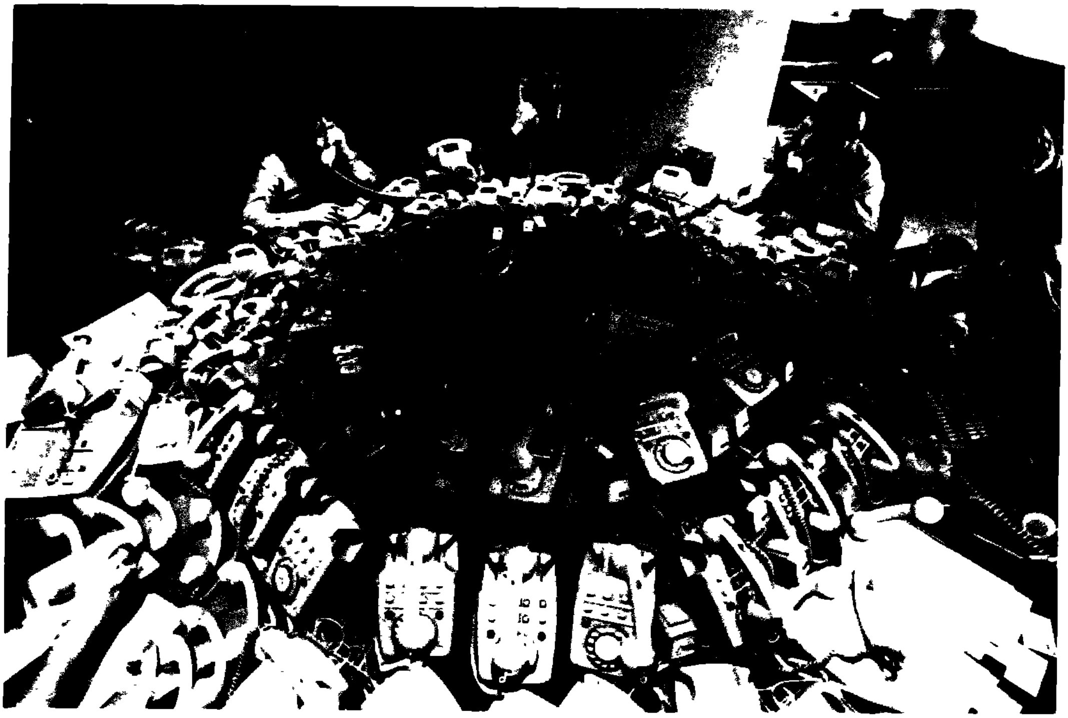
Recent technological developments of world significance

Now, we should briefly list a number of recent scientific developments with technological applications and serious social consequences, each of world significance.

Nuclear explosives for military purposes. Fission bombs in 1945, and after decades of further developments, fusion bombs, guided and programmed delivery systems, concealed launching sites on submarines or within deep-dug silos, multiple targeted bomb launcher rockets, psychologically misnamed 'tactical' or local 'theatre' nuclear artillery, the mysteries of military budgets for space stations in Earth orbits, and of the precision destructiveness of laser technology. The nuclear novelty persists in military fact, a discontinuity in potentially worse disasters, but the conscious quality wears thin, no longer shocking, no longer novel, a disturbing example of the adage that familiarity breeds contempt. But the truth is worse than ever, because the nuclear weapons have not been put under international agreement. Instead they have spread and worsened by continuous innovations. Along with the rest of 'military science' (no longer the study of battle tactics), they have received the bulk of available scientific and engineering financing. The story is incomplete, the technology too.

Cybernetics. Now an 'old' innovative science, cybernetics is still the extraordinary discovery of Norbert Wiener, a science of mechanisms with intelligence; and still incomplete; but robot labour, automated labour, artificial intelligence in production, exploration, quality control, all seem to be maturing. We still have no fully automated factory, but not for lack of scientific knowledge. The 1980s might be the robot decade, a time of robotics, of soaring relative productivity, decreasing general labour time, and increasing engineering labour élites. At the moment, we still have an incomplete hardware revolution.

Information technology. This races on and on with greater capacities, greater programming subtleties, shorter retrieval times, increased miniaturization, spreading through all markets of production, distribution, social scientific research, transforming empirical research from the study of the cosmos to the investigation of hourly supermarket inven-



'Information technology races on and on'. Scene at the Paris Stock Exchange. R. Bossu/Sygma.

tories, promising sensible decision capabilities for all sorts of complex planning, whether socialist or multinational, in the gambling house or the tax revenue bureaux. There is no end in sight for this continuing software revolution.

To summarize these last two points, automation to some extent promises and threatens to replace the blue-collar worker, while programmed computers may replace the white-collar worker.

Agricultural technology. This continues to transform food situations here and there, even while famines develop elsewhere. We have not yet come to terms with understanding the social impact of the Green Revolution, but may anticipate the probable success of saline-water agriculture. Whereas once nuclear power seemed likely to turn salt water to sweet by one of several workable power-based technologies, but then became dangerous and too expensive, now a simpler chemistry, genetically engineered within the plants, will perhaps cope with salt. Perhaps then, at last, the desert will really bloom, worldwide, the social outcome of which is difficult to predict.

Biological engineering. The application of the theoretical and experimental science of biochemical genetics, is now at the start of practicality. At every turn, social impacts appear: medical achievements by genetic manipulation of bacterial production, transforming the pharmeceutical industries; revival of imaginative projects of human genetic improvements, as dangerously idealistic as the older eugenics of the 1920s but far more practical; threats of biological warfare, cheap versions of expensive nuclear devastation; fantasies of animal food production, and plant creation, indeed a directed evolution replacing the splendid statistical causation of Darwinian evolution. Perhaps the 1980s will also be a pioneering decade of applied biology, the decade of biological technology.

Birth control. This and general population control, at first sight hardly novel, so accepting have we become of the pill, IUD and vasectomy, are still incomplete. And now resistance has arisen, in the West as well as elsewhere. The incompleteness is everywhere evident, whether in technical efficiency, in male contraception research, in social psychology, or in the failure of sexual education. The social impact of frustrated birth control will itself be drastic.

Mass communications. Studied again and again by critics and by commodity managers since the beginning of the twentieth century, they have advanced far beyond the skills of journalism, radio and film to the planetary outreach of manipulative and compulsive television and the instant global contact of space satellite systems. This is the basis, in a technology linked to science, for the trivia, gossip, tensions and intimacies of the anticipated 'global village', but also for a Utopian community analogous to the human support traditionally offered by the village.

Medical technology. Twentieth-century medical technology, and its manifold resources in applied natural sciences, spurring and motivating biology, chemistry and physics, have opened up entire new special fields of investigation and competence. There are wholly novel problems of technological scarcity, priority, élitism, capital-intensive centres of research and therapy, and a renewed gap between excellence and poverty. For example, the impressive diagnostic tool of the CAT scan, which uses computer intelligence for calculation, simulation and interpretation, or the external organ simulation in kidney dialysis, typify technology in life-assisting professional care, while the worldwide statistical and managerial skills of public-health professions typify the possibility of applying interlinked medical and social-scientific understanding in dealing with species-wide issues of health and disease. These are far beyond the age of quarantine, close to the age of social (rather than individual) medicine as a form of bio-engineered ecological management; we seem to have entered a time when medical ecology will seem the natural basis for understanding human health. But how incomplete for actual life today, when occupational and poverty hazards are still as grim and threatening as ever, in the industrial as in the mass urban and rural sectors of human life and work.

Polymer studies. How incomplete our modern 'advanced' science remains, but how promising too, seems most sharply shown by polymer studies. To understand polymers, and to produce them artificially, would be to initiate yet another 'age', for the age of polymers would be the time of mastery of the principal building materials of living matter. This would be the chemical physics of life processes, especially of the information capabilities of material nerve fibres, and the extension and contraction dynamics of muscles. There is an unimagined enlargement that artificial polymer engineering would give to practical design, for muscle fibres directly convert chemical into mechanical energy. These 'muscle motors' (as Kapitza terms them) are still the most extensive motor systems on Earth, with higher efficiency than engines, turbines or other heat engines. How tempting to say that creating an artificial muscle fibre will be the stimulus to inventing an effective small mechanical motor, human size, and perhaps (as we now say) 'appropriate'.

The social system of science to produce knowledge. Scientific developments are partly autonomous, and so too are the many larger or smaller 'revolutions' of science and technology. Nevertheless they are socially revolutionary in a further sense which is distinctly non-autonomous: science and industrial production are now fused, mediated by technology (which motivates science even while it draws from discoveries of autonomous science), and by the unusually subtle epistemic praxis that has invented the social system of science to produce knowledge. Thereby there has evolved a technologically advanced analogue to ancient laboratory servants and assistants for the colossal experimental complexities of the knowledge industry. This industry, producing its commodity of knowledge, is only one element in the fusion of science and production processes. How incomplete is the social sciences' treatment of the political economy of science may be judged from the lack of any fully elaborated classical, Keynesian or Marxist analysis.

Resource exploitation. Within the network of world science, and of technological interdependence, resource exploitation is increasingly situated within regional and global markets, within the supra-national corporation and socialist exchange co-ordination; in this matter we recognize a wholly natural and global situation of consumption patterns and production availabilities and of the potentialities of human lives within such consumption-production constraints. But their incompleteness is also plain. Political units are barely rationalized and co-ordinated within themselves, much less interrelated by the global requirements; and international economic units, private and governmental, respond to goals derived from their internal values and autonomous functions. Controlled and central economic planning on regional if not planetary scales is mathematically and formally possible, using high-speed artificial computer intelligence and cybernetic feedback control to distinguish local from central authority appropriateness, thereby accounting for the many variables (of multiple intrinsic values as well as instrumental values) related to social analysis of standards of living.

Élitism and technological threats

These world-scale factors or problems, failures and incompleted technological innovative achievements all rest with élites, whether in countries with traditional political democratic institutions, including Parliament or Congress and a balance of responsible governing powers, or in those with a greater degree of centralized party-governing authority. In the historically evolved division of labour, technical élites have finally come to their own peculiar roles, their power deriving from specialized competence; they are partially insulated from other élites and from democratic decision-making by a scientific and technological sophistication which easily allows for esoteric secrecy (whether military or industrial). The advantages for cognitive achievements are evident in the scientific advances of the modern era. Unlike the specialized division of labour in the industrial work-force, modern scientific specialization has not tended to replace skilled by unskilled workers; rather we may see more highly specialized and skilled labour replacing less specialized and less skilled labour. But narrowness of scientific and cultural literacy may be similar in social danger to the de-skilling of workers in the factory, since there is no inherent requirement upon technological specialists to acquire or use an integrated outlook on either technological or social problems, and no inherent need for a humanist or broadly cultured education. Hence, threats to traditional cultural institutions, and to political or social democracy, have become ominous even while mastery of planetary resources by technologically incisive specialisms seems feasible.

These technological threats to human societies are broadly of three sorts: political, social and ideological.

First, in the political sphere the threat due to élitism may outweigh the benefits of specialized learning and specialized practice: (a) by undermining the competence of representative democracy or by distorting the procedure of electing representative; (b) by diverting or frustrating the development of self-management institutions (such as workers' control in the work place, the market, or other production spaces of societies); (c) by the overriding technological necessity of quick military response to security dangers with the consequent and accepted social necessity of hot-line élitism; and (d) by linking populist counter-élitism to neo-Luddism.

Second, socially, scientific and technological innovations, whether successes or failures, whether achievements or promises, threaten to undermine, dissolve, or drastically weaken the received qualities of cultural life and human consciousness: (a) by challenging the power, validity and even the presence of the literal as well as the figurative icons and rites of traditional religious and aesthetic sensitivity in all their forms; (b) by promoting the psychologically symbolical fetishism of science, and technology, or of anti-science and irrationalism; (c) by transforming human living relations through transforming the social relations of production, consumption and communication; (d) by transforming the social relations of pleasure and fulfilment, and, in the process, weakening the momentum of cultural traditions, leaving the individual increasingly without moorings, open prey to the immediacy and irrationality of quick-fix populist manipulation; (e) the technology of élite social planning being out of the individual's control it is felt by the individual human being as fragmentary rather than integrated, as chaotic, asymmetrical, short-term, as a matter of impersonal life-irrelevance rather than as a life-affirming achievement; and (f) the species nature of global problems and planetary technological optimism then threatens the individual's life experience.

Third, ideologically, technological society poses problems, sets criteria for explanations and solutions, provides resources of people and materials, creating but also distorting the cognitive culture along with daily life. Technological innovations produce their own political economy of culture along with a political economy of science; these are the objects of new work in the social sciences, and in turn they stimulate critics who then must consider whether science and technology are themselves partial, ideological, merely instrumental reasoning, whether seen from traditional (largely religious) premises or from humanist and other viewpoints.