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Imperatives and Creative Culture

Imperatives and choice

The prospect of choice with which the last chapter ended implies criteria for choosing. It therefore implies values. In the choices between broad socio-economic options, the values involved are clear enough: wealth on the one hand and welfare on the other. Even the more narrowly technical ideas discussed concerning resources were seen to depend on values, such as the idea that it is good and right for mankind to seek mastery over nature (table 3). But on the more mundane level, 'values which are incorporated in technological products and which guide and inform the actions of technologists and those who direct their work, are either unrecognized, or simply taken for granted'.[1]

Hence the idea has come to be accepted that technology is value-free. People have come to feel that technological development proceeds independently of human purpose. They see it as the working out of a rational pattern based on impersonal logic. Yet in discussing the beliefs which contribute to the culture of expertise and to conventional world views, the three preceding chapters have inevitably implied a good deal about the values that underpin those beliefs. If people use the steadily-rising efficiencies of steam engines as evidence for a linear pattern in technical progress, that is not only because they believe that this provides a realistic insight into the nature of such progress, but also because they value increasing efficiency as something desirable in itself, they value the rationalism and logic which the linear pattern seems to show, and above all, they value technical progress. Yet if people were to assess technical progress in terms of different values, they might present diagrams showing infant mortality more often (figure 7), and graphs representing efficiency in its various forms less (figures 3, 5).

Observations of this kind tend to confirm that essentially materialist, economic values are dominant within the industrial culture, and that among technologists, efficiency[2] and rationality are also important values. But all these are foreground values. They do not engage at all clearly with the impulses and drives in much of the most dynamically creative technology. The latter are impulses often referred to collectively as the 'technological imperative'. But this is a blanket term, and little is ever said to uncover its real meaning and to reveal the background values that support it. The clearest statements about it tend to describe the imperative as the lure of always pushing toward the greatest feat of technical performance or complexity which is currently possible. It then comes to seem an inexplicable, innovative force that cannot be restrained. Discussion of the technological imperative thus reinforces the determinist impression of technical advance that many people entertain. Technical progress, they say, is 'autonomous';[3] the microelectronic revolution is 'irresistible'.[4] And it is made to appear that engineers, scientists and medical men have been taken over by a blind, uncontrollable power which dictates that whatever is feasible must always be tried, and that every new technique found to be practicable must then be applied. 'We cannot stop inventing because we are riding a tiger.'[5]

This way of talking is an evasion. The technological imperative is partly an expression of values, but not exactly the ethics and values openly acknowledged in professional life and presented as a prominent part of the 'expert sphere' of practice in figure 6. The imperative rather refers to more obscure personal 'experience' of technology and to background values. It is important to identify these and try to understand the sense of compulsion to which they lead.

One suggestion is that most talk about imperatives and the inevitability of current patterns of technological advance hides an 'unquestioning acceptance of economic values'.[6] This, however, seems inadequate in that a good deal of high technology, notably in aerospace, goes far beyond anything that can be profitable or can make economic sense. Some people explain that by pointing to the many developments which are politically rather than economically motivated. Supersonic airliners and space exploration are promoted for reasons of prestige. Microelectronics and automation are part of an effort to centralize control over administration and production. For long periods during the 1960s and 1970s, more than half the scientists and engineers working in the United States have been employed on defence projects, aerospace and nuclear power. Such a narrow concentration of politically motivated effort must have its influence.

Yet there are still occasions when technological development seems to escape political control, and when the imperatives behind it go beyond even military requirements as well as economic sense. The biased projections and one-sided world views of the experts sometimes have the effect of manoeuvring politicians into positions they never wished to take. As we saw in chapter 3, that seems to have happened with some aspects of policy on nuclear weapons. The implication is that technological advance is sometimes pursued for departmental reasons relating to the dynamics of particular professions. Sociologists have examined the latter aspect in terms of the way professionals in science and technology seek recognition from colleagues and gain status within the professional community through their achievements in discovery and innovation.

Undoubtedly many factors are at work, and professional interests are important among them. But I believe that if we are to understand why technological development takes such a hold of people that it is discussed in terms of imperatives and obsessions, we need more than what a sociological investigation of such issues can provide. We also need to enquire about the meaning of technology for those people who develop or use it, and that entails enquiry into what Samuel Florman has described as its 'existential' aspect. His proposition is that 'the nature of engineering has been misconceived. Analysis, rationality, materialism and practical creativity do not preclude' personal values or emotional purposes. Indeed, they are 'pathways to . . . emotional fulfilment', and it is the wish to achieve fulfilment that must account very largely for the so-called imperative. 'At the heart of engineering lies existential joy.'[7]

Florman's views are of considerable interest in that he is a practising engineer in New York state, yet his way of explaining the human significance of engineering is less by direct reference to his own experience than through the exposition of literary works that allude to technique and skill. I shall draw on his approach a good deal, but in order to illuminate the relationship between the existential experience of technology which he describes and the economic values which are supposed to be dominant, it is helpful to refer to another author who at one time also aspired to be a civil engineer in New York state, and to that end applied for a post on the Erie Canal. He was Herman Melville, and in his famous novel *Moby Dick* he described how the voyages of a New England whaling ship were promoted by men 'bent on profitable cruises, the profit counted down in dollars'. These individuals felt confidence in employing a certain Ahab as captain to take charge of their ship, because of his single-minded commitment to the whaling life. But what these 'calculating people' failed to see was that Ahab's commitment arose from the 'infixed, unrelenting fangs of some incurable idea' that was decidedly not connected with profit. They did not realize that this idea – the pursuit of one particular white whale of legendary ferocity – endangered their whole enterprise.[8]

So it is with much technology. Industrialists and politicians are often unaware of the infixed ideas motivating the research and development they sponsor. They do not see that the projects on which they employ technical staff may take on purposes for those people which are quite unrelated to the initial economic or other utilitarian goals of the project. These ulterior purposes may not entail the pursuit of a white whale, and usually will not endanger the project, but they may give it a certain momentum and bias that is difficult to resist.

Florman is not the only one to identify these hidden purposes as the pursuit of existential joy. Mary Douglas[9] speaks of the joy that comes through discovering and understanding how systems work. Einstein is often quoted as talking about 'the joyful sense . . . of intellectual power' that can be found through work in science.[10] And it is very clear that in the practice of technology as well as science this goal has its place. There are many technologists who see their work partly as a response to challenge, and seek joy in achievement. Impulses such as this lie behind J. K. Galbraith's talk about 'technological virtuosity'.[11] The phrase 'technological exuberance' expresses the same thing for Herbert York when explaining why scientists in the United States have often pushed the development of nuclear weapons far beyond the requirements of a rational defence policy. In chapter 3 we observed the stratagems by which the weapons experts did this; the pursuit of technological exuberance and what I shall call 'virtuosity values' are part of their motivation. Oppenheimer, for example, is famous for his statement that one invention used in the hydrogen bomb was 'technically so sweet that you could not argue' against its adoption.[12]

It is a great mistake to allow the myth that technology is value-free to blind us to these impulses and values. It is especially mistaken to regard these imperatives as inexplicable and deterministic. Few technologists will acknowledge the 'infixed, unrelenting fangs' that are often the source of their drive; few talk about existential joy. But the fact remains that research, invention and design, like poetry and painting and other creative activities, tend to become compulsive. They take on purposes of their own, separate from economic or military goals. And if technologists feel like this, may one not expect that technical judgements may be influenced? Or that the products of technology may be expressive of such emotions?

The ethos of the 'technology-is-neutral' outlook outlaws all such questions. They are inconsistent with the supposedly detached and objective methods of technology. But such questions must be asked if we are to understand the apparently blind imperatives which appear to characterize modern technology.

Aesthetics and mobility

The one branch of technology in which taboos against talking about values are almost non-existent is architecture. This has close affinities with engineering, but because it is regarded as art, its role in expressing cultural values is openly discussed. And in writing about the products of technology, architects have often noted that 'constructive and artistic genius' shines out with 'as clear a light' from automobiles, aircraft, refrigerators and radio sets as from any building. Maxwell Fry, a leading architect of the 1930s and 1940s, followed these remarks with a comment on the mechanical design of railway locomotives; the earliest ones were clumsy and ugly devices. But as engineers gained experience, more refined types were produced which were so 'purged . . . of clumsiness and inconsequence that they became objects of the most impressive beauty'.[13]

This preoccupation with the relationship of machines and architecture has often been asserted by quoting Le Corbusier's saying, 'a house is a machine for living in'. That has been taken to mean that buildings should be austerely functional, and that architecture should be as emotionally neutral as machines are supposed to be. But Le Corbusier's architecture was not like that; it was vigorously expressive, and lived up to another comment he made, that his aim in building was 'to create poetry'. The initial statement about houses and machines needs another interpretation, therefore, perhaps to the effect that machines themselves are expressive of cultural values; and perhaps also recognizing that engineers, too, can sometimes create poetry, or construct the technically sweet.

Certainly one may see the aesthetic impulse in almost all branches of technology. It has often been clearest, though, in the work of craftsmen. We speak of them as having a 'feeling' for materials and for the products they make; they enjoy the texture of wood and the changing colour and malleability of metals as they are heated, forged and filed. A leading historian of metallurgy has asserted that nearly every early innovation in metal-working technique derived from an aesthetic impulse.[14] Craftsmen improved their skill not only by trying to make a knife or sword sharper, but also in trying to improve its appearance, both as regards shape and decoration.

In more advanced technology, aesthetic judgement is still important, because in the design of machines and structures, not every choice that has to be made is rigidly determined by practical requirements, and not every judgement can be settled by calculation. Thus an engineer responsible for the renewal of sewers in one of Britain's industrial cities, some of them 150 years old, has found himself advocating 'technically sweet solutions, where I have proposed rationalizing the existing disorganized system with new sewers in tunnel'.[15] The plans go beyond what is strictly necessary to deal with the initial problem partly in order to reduce the amount of hazardous work in confined spaces, but partly for other reasons. One is a wish to 'improve the order of things', and do a job such as driving tunnels that seems like 'proper engineering'. There is also a strong feeling for materials, with a clear negative reaction against the plastic panels or *in situ* resin linings that would be used to patch up sewers if new work were not undertaken, and a positive preference for concrete. 'Even better is brickwork . . . Some of the most satisfying jobs recently have been on re-lining of existing brick sewers . . . by a new skin of engineering brickwork (this also was the cheapest solution).'

In view of what has been said about the unattractiveness of maintenance work for many people, this engineer's final comment on the repair of brick sewers is particularly significant. He speaks of a '*strong* satisfaction' experienced in 'restoration and adaptation of the existing structure . . . In fact, planning and executing a good repair on a trusted existing structure (or machine) which has already seen worthy service is to me more satisfying than creating from scratch.'

This feel for materials and the visual satisfaction of knowing that 'if the job looks right it *is* right' may be shared by many engineers but only occasionally, with some of the most famous ones, is it recognized and discussed. Thus Robert Maillart's brilliant designs for concrete bridges have been studied with a view to identifying the aesthetic judgements involved and the connection between technical logic and the artistic features. The term 'artist-engineer',[16] borrowed from a Renaissance context, has been applied not only to Maillart, but also to F. W. Lanchester, designer of automobiles, and to I. K. Brunel, builder of ships and railroads.

Everybody who uses the products of technology may share in enjoyment of their aesthetic qualities, just as everybody entering a building may share something of the architect's feeling for its structure, space and decoration; and people's everyday enthusiasms are reflected by their purchase and use of equipment. I can speak best about personal experience: equipment which I find enjoyable and even stimulating to use includes a calculator, slide-rule, bicycle, camera, typewriter and xerox copier. But the enjoyment and sometimes exhilaration I feel stems not only from the good aesthetic design of most of these products, but also from the way they enlarge my personal capabilities. The bicycle quadruples the speed I can travel under the power of my own muscles; the xerox copier, hiding corrections, turns my inadequate draughtsmanship into presentable illustration.

But beyond these experiences of aesthetic pleasure and enlarged capability which people derive from technology, another source of enjoyment is associated with having mechanical power under one's control, and of being master of an elemental force. The teenage enthusaism for motorcycles reflects this. Many farmers, it is said, buy larger tractors than they really need, to the detriment of soil structures, because of the pleasure they get from using such powerful machines. Some automobiles are designed to appeal to this impulse; others, of more modest power and pretension, seem designed mainly to enlarge personal capability, like the machines mentioned in the previous paragraph. The dominance of the automobile in the western way of life is not due to blind imperatives, but to the fact that its usefulness is complemented by these two very considerable satisfactions. Exhilaration in speed and power, and the desire for mobility, have perhaps always been part of the human personality; and as Florman says, 'Technologists, knowing of this desire, were, in a sense "commissioned" to invent the automobile. Today it is clear that people enjoy the freedom of movement of which they had previously dreamed.'[17] In most invention, basic human impulses like this precede the technological development. Dennis Gabor talks about 'archetypal human desires' which include the wish to communicate at a distance, to travel fast, to fly.[18]

The impulse to fly, especially, was evident long before aircraft were possible. Perhaps from the time of the Icarus legend, and certainly since Leonardo's sketches of flying machines and Kepler's discussion, in 1610, on flying to the moon, people were attracted by the prospect. Just before 1800, though, this vague impulse became a practical intention, with early hot-air balloons, and with George Cayley's work on fixed-wing gliders pursued with great persistence from the 1790s till 1852.

Economic aims and the profit motive seem quite irrelevant to all this; the imperative here is clearly rooted in non-economic 'virtuosity values', even sporting impulses. Practitioners of hang-gliding today view Cayley as partaking in their sport, and say the same of Otto Lilienthal, another early flyer who experimented with a form of hang-glider during the early 1890s. Such equipment could not conceivably have had a utilitarian purpose: its development, one may argue, was a cultural enterprise, related to the primitive impulse to fly, and to craft skill and aesthetics:

> To learn wind's whims by touch, Lilienthal
> became bird –
> willow wands, waxed cloth, stretched
> resonant as a drum
>
> leapt, sprinting
> wings spread into
> wind's lift
>
> . . . Craftsman, fashioning
> shapes of air . . .[19]

Orville and Wilbur Wright began their experiments on flying after reading about Lilienthal's efforts, and at first they worked solely with gliders. But one writer on gliding and man-powered flight suggests that the Wrights' goal altered fundamentally at the point where they first mounted an engine in one of their gliders. That gave the machine potential to become a thing of economic utility; and this change, it is alleged, diverted technological development away from the sport of 'pure flight', delaying its progress.[20]

The bicycle, the automobile and the aeroplane developed at about the same time using related technologies. In the United States there was a boom in bicycles in the 1890s; it resulted in a string of small workshops including the cycle repair shop established by the Wright brothers in 1892. Techniques for making light-weight frames and for precision manufacture of gears and bearings arising in these workshops were later useful in automobiles and aircraft as well as bicycles. The interactions within this family of industries and the many innovations produced, had very much the character of a movement in technology such as those discussed in chapter 2. There were not only technical links between the three new modes of transport, but they all had similar purposes also, concerned with the mobility of the individual. One expression of this was the interest in using the new vehicles in sport and for establishing speed or distance records. In every respect, there was the sharpest possible contrast with the economic purposes of the railways and steamships produced by an earlier phase of innovation in transport.

The discovery of new dimensions of mobility which generated such enthusiasms for bicycles and aircraft, was experienced in a new form when snowmobiles of the type described in chapter 1 began to appear in the 1960s. One user speaks of an 'almost animal sense of freedom when you realise that the thing can go practically anywhere – shooting up snowbanks . . . across frozen lakes'. There is an immediate contact with wind and weather, a sense of 'anarchistic mobility', and also, as with bicycles and gliders, 'the machine becomes an extension of your body and your senses'.[21]

With all these innovations, then, talk about 'technological imperatives' may disguise a whole range of other impulses concerned with aesthetics, materials and mobility. Especially significant is the impulse to master and manipulate elemental force. One sees this with automobiles and motorcycles, but nowhere has it been more evident than with the steam engine. Over the three centuries of its development, this machine has been celebrated in many ways. Steam locomotives and steamships appear in Turner's paintings; factory-owners built enginehouses like temples or chapels in which to install these highly prized machines; and engines were given names, of which two of the earliest recorded, *Resolution* and *Adventure*, speak volumes about impulses in technology. On the railroads, 'Steam locomotives were a sublime demonstration of man's partnership with the creation. The skill of designers . . . the courage and confidence and sure-touch of drivers;

the rippling muscles and the sweat of firemen; the combination of fire and water and coal and sparks and speed – it was drama and spectacle and poetry rolled into one . . . the embodiment of energy and power.'[22]

But locomotives also take the idea of mastery of nature into another dimension. Walt Whitman not only addressed one as 'Fierce-throated beauty', and 'emblem of motion and power', but called it 'pulse of the continent',[23] referring to the role that railroads were playing in his time, opening up the American West for settlement and helping push back the 'frontier'. Railroads are not often seen in that light today, but frontier values are still an important part of thinking about technology, especially in space and in the few remaining unsettled, unexploited regions of the earth. In America's arctic north, our culture is one in which man is encouraged, 'to conquer the frozen and waste spaces that he sees, with roads, mines, drilling rigs, gas wells and pipelines. He dreams of the technological conquest of the northern frontier'. In the vast, sparsely inhabited interior of Brazil, another of the last frontiers is to be found,[24] and trees are destroyed and roads are built so that it too may be conquered.

Cathedrals of power

The existential joys of technology would seem from all this to extend from the quiet, aesthetic satisfactions of craftsmen to the exultation of the driver of a speeding steam locomotive and the adventuring spirit of frontier conquest. These enjoyments are sanctioned and celebrated by aesthetic ideals and other 'virtuosity values' that claim intrinsic merit for technological endeavour, independently of its utility or economic benefits. Among these values is the idea that it is right and good for man to seek mastery over nature, and that this can be a goal in its own right.

Some commentators see this 'project of conquering nature' as taking shape during the scientific revolution of the seventeenth century, inspired by the voyages of discovery made from the time of Columbus onward, inspired by humanist views of man as separate from and superior to nature,[25] and using ideas also from the Biblical creation myth, in which Adam and Eve were told to 'subdue' the earth and 'have dominion . . . over every living thing that moveth upon the earth'. All three strands of thinking were important to Francis Bacon, when, around 1620, he wrote about an idealized scientific community whose name, 'the College of the Six Days' Works', deliberately recalled the Bible story. Its objects were the extension of power over Nature, and 'the enlarging of the bounds of Human Empire, to the effecting of all things possible'.[26] There we have a statement of frontier values and the technological imperative all rolled into one.

Bacon has been much quoted by technologists with an interest in expounding the cultural significance of their work, though they often forget that he wrote about compassion and discipline in the use of knowledge as well as mastery of nature. Another approach one finds in discussions of the non-economic significance of technology is the identification of its products with archetypes whose cultural achievement is widely recognized. Visiting Liverpool docks at a time when they were the largest in the world and still being extended, Herman Melville said that their 'extent and solidity . . . seemed equal to what I had read of the old Pyramids of Egypt'.[27] In 1913, Walter Gropius wrote about American grain silos which 'can stand comparison with the constructions of ancient Egypt'. Such parallels usually indicate admiration, but Lewis Mumford has said that the objective of the pyramid builders 'was as irrational as our own phrenetic dedication to nuclear weapons and spacemanship'.[28]

Although Melville did not write primarily about technology, he was very aware of the significance of its archetypal achievements, using them as symbols more comprehensively than almost any other author, and linking them with images of fire and with the Prometheus legend. Thus he referred not only to pyramids, but Roman aqueducts, medieval cathedrals and the steam engine. All these symbols are now common currency, and the cathedrals have been quoted especially often in discussions of the aspirations of technology. One reviewer asked of London's Battersea Power Station in 1934, 'Is it a cathedral?' Its architect, Giles Gilbert Scott, was better known as the designer of Liverpool Anglican Cathedral, and was later said to have built two cathedrals, 'one for God, one for Electricity'.[29] Similarly, in 1954, the Capenhurst nuclear fuel plant was described as a 'temple to whatever muse it is that gives inspiration to engineers'.[30] Such comments became even more frequent after an article on large-scale science in the United States was published by Alvin Weinberg in 1961. This pointed to 'the huge rockets, the high-energy accelerators, the high-flux research reactors' then being built as, 'symbols of our time', just as Notre Dame is a 'symbol of the Middle Ages'.[31]

In 1969, Robert Jungk took up the same theme in writing about the CERN high-energy particle accelerator located near Geneva. Echoing Weinberg, he said that this is 'one of the great cultural achievements of our time, the contemporary counterpart of the temples of antiquity, the cathedrals of the Middle Ages'.[32] Three years later, Peter Medawar was talking about how one could claim that a space probe, 'like a cathedral . . . is economically pointless, a shocking waste of public money; but like a cathedral, it is also a symbol of aspiration towards higher things'.[33]

This may offer further clues about imperatives in technology that go beyond utilitarian goals. Any account of, say, a particle accelerator, a nuclear power station, or of the Eiffel Tower has to face the existence of such goals. The latter, in particular, is famous, 'not for its usefulness but its symbolism'. It was the outcome of a hankering widely felt in the nineteenth century to build a tower reaching a symbolic 1,000 feet (or 300 metres) above the ground. Such a construction had been considered for the Philadelphia centennial exhibition in 1876. But it was Gustav Eiffel, a French railroad engineer, who achieved it. Mentioning pyramids and cathedrals, one writer on the Eiffel Tower suggests that all these monuments reflect 'a compulsion constant throughout history to thrust mighty structures toward the sky in moments of special pride.'[34]

Many people, however, may be inclined to dismiss these references to cathedrals, and the snatches of poetry quoted earlier, as emotional froth that has no relevance to the real, practical rationality of technology. It may be, though, that we ought to recognize that the culture of technology comprehends at least two overlapping sets of values, the one based on rational, materialistic and economic goals, and the other concerned with the adventure of exploiting the frontiers of capability and pursuing virtuosity for its own sake.

These two sets of values can co-exist so long as they do not set up conflicting demands. The adventuring, virtuosity-seeking spirit is felt to be admirable so long as it can be paid for, and nobody's security is threatened by it. People have been happy to watch television coverage of landings on the moon and space-shuttle test flights. But when it comes to nuclear energy or weapons, the risks are less remote, and enjoyment of adventure in mastering nature seems less appropriate. Yet nuclear energy must be attractive to many engineers and scientists as perhaps the ultimate example of human mastery over elemental force. Even the test explosion of a nuclear bomb, brighter than a thousand suns but still under the scientists' control, is something to glory in as 'superb physics'.[35]

It is significant, however, that arguments about civil nuclear energy are never couched in these terms, but always refer to economics and utility. Benefits claimed for nuclear power are cheap electricity and a way of meeting anticipated shortages of energy. Risks regarding safety and health are also put into an economic context – they are said to be much less serious than many risks posed by chemical industries, or by air travel, and are sometimes assessed in terms of life insurance.

One result is that the arguments deployed in both sides in the controversy always seem a little forced – they carry too heavy a load of unstated value judgements; they are proxy arguments that stand in for more significant issues which nobody wants to acknowledge. Some of these issues are political, but some are associated with adventuring imperatives that belong to the cultural dimension of technology. Questions of whether or not electricity will be marginally cheaper are mostly irrelevant. Those who argue against nuclear electricity generation perhaps ought to be saying that the power plants are as futile and unnecessary as the Eiffel Tower. Those who favour it probably have a conviction that sometimes Eiffel Towers are crucially important to the future of man's technological enterprise.

One distortion arises, though, from the double-edged cultural significance of the Eiffel Tower, as of the Apollo moonshots. These are both very great human achievements; each can be regarded as 'a small step for mankind'. But both projects were also expressions of national pride, capable of being exploited for political purposes. With nuclear technology, this second aspect seems to have become very important. The over-riding 'motivation' in nuclear development has nearly always been 'pride', according to one recent review, especially pride of the sort called patriotism. So in France, which in the 1980s has the world's most successful civil nuclear power programme, the public is 'as suspicious of nuclear power as the next nation', but '. . . sees its success as one of the great symbols of French strength'.[36]

Critical scientists have argued that the French programme consumes almost as much energy as it produces; they have alleged that the uranium enrichment plant at Tricastin on the River Rhône uses all the electricity output from four nearby nuclear reactors; and even an official report prepared under the supervision of J. M. Bloch-Lainé 'raised severe doubts' concerning the latest series of orders for nuclear plant. Other experts have said that the nuclear reactors will be white elephants by 1990, immobilized by uranium shortage and lack of demand for electricity.[37] But all that is to judge the programme by purely utilitarian criteria and to forget that it also has a political and cultural purpose: it was initiated for 'La France', not only to produce electricity, and just as an American motorist may in the 1960s have bought a much larger automobile than he really needed or a farmer may enjoy using a more powerful tractor than he requires, because of the sense of mastery over the elements it gives him, so a nation may feel a cultural imperative to support a larger nuclear power programme than is economically justified.

In Britain, the 'cult of sheer size' and of technological complexity led, in the 1930s, to 'uneconomically over-size ships like the giant Cunarders', and after 1945, to 'grotesquely uneconomical planes, of which Concorde is simply the last of a long line.'[38] In architecture, there have been heavy commitments to 'what is expensive, but technologically "sweet" ', such as the high-rise flats built in many inner cities during the 1960s; and in medicine, heart transplant operations seem to reflect similar values.[39]

Much the same has been said also about Britain's nuclear energy programme; in 1965, five new power stations were ordered based on a relatively untried concept, the advanced gas-cooled reactor (AGR). There were many difficulties and delays during construction and costs mounted. One economist who carried out a detailed study was moved to say that the decision to build the five AGR plants could rank with the Concorde airliner programme in the exent of the financial loss that resulted. These were the 'two worst investment decisions ever made'.[40]

It is easy to be cynical about such projects and to feel that when references are made to cathedral archetypes, these are merely rhetorical excuses for financial irresponsibility. But for many people, Concorde is a most beautiful and exhilarating aircraft, and the AGR a creative step forward in reactor design, especially regarding safety. Judged by values that have to do with technological virtuosity, these things may seem entirely admirable. And considered also as part of the 'project of conquering nature', the cathedral analogy is entirely appropriate. With upward-thrusting, gravity-defying lines and elaborate buttressing against wind pressures, a cathedral structure may seem to conquer elemental force just as surely as Concorde; it is also, very often, a marvellous feat solely in terms of artistic creativity. So, it may be claimed, is much of today's high technology.

Cynicism, symbolism and creativity

David Dickson has observed that although we may sometimes hear discussion of, 'technology and art', we rarely hear anybody talking about 'technology as art'.[41] Yet it is not only the apparent usefulness of technology that impels us to develop it. There are imperatives that drive us beyond usefulness, though as we have seen, efforts to explain them get us into difficult areas. Aesthetic satisfactions may be easy to understand, but when people talk about the cathedral-building impulse as 'aspiration to higher things' one may suspect an evasion. What higher things? Are we merely seeking an 'endless process of further technological triumphs'? If the ultimate goal is human happiness, may it not be that this 'lies in the quest' rather than in achievement? 'And is not this sort of quest itself a kind of enchantment?'[42]

The medieval cathedrals themselves point toward two kinds of interpretation. On the one hand, they may be simply accepted as artistic achievement, representing the New Jerusalem to the people of their day, built to the glory of God, and reaching up to heaven. On the other hand, though, they may seem to have a mainly political significance, connected with inequalities and power relationships in the society that built them.

Both kinds of interpretation have been applied to technology and the sciences. There are some scientists, according to Einstein, whose interests are contemplative, and who discover in their work 'the silence of high mountains . . . built for eternity'. Quoting this, Robert Pirsig asserts that the same is true in technology. 'The Buddha, the Godhead, resides quite as comfortably in the circuits of a digital computer of the gears of a cycle transmission as he does at the top of a mountain or in the petals of a flower.'[43] And Samuel Florman, the civil engineer, refers to William Golding's novel *The Spire*, which explores the motivations of cathedral building, and adds the comment that: 'Not only cathedrals, but every great engineering work is an expression of . . . purpose which cannot be divorced from religious implications . . . every manmade structure, no matter how mundane, has a little bit of a cathedral in it, since man cannot help but transcend himself as soon as he begins to design and construct . . .'[44]

It may be that part of the reality of the technologist's experience is truly a sense of reaching out toward the transcendant, but for those intent on political explanations, this is at best self-deception. More usually, indeed, the high-flown language will be regarded as little more than the symbolism of advertising. In the 1930s, electricity supply engineers liked their generating stations to be 'cathedrals of power' because they wanted 'symbols of the prestige and modernity of electricity'.[45] Today, the symbolism used in publicising a new automobile, with its play on virility and status, is only too familiar.

In discussing these matters, David Dickson notes that the building of the medieval cathedrals served to reinforce the hegemony of the church authorities. The cathedrals were a means of political control over vigorously developing urban communities, providing a carefully regulated outlet for their wealth, enthusiasm and civic pride. Similarly, a successful space exploration or nuclear project can today give a sense of pride and purpose to an individual nation, and can provide some distraction from more divisive issues.

Civil engineering in Nazi Germany presents a specific example. Giant aircraft hangers made 'the most daring and successful use of new material like shell-concrete'. Autobahns were built 'with magnificence and sweep which can leave no one unmoved. Germans, seeing these things and being proud of them', felt that the regime which produced them 'must be worth something'.[46] Dickson notes that heavy industry had 'an almost mystical significance' in the early years of the Russian revolution, and comments that the '*significance* attached to technology' under these circumstances often 'disguises the exploitative and alienating role technology plays' within industrial societies. That seems especially relevant to some of the euphoric language currently being used in Britain about information technology (IT) and microelectronics; 'there's no future without IT', one booklet asserts, in a propaganda exercise initiated on instructions from the prime minister, Margaret Thatcher.[47] One is reminded of another British prime minister, Harold Wilson, who aimed to promote the 'white heat of technological revolution'. That was the prelude, in 1964, to ambitious attempts to reform government administration of technology, and to promote a range of specific projects, including aluminium smelters linked to nuclear power stations. But the portrayal of technology in terms of virtuosity – the mastery of an elemental 'white heat' – seemed in the end symptomatic of a lack of economic realism.

Such experiences have led to a good deal of cynicism about grandiose claims concerning high technology. One engineer, suggesting a classification of technological achievements, ranks supersonic aircraft, 'very large' power stations and the space race as 'cosmetic machines' and status symbols.[48] Satirizing the same types of technology as they might emerge in a solar age, the Belgian group, Mass Moving, exhibited a particularly remarkable 'cosmetic' machine at Bath in 1974. All shiny metal and complex pipework, it had a large parabolic reflector focusing the sun's rays onto an elaborate boiler. But the creative pretensions of the equipment were out of joint with its practical utility. When it was set to work, it laboured mightily to raise a head of steam – but then used it only to blow a tin trumpet.

Exposure of the false pretensions and phoney symbolism surrounding high technology may often be wholly justified. But there is a third interpretation of the claims that are made and the archetypes evoked in such discussions which deserves attention. This is that they refer neither to any transcendant goal, nor to symbols disguising political aims, but that they simply celebrate the human drive and creativity behind successful innovation. When J. K. Galbraith uses the term 'technological virtuosity', he is chiefly referring to the way technical creativity may be pursued as a goal in its own right. He notes that while the primary goal for any industrial corporation must be economic expansion, technological virtuosity is an important subsidiary goal. This again may be partly for political reasons, because virtuosity attracts customers and helps secure the interest and loyalty of staff. But innovation which demonstrates virtuosity has 'standing in its own right'. As in the scientific work of a university, prestige accrues to the visibly creative organization. And while, in the American corporations Galbraith had in mind, this goal may be held in balance with economic aims, in parts of British industry its over-emphasis may have been a crucial flaw. Chemists working for the chemical firm ICI have remarked: 'We think of ourselves as being a university with a purpose.' Not surprisingly, ICI tends to compare badly with Du Pont in financial and marketing skills. Excellent aero engines have been developed by Rolls Royce, but with some serious financial hiccups, because 'ever since the First World War, commercial values had not been allowed to intrude upon dedication to technical perfection'.[49] Investigating the slow development of electricity supplies in Britain during the 1920s, an official committee found that, 'many of the industry's senior men still accord pride of place to engineering, with the emphasis on hardware and its technical efficiency, rather than on financial and sales questions and service to the consumer'.[50]

Several engineers with whom I have discussed this question speak of I. K. Brunel as the great exemplar of their profession. His career presents many instances of the pursuit of technical ideals regardless of more mundane considerations. Clifton Suspension Bridge, he said, should above all things be 'grand'. The magnificent Great Western Railway, he insisted, must have the broad-gauge tracks which he saw as ideal, despite commercial objections. The *Great Eastern* steamship, built between 1854 and 1860, was to be the largest and most luxurious ship ever constructed; it displaced 32,000 tons, and certainly was the biggest ship built until the very end of the century.

Near the end of his life, during two visits to Rome, Brunel spent many hours on his own in St Peter's. He was not a religious man in any conventional sense, and these solitary contemplations provoked comment from his travelling companions. But his biographer points out that a great deal of the spirit in which Brunel himself had worked was expressed there;[51] under the dome designed by Michelangelo, Brunel probably felt a strong resonance with his own goals and values.

To suggest that Brunel saw St Peter's as symbolic of the impulse that had gone into his own work is to say no more than Alvin Weinberg admitted in comparing nuclear accelerators and reactors to the cathedral of Notre Dame; it is to say no more than Samuel Florman, the civil engineer, who sees every great structure as a 'diagram for prayer'.

Yet it is precisely here that a major dilemma lies. For while we admire Brunel's steamships and bridges, and while we applaud Apollo rockets and jet aircraft, we are guiltily aware of the wasted resources and environmental damage for which many such projects are responsible. We are aware that some of the funds used could be more directly used to relieve suffering and give benefit to people. But so highly do we tend to value creativity that it is not in our nature to place limits on it. We tend to feel that the innovative impulse should never be burdened with too much political restriction or economic parsimony. The word creativity always evokes approval, never distrust; the need for it to be balanced by responsibility is not often stressed, and we do not seem to notice that it is a thin line indeed that separates the wholly admirable artistic or innovative impulse from the arrogance of an individual on his personal ego trip.

But if we go to the other extreme, and denigrate engineers for the apparent irresponsibility of some of their projects, we are failing to recognize the conflicts that they themselves feel between unbridled enjoyment of their creativity and a wish to benefit mankind. That Brunel felt more than just his awesome creative drive is shown by many small incidents, but most notably by his reaction to the dreadful conditions faced by the wounded of the Crimean War. He designed a prefabricated hospital of a thousand beds, and pushed its construction forward so vigorously that it was manufactured, shipped from Britain, erected and equipped within nine months.

In 1974, a notoriously pessimistic report on Britain's industrial future recognized something of the significance of all this. Too many prestige projects, and a lack of economic realism in engineering, had damaged the nation's prosperity. There was also the anxiety shared by the whole of the West about energy supplies and the environmental consequences of the economic growth we all wish to see. The dilemma that had to be faced was one which the writers of the report saw expressed in the virtuosity values of Brunel. In this 'near mythic "Great Engineer" ', they suggested, 'we see the Promethean figure' who gives us cause for admiration but also for 'persistent anxiety about where our civilization will lead us'.[52]

6
Women and Wider Values

Contrasting sets of values

In the ancient world, the achievements of those who today we would call technologists were sometimes celebrated in legends that described marvellous feats by mythical metal-smiths and the drama of their flaming furnaces. The Greeks' artisan-god, Hephaistos (known to the Romans as Vulcan), was often portrayed like this in stories that date from the bronze age. When he made a great shield for Achilles, he had twenty bellows working:

> and twenty Forges catch at once the Fires;
> . . . In hissing Flames huge silver Bars are roll'd
> And stubborn Brass, and Tin and solid Gold.[1]

Hephaistos was widely renowned for his 'craftsmanship and cunning', and legend had it that technology among humankind began when Prometheus stole fire from Hephaistos and gave it to man. But one other deity the Greeks linked with technical skill was the goddess Pallas Athene (or, to the Romans, Minerva). She stands for the intellectual and moral qualities required in practical work, and for meticulous craft skill. Homer wrote of a carpenter who was 'well versed in all his craft's subtlety' through Athene's inspiration, and mentioned a goldsmith who was taught his trade jointly by Athene and Hephaistos. In other passages, Homer wrote about the practical skills of real women such as the aristocratic Penelope, known for her weaving and her wisdom, and others who collected and prepared medicinal herbs.

There was real admiration for the skills of women, though it was always made clear that these were of a different order from those of men. On one of the Greek islands there was a community where the