CHAPTER 11

OPENING THE BLACK BOX OF TECHNOLOGICAL DEVELOPMENT

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"Our thinking about technology is filled with stereotypes." So begins Rip's essay on the analysis of technology as an approach-avoidance dilemma. Stereotypes exist because they make the world predictable, even if the prediction is partially wrong. Stereotypes about technology are a mixed blessing: They capture widespread views but justify the need for scholarly inquiry, thus functioning as black boxes. Stereotypes of technology range from "liberating" society to "controlling" and "fixing" societal ills. Thus, technology has been used as both a legitimating ideology and as a scapegoat in historical and economic analysis of social development and progress. Resisting such technological determinism as an explanation for social and cultural change is important. To do so requires a framework for critique of the culture, not just its technology. If the framework allows analysts to get inside the black box, they must then beware of a creeping sociological determinism that can color what they see.

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Our thinking about technology is filled with stereotypes, some more apt than others—technology as an autonomous force, a blessing for humanity (or a blessing in disguise); and at the other side of the spectrum of evaluation, technology as the bane of modern civilization, a destructive force or a moloch, as the moulder of one-dimensional man. Stereotypes exist for a reason: they capture features of a social entity that are important to society or to some groups or strata in society. As the phenomenon of anti-Semitism (and of racism in general) shows, the stereotypes may not have much substance, in the sense that Jews do not actually have many of the characteristics that are ascribed to them. The function of the stereotype (e.g., to create a scapegoat) is what maintains it.

Stereotypes about technology are a mixed blessing. The widespread view that technology stands for instrumental, utilitarian rationality may be a distortion of the complexities of historical developments. There certainly is a lot of *esprit d'ingénieur* in technology, but also *esprit de bricolage*, craft culture and associated romantic-mystery views.[1] Even so, the stereotype may be the beginning of scholarly inquiry into the rise of technology as instrumental rationality (and also, I would add, into the emergence and sedimentation of the stereotype). Such historical and sociological studies may eventually overturn the basis for the stereotype (or confirm it, for that matter). The social uses of the stereotype will not be changed by it, but a scholarly discussion of the role of technology in relation to other human activities must recognize the stereotypes for what they are.

Stereotypes function as black boxes. That is their strength: no argument is needed; their impact is immediate. But one must open the black box in order to explain how such stereotypes could emerge, to assess their harmfulness (or possible benefits), and, perhaps, to do something about it. By now, enough insights have accumulated in the studies of technological development to reach some conclusions about the processes at work and their outcomes. As this chapter will show, there are also lacunae. At some points, my argument will therefore be somewhat speculative. But I think there is enough evidence to support my thesis about technological development as one feature of societal development.

Process and legitimation

As a general strategy for social and historical research, it is important to distinguish between the level of processes at work and the level of legitimation and ideology.[2] Technology stands for processes of design and construction, for products (artifacts, chemicals, effective procedures), and sometimes also for their effects. But there is also an idea of technology, which not only legitimates but also influences action. Consider, for example, the following: "Technology will liberate us from our dependency on nature"; Lenin's dictum, "Progress is Soviets plus electrification"; the criticism, "Technology is controlling our destinies"; and the recent slogan, "Technology will help us overcome economic recession." It is clear that stands have been taken, and political measures have been implemented, on the basis of such ideas about technology.

To be more precise about the way I see the level of legitimation and ideology, I shall introduce the concept of "ideograph" (after McGee 1980) to replace the earlier discussion of stereotypes and their role. McGee articulates a rhetorical perspective:

> Human beings are "conditioned," not directly to belief and behavior, but to a vocabulary of concepts [McGee gives as examples "liberty," "non-American," "the people"] that function as guides, warrants, reasons, or excuses for behavior and belief. . . .
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> [There is] a rhetoric of control, a system of persuasion presumed to be effective on the whole community. . . .
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> Words used as agencies of social control may have an intrinsic force. . . . They are the basic structural elements, the building blocks of ideol-

From Arie Rip, "Opening the Black Box of Technological Development," in *Religion and Modernity: Survival or Revival?* Session 2 of the ACTS Eighteenth International Conference for the Sociology of Religion, Leuven, 1985 (Lausanne, Belgium: CISR, 1985), 107–119. Reprinted with permission of CISR and Arie Rip.

ogy. Thus they may be thought of as "ideographs," for, like Chinese symbols, they signify and "contain" a unique ideological commitment; further, they presumptuously suggest that each member of a community will see as a gestalt every complex nuance in them.

The point of introducing such a new concept of ideograph is that it allows us to see how events, situations, people, things, or arguments can be assembled into a forceful pattern, a network that is structured by its ideograph and derives its force from the pattern and the way it can be presented as an ideograph. To give an example, consider the ideograph "science&technology as catch-all problem-solver," or "science&technology" for short.[3] Nowadays, when some problem is identified in the public domain, science&technology will be invoked. As soon as the ideograph has been introduced into the debate, proposals to let science&technology solve the problem cannot be resisted (openly). The rhetorical structure is the same when in a debate about procedure, that party has a clear advantage that can capture the ideograph "democracy" for its own use, for instance by accusing the other party of proposing something that is not democratic, or at least less democratic than one's own proposal. The accused party has to defend itself, independently of the actual content of his proposal, because it is the ideograph that exerts the power.

The example of science&technology as problem-solver must be continued since the ideograph not only provides closure of debate but also of actual practices. When some programme of research and development has been set up to solve problem X, and it remains intractable, this is blamed on external obstacles, on lack of cooperation, and so on, not on the problem-solving capacity of science&technology. And often further research is started to help solve the problems about the perceived obstacles.[4]

To avoid misunderstanding, I note that science&technology do solve problems. And that it may be necessary to remove obstacles in the environment in order to benefit from the contribution of science&technology. The point of the example is that the force of the ideograph "science&technology" is independent of the actual successes in the situation at hand. This may lead to wasted or counterproductive effort. On the other hand, the ideograph provides social and political backing for measures that prove to be helpful in the end but would not be taken easily without such support. Ideographs are a fact of life, and life is sometimes actually the better for it.

Technological development at the micro- and meso-levels

Technological development has been studied from a historical and from a management perspective, and the field has matured in the last decade from the original and rather narrow approaches to in-depth as well as comparative analysis of dynamics of development. In addition, sociologists have become interested in processes of technological development. In the following, I shall build on these recent insights.[5]

One of the striking results is the absence of technological determinism at the micro-level. The inventor-entrepreneur of the nineteenth and early twentieth centuries (and appearing again in some present high-tech sectors) is not following a technical imperative but mobilizing resources for his own ends. Thomas Edison was motivated to search for high-resistance filaments in electric light bulbs (a move that went against conventional wisdom) because he continually compared costs and effectiveness with the then-dominant gas lighting (Hughes 1983, 33). The emergence of organized innovation has shifted the context and nature of the resources but not its contingent, entrepreneurial character. Individual inventors may have become employed researchers, but managers, systems engineers, and financial experts have taken over the entrepreneurial role in innovation (Hughes 1983).

Economists studying innovation processes have reacted against earlier "science&technology-push" views and emphasized "market (or demand) pull" (Freeman 1974). The push-pull polarity has now been replaced by interactive models, where "product champions" fulfill an essential role in overcoming barriers to innovation. In addition, the links with professional communities of technologists and the interaction with universities are being studied to optimize innovation, as well as to show their influence on style and direction of technological developments (Constant 1980).

The next step is to devise models for technological development. Evolutionary models (or metaphors) are prevalent, and the more sophisticated models take culture and social interaction into account. At the micro-level, search processes have been analyzed in terms of variation (of potential problem solutions, sometimes also of problem definitions) and selection, by the organizational environment and by wider market and institutional factors (Pinch and Bijker 1984). Attempts are being made to extend this approach to the meso-level (Bijker 1984).

In a different way, the economists Nelson and Winter have conceptualized technological development as evolutionary (Nelson and Winter 1977, 1982). They are interested in the meso-level and want to explain the occurrence of certain "technological imperatives." Their central notion is that successful heuristics will be followed and thus give rise to a sequence of technological development, or a "trajectory," that has the appearance of being technologically determined. An example would be the design of the DC-3 airplane: metal skin, low wing, piston powered engines.

> Engineers had some strong notions regarding the potential of this regime. For more than two decades, innovation in aircraft design essentially involved better exploitation of this potential: improving the engines, enlarging the planes, making them more efficient. (Nelson and Winter 1977, 57)

The original success, as well as the detailed shape of the trajectory, is determined by the "selection environment" (which includes both market and institutional factors). But there are clearly powerful heuristics that promise pay-offs from advancing the technology in a particular direction independently of the exact nature of the demand conditions. These heuristics then function as technological imperatives because they become the preferred strategies of the actors.

Van den Belt and Rip (1984) have further emphasized the contingent character of the imperatives by studying their emergence in the particular case of dyestuff chemistry and the dyestuff industry in the second half of the nineteenth century and by tracing the constitutive role of what they call the cultural matrix of expectations about the technology and about particular heuristics. In the early period of synthetic dyestuffs, for instance, all sorts of people were attracted to try (and err) in preparing new colouring matters on the basis of coal-tar products. Slowly, successful heuristics emerged and sedimented, for economic and professional reasons ("colourists" moving from one firm to another). Scientific explanation was only partial, and practitioners preferred to use their trusted "Rotöl" instead of scientific recipes. The conventional view of synthetic dyestuffs as a triumph of organic chemistry is a retrospective distortion. One of the effects has been a misleading suggestion of determinism in the evolution of the trajectory.

An intriguing example of the constitutive role of social and political factors is provided by the bridges on Long Island (Winner 1980). Many of these overpasses are extraordinarily low, but since they are part of the landscape, travelers may not give them a second thought. However, some 200 bridges over parkways on Long Island were deliberately designed and built low by Robert Moses, the master builder of roads, parks and bridges, and other public works from the 1920s to the 1970s in New York, who wanted to achieve a particular social effect. As a colleague told his biographer, "The old son-of-a-gun had made sure that buses would *never* be able to use his goddamned parkways." So only automobile-owning whites of "upper" and "comfortable middle" classes, as Moses called them, would be able to use the parkways and reach Jones Beach, Moses' widely acclaimed public park. (And he made doubly sure of this result by vetoing a proposed extension of the Long Island Railroad to Jones Beach.)

The point of this example is not that racial and class prejudices are introduced into technology but that technological development is characterized by inversions of cause and effect. What is constituted by technological entrepreneurs mobilizing resources within institutional and cultural constraints, and thus is a product, becomes a force on its own, independent of its origins. As Winner notes:

> For generations after Moses has gone and the alliances he forged have fallen apart, his public works, especially the highways and bridges he built to favor the use of the automobile over the development of mass transit, will continue to shape that city

> [New York]. Many of his monumental structures of concrete and steel embody a systematic social inequality, a way of engineering relationships among people that, after a time, became just another part of the landscape.

And when accepted as just part of the landscape, the artifact continues to exert its force and shape social relationships.

The inversion of cause and effect, or the transformation of a dependent variable (technology as a product) into an independent variable, can be located in an artifact that is not (or no longer) recognized as the assemblage of social and technical resources. As with the ideograph, the artifact is not powerful by itself. It has to be perceived and accepted as "natural" or "effective" in order to exert its force.[6] In other words, technological determinism is in the eye of the perceiver.

The conclusion of this rapid and somewhat fragmentary review is that not only is technological development socially constituted, but so is its appearance of determinism. However, this should not be taken to imply that it is easy to resist the force of technology. Opening the black box of the artifact and recognizing its social origins do not dissolve the power of the networks in which the artifact or procedure is embedded and from which it derives its force. A translucent box does enable people to conceive of resistance and to employ their own forces more effectively to such an end.

Technological development at the macro-level

How do technological developments at micro- and meso-levels add up to macro-processes? Much less is known here. Innovation studies and traditional histories of technology provide few guidelines, and there is room for general historians and for philosophers and sociologists of culture to analyze, speculate, or both.

The argument in the previous section can be read as showing that the question about macro-developments does not differ in kind from the general sociological issue of the relation between "micro" and "macro" (Knorr and Cicourel 1981). Instead of discussing general issues, I will present the work of two sociologically or philosophically inspired historians. This creates some perspective on actual technological developments and gives an idea how to address the macro question.

Hughes's 1983 study of the electrification of Western society in the period 1880–1930 provides numerous examples of meso-developments with implications for macro-developments: first in the institutionalization of direct-current systems in the United States and Germany (not in London, where the social context was not amenable), and then in the "battle of the systems," direct versus alternating current. The rise of the latter can be traced to segments of the professional community that were able to create a privileged position by their expertise in the complexities of alternating current and to possibilities for firms like Westinghouse to compete in spite of Edison's dominance.

An important determinant of the developments (both in d.c. and a.c.) was the capital intensity of the power plants. Good load factors were necessary, and were realized by the creation of networks: technical networks of cables and junctions to link actual and potential customers and social networks of supply and stimulated demand. (The "load-hungry utilities" were instrumental in installing nightshifts in chemical plants.) The outcome:

> A great network of power lines which will forever order the world in which we live is now superimposed on the industrial world. Inventors, engineers, managers, and entrepreneurs have ordered the man-made world with this energy network. (Hughes 1983, 1)

The networks of power that Hughes describes show the power of networks. And their power derives from the way they assemble and organize physical, intellectual, and symbolic, as well as economical and institutional, resources of the society in which such networks grow. As the example of capital cost and load factors shows, the pattern of the resulting network reinforces the importance of such considerations. Although in each particular case the outcomes are contingent on the mobilization of resources, there will be an aggregate trend.

The other possibility of finding out about macro-developments is to start with overall societal development and, as it were, fill in for technological development. Some obvious candidates turn out to be disappointing, at least for the moment. In Marxian analysis, technology remains a black box, while Elias's civilization theory appears to neglect technology. Very interesting results have been obtained by the mixed approach of Dutch historian and social philosopher Bertels. He traces secular changes and transitions in society in relation to changes in technology in the same way that Foucault analyzes "epistemes" (Foucault 1966).

Three transitions are especially important for technological development. In the eighteenth century, and more emphatically in the nineteenth century, there emerged new techniques, not just machines, but also the attendant organization of labour and the introduction of efficiency and utility as goals. Changing views of labour, and of man, can be traced in the same period, and perhaps made possible the rise of the new techniques. The late nineteenth century saw the second transition: rationalization, not just by the marriage of science and techniques (technology), but also in the organization of the factory (Taylor's scientific management). This rationalization, fueled by the emergence of mass markets, especially since the 1920s, diffused into other sectors of society and provided the framework for the new, scientific technologies of electronics, chemistry, nuclear, and space. By then, however, a third transition had appeared, visible from the 1950s onward. It can be characterized by the shift from energy to information; by the importance of strategic thinking, planning, and policy development; and, not unrelated to the emphasis on strategy, by the dominance of the military in technological development (Bertels 1981, Pieterson 1981).

This brief resumé must suffice to indicate a framework that can be (and is being) filled up with historical studies of social-cum-technological development. Even if speculative, such a framework provides incentives to extend perceptive analyses on the meso-level, like those of Hughes, to the macro-level.

Culture critique instead of technology critique

The conclusion of the preceding sections is that technological development should be seen as one aspect of societal development. One implication is that whatever instrumental (or "functional") rationality is embodied in technology is there because it is part of our institutions, which often have emerged together. Weber's views on rationalization and disenchantment, for instance, can be linked both with the rise of bureaucracy (as Weber does) and with the rise of (scientific) technology (as Bertels does). Technologies and institutions legitimate each other and mutually reinforce trends in societal development.[7]

In contrast, the conventional view seems to picture technology seducing society to enjoy its fruits and inducing cultural and institutional changes towards increasing instrumental and utilitarian rationality. This view neglects the inversion of cause and effect and mistakes ideograph for processes at work. Thus, a concern about technology versus substantial rationality may remain ineffectual because condemned to a battle of ideographs. (In fact, rationality, whether instrumental or substantial, is itself an ideograph, a banner behind which one can mobilize resources for change or for maintaining existing order.) One should recognize the processes at work, in which decisions and strategies determine contingent outcomes,[8] and study the emergence and role of ideographs, both "technology" and "rationality," as phenomena in their own right and important for an understanding of culture.

Doing away with technological determinism may lead one into sociological determinism: technological developments are socially constituted, and the inversion, or transformation to an independent variable, depends on the acceptance of technology as powerful. But there are always possibilities for social and cultural change in our societies, even if one may be pessimistic about the chances of success of any particular one. An example is the increased importance of religion and religiously inspired groups in peace movements and the opposition to nuclear energy and nuclear arms. The power of religion is that of an ideograph, as well as a resource ("motive") that influences individual decisions, including processes of technological development.

So the difficulty of changing socio-technical developments is not one of principle. In practice, our lack of knowledge of the dynamics of technological development at the macro-level, and the prevalence of ideographical argument, severely hampers effective action. If the black box is not opened, one is condemned to fight a battle of ideographs only.

The physicist Eddington has used a powerful metaphor:

> We have found a strange foot-print on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the foot-print. And Lo! it is our own. (Eddington 1959, 201)

Technology is an impressive accomplishment, but recognition of its social construction is the first step to a real understanding. Changes, however, must still be achieved against the constraints of existing networks of sedimented socio-technical developments.

NOTES

1. Lévi-Strauss's terminology, as adapted by Barnes (1974).
2. This strategy is adapted from Bertels (1981), but neglects his third level of personal experience and mentalities.
3. In the age of scientific technology, science is often taken to include technology, e.g., when "science policy" also implies technology policy. To indicate this lack of differentiation, I write science&technology as one word.
4. These practices have been documented for British science&technology policy by Mencher (1975), who coined the term "Scientific Opportunity Syndrome" to characterize them.
5. An important stimulus has been the International Workshop on New Developments in the Social Studies of Technology, Twente University, July 1984. The proceedings, edited by Wiebe Bijker, Trevor Pinch, and Thomas Hughes, will be published by MIT Press.
6. Note the similarity to Berger and Luckmann's (1967) concept of reification. The thrust of the argument is that artifacts and institutes should be analyzed in the same way. For the general argument, see Callon and Latour (1981) and for the application to science (and a discussion of the importance of the networks), see Callon, Law, and Rip (1985).
7. In the same way, science (as ideograph and as process) and the rising bourgeoisie of the eighteenth century forged an alliance.
8. Any framework to analyze technological development should start from here. Compare Laeyendecker and Laeyendecker-Thung (1984).

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