WHY TECHNOLOGY LENDS ITSELF TO CRITICISM

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This first contribution does not yet present a critique of technology; I want only to demonstrate that technology is by its nature amenable to criticism and differs therefore in this respect from, say, the weather or gravitation.

First I will provide precise definitions of the concepts "technics" and "technology", hoping that other participants in the debate can get along with them; next I will discuss five views which in respective order allow more and more room for social influences on technological development and thus for criticism. Finally, I will link up social criticism and the criticism of technology by presenting the thesis that the technologist is an agent of social change in spite of himself.

I. "Technics" and "technology"

I.1. *Terminology*

What should we understand by "technics" and "technology" [1])? This is my proposal: "technics" is the generic, a-historical category, which is therefore not amenable to criticism, and "technology" is the specific form technical activity has assumed in modern societies and which can therefore be criticized.

"Technics" is something universal, something which to all people, all societies and all cultures has always been available and will (necessarily) be so in the future, namely: "procedures - with or without the use of instruments - for transforming external nature to satisfy human needs". I will briefly discuss the elements of this definition.

I.1.1. *External nature*

Technics is involved in the metabolism of humans or societies with the (an)organic nature that surrounds them, which is called "external nature" to distinguish it from the "internal nature" of the human bodies. Because these bodies must be fed, protected, born and nurtured, man must, just like other biological species, enter into a metabolic relationship with the natural environment. Humans intervene in their environment by picking fruits, catching fish, building houses, tilling the soil, cultivating and breeding

plants and animals etc. The complexity of this intervention may vary: hunters and gatherers consume without qualms what nature offers them, agriculture requires a more complex series of actions and stereo-towers are highly complex combinations of a variety of carefully processed materials.
(By restricting myself to "external nature" and "metabolic processes" I do not want to imply that it would not be meaningful to speak of "social techniques" - i.e. action precepts aimed at influencing behaviour -, but only that it appears sensible to me to exclude these from the present discussion. We will see that metabolic techniques possess already many social elements!)

I.1.2. *Procedures*

First and foremost in my definition figure *"procedures"* - standardized patterns of human actions. Thus I do not draw primary attention to machines and apparatus - which usually come to mind directly - but to the routinized human actions in handling them. First of all this has an historical reason. The techniques used by primitive people to catch animals and fish did not involve the use of instruments *at all*. From a historical point of view human skill and social organization precede the use of tools. This argument also has systematic relevance: action routines without tools are thinkable, but not the reverse. Technics is therefore, first of all, "what you have to do in order to ...", sow, clean your teeth, or play the piano; it involves individual and/or collective skills. We always find those standardized human actions in "labour", that which people untertake, individually or (mostly) collectively, by means of division of labour, to satisfy their needs. Labour always involves technics, in the sense of "transforming external nature for the sake of need satisfaction", but of course that does not exclude that this social activity "labour" can also assume the form of religious rituals, power relationships, repression or aesthetic enjoyment. In the notion of "technics" we limit ourselves to one aspect only, i.e. the instrumental ("zweckrationelle") aspect, of those conceivably much more rich and meaningful human activities; it is not meant thereby that labour is *nothing but* a skillful handling of tools and procedures.

I.1.3. *Instruments*

The definition refers to *instruments*, but considers them secondary and optional. Instruments are man-made, material objects for the purpose of lightening labour operations. We may think of tools (hoe, hammer, typewriter) that strengthen bodily functions, machines that substitute for human energy and only require overseeing, and finally automatons that independently execute complex operations.

Our definition therefore conceives all technics as socio-technics, which is unthinkable without being embedded in human action. Instruments are objects with directions for use which discipline human action. A coherent set of instruments and actions is called a *socio-technical system.*

A system may be a directly visible part of society (a factory, a railway-network), but that is not necessary. Also in premodern societies, in which all action had a sacral or ritual character, the system *aspect* can be distinguished analytically. Whatever the pattern of culture, people are bound to exhibit a certain systematic behaviour in handling their cattle, water and crops, or else will simply die.

I.1.4. *Need satisfaction*

The transformation of external nature (matter, energy) by means of instruments and labour operations is not a purpose in itself, but functions in the service of human *need satisfaction.* It is oriented to results: products, services, facilities. Human bodies (internal nature) require for their maintenance nutrition, protection, nurturance, health, safety, transport and possibly higher, so-called cultural needs. But, of course, *all* needs are need interpretations fixed in cultural patterns, and are at the most based on a certain biological substrate.

I.1.5. *Knowledge*

Finally: all technics presupposes *knowledge* of a certain type, instrumental knowledge. That is knowledge of cause-effect relations involved in dealing with material objects, or let us say: in dealing with nature. One uses insights which predict that one particular phenomenon follows another more or less regularly.

Of course I do not mean that in primitive cultures too such knowledge had a scientific or explicit character; it does not need to be theoretical or rational knowledge, but may be derived from cumulative experience; it may change as a consequence of accidental occurrences. Knowledge about which plants are poisonous and which are edible, how to catch certain animals; how to construct a 64 megabyte memory; this is all knowledge of the same,

instrumental type.
It may be stored in handbooks, but also in ritual practices or in a sacral contemplation of nature: insight into the regularities of the interaction between man and nature is a component of *all* cultures which is indispensable for the survival of the human species.

Technics has thus been defined as a universal category, inextricably linked with the human condition. Technics is necessary - because although the sun rises automatically, humans can maintain themselves only through coordinated efforts.
A consequence of this abstract definition is that we meet in reality a whole array of different technics provided with all kinds of epithets. One may speak of technics on various levels: the technics of the sower, of arable farming, of agriculture as a whole or even the technics of a given culture. Technics is also differentiated according to production sectors; the technics of arable farming, animal husbandry, the building trade, manufacturing industry etc. It is even differentiated according to entire cultural periods: paleo-technics, the technics of Antiquity, artisanal technics and modern technics.
For technics in the latter sense we will use today the term "*technology*"; as a particular, concrete historical form which technics has assumed in modern societies. We do not therefore consider technology as the very form of technics, or as the highest form, but only as provisionally the latest form of technics in *our* society, while realizing that, partly through our own agency, a new form of technics may eventually arrive in history. At issue in the debate is therefore how our technology can be distinguished in a meaningful way from the technics of other societies and what the characteristics should be of the technics of a future just and free society, anticipated by philosophy and critical theory. Should our technology be characterized as capitalistic, centralistic, large-scale, science-based, alienating? Is a liberating, appropriate, humane and environmentally friendly technics thinkable? I won't start the debate, that is the task of technology criticism proper.

First I want to show briefly how fruitful (and non-arbitrary) the conceptual definitions that I introduced may be. For definitions cannot be said to be true or not true, but only useful or not useful for certain debates.

I.2. Historical controversy

With the definition given above it turns out that we can largely resolve the historical controversy between the critical theorists Habermas and Marcuse on technics and the criticism of technology. In his *One-dimensional Man* (1964), the book that was such a great stimulus to the student movement, Marcuse stipulated that the traditional conception of the neutrality of technology could no longer be maintained. Technology cannot be considered apart from its use.

> "Technology in itself, not just in its use, is control (of nature and of man)" [2]).

The instruments for controlling nature are, according to Marcuse, simultaneously means for exercising power over people.

> "Today, domination perpetuates and extends itself not only through technology but *as* technology ..." [3]).

Underlying technical instruments and scientific concepts there is a certain "project" [4]) of a society in which the individual can live only in unfreedom and subordination. A free society requires therefore the severance of this fusion between technology, knowledge and power, and the development of new, non-dominating science and technics, based on a different concept of nature, by which different laws and facts may be uncovered. According to Marcuse, science and technics have assimilated a historical, transitory, repressive a priori.

It is to this views that Habermas objects in his famous essay in which he develops his technocracy thesis, "*Science and Technology as 'Ideology'*", written on the occasion of Marcuse's 70th birthday.

Habermas expostulates to Marcuse that his alternative technics is inconceivable, as the characteristic of the "domination of nature" is inextricably linked with labour, by means of which humans have to maintain themselves against external nature in whatever historical period.

Of course, an alternative way of dealing with nature, e.g. aesthetic or communicative, is not inconceivable on principle, but no form of technics can be based on such a relationship, Habermas asserts [5]).

I think that in this controversy both partners are right to a certain extent. The precise extent can be clearly formulated with the help of the notions "technics" and "technology" introduced above.

On the one hand, Habermas points out to Marcuse - rightly so, I think - that alternative technics will remain technics and therefore imply control of nature through disciplined action. On the other hand Marcuse points out to Habermas - again rightly so, I think - that his universal category "technics" need not preclude that it may assume a particular concrete form ("technology") in a particular society like ours, such that it may help to perpetuate inequality and power relations. A different society will therefore require different technics, liberating technics that will put an end to the repression of man by man. In my opinion Marcuse has to concede that the control of nature is not intrinsically connected with the domination of humans, but only temporarily and locally in our type of society.

Paraphrasing Habermas, we can summarize the entire debate in one sentence: for technics there is no more humane alternative, for technology there is.

II. Views on technological development

Next I will discuss five views on technological development, to see how power relations (standing for all the things that can be criticized) may enter the design of technologies. Of the order in which I will present these views, it can be roughly said:

a) that they have been developed in this order in socio-philosophical and historical thinking about technology
b) that they also become more and more adequate and less one-sided
c) that they allow more and more room for non-technical factors.

II.1. *Technological determinism*

The view of technological determinism can be characterized thus:

Technology develops autonomously, according to its own immanent logic; it determines its own dynamics. There is only *one best way* for solving humanity's problems, i.e. the solution of maximum efficiency. Technological development follows a fixed, one-dimensional course, a straight line along which only stagnation and progress are possible. In the process of social development technology is therefore the independent factor, corresponding to its role as "exogenous factor" in traditional economic theory. Society has only to adapt itself structurally to the *Sachzwang* [6]) of technology. There is a systematic *cultural lag* [7]); culture always lags behind the progress of technology.

This determinism can be found in optimistic and pessimistic variants. Pessimists (of the Brave New World type) foresee that civilization will be overwhelmed by the technological Moloch. Optimists (like the Dutch government and its supporters, the 'Science-and-Technology' sections of the newspapers, but also certain tendencies within Marxism) greet technological progress as a pre-eminent instrument for prosperity, welfare and/or a free society. Social thought is restricted to eliminating the obstacles for technological progress and absorbing its consequences. The optimists are backed by a host of historians of technology (of a rather a-historical calibre) who explain entire cultural revolutions from technical innovations, which apparently need no further social explanation than a reference to unique inventive geniuses. Thus Lynn Whyte explained the whole of feudalism from the invention of the stirrup [8]).

In my opinion this view cannot be upheld [9]). There are two reasons:

a) efficiency is not a separate norm standing apart from other social and cultural norms; we will shortly meet some examples;
b) technical development does not follow a fixed, necessary course; repeatedly alternatives will occur which do not lend themselves to an unequivocal choice.

II.2. Technology as applied science

The thesis which equates technology to applied science has been most explicitly formulated by Bunge [10]). He considers technology as a derivative of scientific development, which is taken to be autonomous and viewed as the motor behind technological innovation. Science is seen by Bunge as oriented toward truth and toward universal regularities, technology as oriented toward practical usefulness. Technology mediates between, on the hand, objective scientific knowledge, obtained by independent research, and, on the other, the a-rational knowledge of (social, moral and legal) precepts of society and the thinkerers' rules of thumb derived from the arts and crafts. Technological progress is the consequence of the further penetration of science ("scientification") and the de-coupling of common sense which is its complement.

This scientistic view is also untenable in my opinion:

a) First, the philosophy of science of the last 70 years has considerably detracted from the privileged epistemological status of science. Science appears bound to paradigms whose adequacy cannot be justified theoretically, but amounts to a normative question [11]).

b) Through its experimental character science has become intrinsically linked to constructive success: apparatus and facilities have to be designed, often in an artful way, which bring about the conditions under which scientific hypotheses can only be tested, or, more exactly, which construct the objective reality to which theory refers [12]). Without making dirty hands in practical construction experimental science will not thrive and prosper.

c) Technological development appears not only to depend on scientific progress, but has its own dynamics and even feeds back as a determining factor on scientific development.

II.3 Externalist approaches

Fuelled by the concern about technology, in the last twenty years a lot of historical and sociological research has been undertaken to undermine technology's claim to neutrality (according to the previous views) [13]). A wealth of concrete material demonstrates that various factors beyond the scientific and technical setting have influenced the design and introduction of technologies. I call these approaches externalist.

One study showed that the New York architect Robert Moses deliberately designed the 200 underpasses in Central Park with less than 2,70 metres height, to provide access to rich whites in private cars, but not to poor people and blacks in city buses [14]). A political ideology permeates the architectural design.
Your refrigerator makes a humming sound because it is a compression apparatus provided with a electric pump and not an absorption refrigerator heated by gas (which you can sometimes meet on camp). This is not due to its technical superiority, for in this respect the absorption refrigerator of 1925 scored much better. But its producer did not command the amount of capital needed by General Electric to finance the development and marketing of refrigerators for use in personal households. Here we haven before us a case in which the nature and form of the technology have been directed by economic considerations [15]).

A separate and extensive research tradition [16]) around the theme "technology and labour" has by now produced numerous instances of production techniques that were installed by capitalist entrepreneurs to discipline or "rationalize away" refractory (or well-organized, or strike-prone) employees. The nicest example in my opinion is Arkwright's spinning machine [17]), the symbol of the Industrial Revolution in 18th century England. From a technical point of view it was nothing new. It had been developed already 50 years before, but at that time it had been rejected by the independently working cotton spinners because it would be driven by steam- or water-power and therefore turn them to slaves of the machine. For the very same reason that the artisans rejected the spinning machine, it was very suitable for the cotton-spinning industry on a capitalist basis that emerged 50 years later, a welcome instrument in the hands of entrepreneurs struggling with soldiering personnel. The notion of efficiency had assumed a new meaning. This was clearly seen, at least, by the Luddites and machine breakers.

But also in the 20th century many instances are recorded of production technologies that were installed by entrepreneurs to get rid of categories of skilled labourers who derived power from their indispensability: numerical control of lathes against highly skilled machinists (Noble [18]), a new generation of computers against the programmers [19]), etc.

The externalist approach is however insufficient; it does not point the way to an alternative philosophy of technology, but demolishes only the received view of autonomy by patient historical research, without offering anything in its place. Moreover, it usually restricts itself to designating one non-technical factor.

II.4. *Systems approach*

In this respect at any rate, the systems approach is broader [20]). It considers technologies as components of socio-technical systems. These are networks of connected elements, which are partly technical (instruments, machines, flows of raw materials and products) and partly social, in as far as acting people, organizations and institutions are involved. An agricultural technology can thus be understood as the point of intersection in a network of safety requirements, market relations, boundaries of labour organization, government prescriptions, demands of processing industries and banks, etc. Technological development is explained as proceeding from functional shortcomings in a system. So we have a much richer set of conceptual tools. But because I want to take one further step in my story, I will concentrate here on the *soft underbelly* of the systems approach. I consider it a useful and indespensable approach, but not sufficient to understand technological development. Why not?

a) Within the systems approach you can plug in a lot of empirically ascertainable cause-and-effect relations between material (physical, biological) objects and functional social actions, oriented to bringing about certain effects. But human and social action cannot be understood exclusively in terms of causality and function. A system is surrounded by a human life-world which is supported by values, norms, personal ideals and visions of the future, which are perceptible from a systems point of view only when they give rise to effective economic demand, legal regulation, frictions on the labour market or occupation of factory buildings.

b) For a system (in the systems approach) *nature* is only a source of raw materials and space, whereas for people nature also represents different (e.g. aesthetic) values.

c) The system provides *products* and *services* in certain amounts and with certain specifications, but the systems approach is unable to analyze the question why these are meaningful satisfiers of human needs.

d) In the systems approach *people* appear only as the performers of certain standardized actions, which are viewed by the system exclusively from

their function or useful effect. The question whether this particular job is a meaningful form of work and whether this particular labour organization is democratic or repressive, cannot be answered by the systems approach - which is notoriously blind for power relations.
To epitomize my criticism: the systems approach could lead to a kind of technological determinism in a modern dressing, "systemic determinism"; the elaboration and expansion of a functionally ordered social domain is held to follow its own dynamics, which denies the existence of an evaluative "outside", for which the system was of course intended in the first place. "Efficiency" as the leading norm in technological determinism will then be replaced by "functional integration" in the systems approach.

II.5. *Contextual approach: a promise*

Now I come to the fifth view on technological development, which in my opinion is the most fully-fledged: the contextual approach.
I think that this is the *richest* approach: it does not deny that science is applied in technological development, but it does deny that science is a directive and unequivocal input; it does not deny that external factors like ideologies or power relations play a part, on the contrary, it considers them as "business as usual", not as an aberration; it does not deny the working of systemic factors (like competitive and market relationships, regulation, etc.), but rejects the claim that these may provide conclusive explanations for technological development.
The central thesis is that there is no clear-cut boundary between the social and the technological; that there are no "inside" and "outside" with "outside" acting upon "inside". There is no such thing as a technological method (prescribing or precluding certain developments) which can be distinguished from various so-called social factors. Technology itself is a *social construction*.
When you are on camp with a couple of people, after having arrived at a camping-site on which not all places are free, you will have to negotiate with each other about where to set up the tents; everybody puts in his own values, wishes, needs and information, sometimes of a contradictory nature: out of the sun, entry to the east, a flat place, room to sit, close to the water, not too close to the swimming-pool, close to other children, not too close to neighbours, etc. Information about the sun's position, the type of soil, the area of the tent etc. is being worked upon in what we call a

social process: a decision will finally come out which in the best case is satisfactory to everybody and in the worst to nobody. Nobody would like to claim that this is a regular, methodical process; many would surmise that in technological development things are going much more systematically. But that is not true. In the laboratory social and technical factors are also inextricably knotted together. Even more: what the participants consider to be technical factors is itself an active social factor.

I want to illustrate this thesis with some examples drawn from a new branch in the sociological study of technology [21]), which focuses on situations in which technologies are still in the making, so that perception is not impeded by the taken-for-granted assumptions which surround already established technologies. The new approach also pays attention to the conflicts inherent in technological development, to controversies and partisanships and to the contributions of those who will be victimized by a new technology.
Because this research programme is still in a rudimentary state, the range of examples from which I can draw is limited; they do not pertain to agriculture.

Contextual approach: example 1.

My first example is drawn from a study by Weeder and Kester [22]) on the Tenax project, on which employees in the AKZO laboratory were working in the sixties.
Researchers tried to make polyphenylenes (a kind of polymers) suitable for isolating underground power lines, by casting foils of them. But some years later they are working on a different material to spin yarn for textile applications.

a) The first thing to note is that apparently the goal of a particular research project is not something fixed and externally given, but a shifting result of a negotiation process between the researchers and their environment (in this case: the marketing department of a firm). The aim that is sought is in fact only known when the technology has been completed.
b) A research goal is not changed straight away; meetings are being held on it and arguments are being offered, but these have a local character only:

such-and-such has been tried, so-and-so has been contemplated, one expects something, ons has no confidence that, etc. It's a decision-making process like the one on the camping-site, guided by fragmentary information, guesses, information whose reliability is judged by the status and experience of the informant. It's a rather erratic process, far from methodical. Latour [23]) calls it "opportunistic"; heterogeneous, incommensurable arguments are being used, apples and pears are being added without further ado. The only justification is in terms of local circumstances, then and there and in that laboratory.

c) "Objective facts" are hard to find. The assertion (about one of the polyphenylenes): "PPO melts at 80 degrees Celsius", obtains the status of a proven fact after three men have tried in vain to change this during two years, using the standard methods of the lab. The *facts are social constructions;* it is perfectly possible that they would turn out to be different in another lab. In the abstract there may be unshakable scientific facts ("The Second Law of Thermodynamics precludes the perpetuum mobile") but most of the more concrete so-called scientific statements are much more woolly; they allow for different interpretations in different circumstances. Almost everything is negotiable. Scientific facts are nothing but highly dubious guesses which have completed a successful career. The fact "A=B" once began as a risky hypothesis of a few researchers: "A might possibly be B", went through "there are indications that "A=B" and "it is almost generally assumed nowadays that A=B", until finally - unless the career became interrupted somewhere - all the modalities were removed and the "fact that A=B" became stabilized. In principle, however, the entire process is never closed definitively; the status of a statement can always again be demoted.

d) *The social* and *the technological* turn out to be *interchangeable.* Working on textile applications, one initially takes as a social fact that textile yarns must be resistant to the cleaning liquid TRI. But when after two years one has not succeeded in adapting the material to this requirement, whereas it proves washable at higher temperatures, this social fact is being deconstructed; now it is the marketing department's turn to search for a niche in the detergents market in which solubility in TRI is no drawback. It is possible to solve social problems technically, but it is also possible to solve technical problems socially. In practice both tasks are continuously shifted back and forth.

e) The example draws attention to the importance of "in-house knowledge" within the firm, of the standard methods at one's disposal and of the market segments to which one is oriented. In analogy with Kuhn's paradigm it would be possible to speak of *technological styles* and of a laboratory culture which determine the outcome of the design process.
At this point I refer to what will be called the professional community by Albert Mok and *L'art de la localité* by Jan Douwe van der Ploeg.

Contextual approach: example 2

I will further illustrate my thesis of the socially constructed character of technology with the "electric car" project of the French national electricity firm *Electricité de France* (EDF), studied by Michel Callon [24]). This project is brought out in full relief, because there is a permanent adversary and rival on the scene, the Renault (petrol) car firm.

When in 1973 EDF presents its research project for the next 20 years, we can see how a technological research programme is intrinsically connected with a socio-political programme for societal change. EDF grounds its estimations of the demand for electrical vehicles on an analysis in which the social criticism of the sixties still echoed.
The petrol motor car is written off as an obsolete, noisy, energy-spoiling and city-polluting specimen of *petit bourgeois* possessiveness; there is a need for a more clean, efficient and quiet vehicle with more possibilities for collective use.
This socio-political analysis is combined with an evaluation of the technical state of affairs: the petrol motor is at the end of its development, not amenable to much further improvement; the efficiency of batteries, by contrast, can be much improved in the short run; fuel cells (a kind of batteries in which two chemicals, e.g. H and O, react to give an electric current) are at the start of a promising development. They will be applied in, successively utility vehicles (dust-carts, PO cars, taxicabs), city buses and later also private cars. Renault, of course, is not much pleased by such an analysis; somewhat later, when the socio-political tide (energy crisis)

has turned and the criticism of the student movement ebbed away, Renault will strike back. Renault's analysis is diametrically opposed to that of EDF. The general tendency is that, where EDF sees socio-political problems, Renault perceives technical questions only, and vice versa.

Renault perceives noise, low efficiency and exhaust gases caused by cars as temporary technical problems whose solution (with the aid of electronics) is already progressing rapidly. The technical prospects of accumulators and fuel cells are considered by Renault as no more than pies in the sky; Renault denounces these scientific-technical estimations as social constructions: EDF has yielded to the pressure of a couple of ambitious researchers. Conversely, Renault accuses EDF also for having minimized a gigantic social problem (to wit: the enormous infrastructure necessary for building service stations everywhere in order to change fuel and electrolyte) into a minor technical question.

Where one actor sees a technical problem, another actor perceives power relations and social strategies only. Note that the juggling with the labels "social" and "technical" is not a peculiar hobby of sociologists, but that the project leaders and the project definitions themselves stick these labels to the problems in society. This labelling is done in a particular way: "technical" are called all those problems one expects to be able to deal with with one's own know-how, "social" are called those aspects that have to be solved "outside", through social reorganization, building of political volition, further interpretation of needs, and the like. In social intercourse these labels have a particular rhetorical value: "technical" stands for soluble within a sphere of expertise, reliability, non-political, non-controversial". In this sense we have to recognize that the distinction between a technologist and a social strategist is a futile one. In reality we meet only with actors who, depending on what suits most, at one time act as technologists and at another time act as social strategists, and who usually hide the second role behind the first. A technological problem can be identified only on the basis of an antecedent socio-political stand. The separation between social and technical aspects implies the triumph of a particular interpretation or construction of social reality. Whoever postures as a technologist is an *undercover* politician.

The electrical car project also points to the *mobilizing effect* of a socio-technical analysis: EDF organizes decision-making on the basis of its plan. It unites around itself:

a) electrical engineering firms that will develop the motors
b) some municipalities willing to do the experiment
c) the state, represented in the Ministry of the Environment
d) an array of sub-contractors to whom detailed problems can be delegated
e) and even - for the design of the car bodies - Renault, which prefers the certainty of this subordinate position to the risk of missing the bus altogether.

On the basis of a socio-political analysis a power bloc is formed which will intervene into social reality. Whether we will, by the year 2000, see these actors as unworldly dreamers or as pioneers in the modern solution of the transport problem, will depend among other things on the success they will achieve in transforming society according to their own plan. The empirical evidence for a socio-political analysis is not directly available but can be supplied: by adapting society to the story. Both EDF's and Renault's analysis (or more generally any legitimation of a technological project) bears the formal characteristics of *social criticism*: which is not judged only by its empirical validity here-and-now, but also by its mobilizing potential, its capacity to concentrate forces which can model reality in conformity with the design. Being in the right and being put in the right are connected. Or, as Jan Douwe van der Ploeg will state: that social analysis is real which has real consequences. Good social criticism is a *self-fulfilling prophecy*: It makes itself come true by means of the actions of those whom it addresses.

In this manner my thesis on "technology as social construction" acquires an additional meaning. In its first meaning the thesis referred to the fact that the process in the laboratory is directed by all kinds of social interests, group interpretations, ideologies and power relations. In its second meaning the thesis refers to the fact that not only objects, hardware, instruments and apparatus are being constructed, but simultaneously also social reality is being constructed. Here the technologist appears as a social reformer. Technology also constructs the social: labour relations are changed, new markets are opened up, state inventions are enforced, competitive relations (national and international) are altered.
The technologist who introduces into society an artefact based on scientific (and social) knowledge (a new machine, a new product, a new process), introduces also, often unnoticed, a second artefact, i.e. new social

relations. His apparatus has a stowaway on board, an unexploded shell, which, should it explode, will be legitimated as the "necessary adjustment of society to technological progress". An account of technological design and development must, to be true to reality, recognize that in the laboratory scientific-technical and social factors are inextricably tied together. During the design process of technologies, negotiations are taking place about what is scientifically possible *and* socially desirable. Scientific possibilities and social desirabilities are repeatedly rearranged until a *thing* has been obtained which has a *meaning* in the human community. This negotiating process involves interventions in the material domain (technical tinkering) and in the social domain of the production of meaning: interpreting, or tinkering with, values. Technologists do not search for means to ends which are pre-given or determined by others. It is much more realistic to view their activity as the search for a suitable combination of producible object and desirable aim. Just as a key-maker sells the key simultaneously with the lock to which it fits.

III *Criticism of technology and rational technological development*

At this moment it would be necessary to present a philosophical model of technological development which does justice to the social-constructivist results that where sketched above. Such a model could be largely drawn from the work of Radder [25]) and of Kunneman [26]), but limited space does not allow me to discuss it here. I will restrict myself to the question what the significance of this view of technology is for the criticism of technology. With the examples given I hope to have made clear - and many of you can probably confirm this from their own experience - that during the design process of technology numerous choices have to be made, decisions taken, judgments passed, which cannot be legitimated in a compelling way on theoretical, scientific grounds alone. These thresholds of scientific uncertainty are conquered in practice by means of all kinds of *ad hoc* decisions, local conventions, intuitions, experience, but also strategic considerations (e.g. the interests of our lab or our firm) and views on socio-political reality. Often group views of the world and group interests will be involved.

Of course, not all bumps in the construction process of technology are equally important from a societal perspective. Many times improvisations will be inevitable; these can usually be trusted to the rules of thumb, experience and local conventions of the researchers. But there are moments when choices are made which clearly relate to the social perspective of the participants and of the project. Harry Kunneman called them the "normatively relevant" [27]) choices. These should be the focus of technology criticism.

For technological determinists such influences on technological development - assuming that they are willing to recognize their existence - would be an abhorrence, for they would constitute a blemish on the rational blazon of technology. In their strategy only a further elimination of all these kinds of irrational, pre-scientific and ideological judgement by means of further "scientification" would be thinkable. Technology criticism, by contrast, does not consider these non-technical and non-scientific factors *per se* as contaminations or threats to the reality of technology, because these factors themselves can be rationalized, without being "scientified". Social theorists generally, and Habermas [28]) in particular, consider social structures and human needs as practical questions which can be rationalized in their own right. Technology criticism cannot deplore the fact that in certain concrete situations in the past (e.g. under capitalism) technology had a normative character. In principle, technology will always have a normative, value-laden character.

Rational technological development - in my view the aim of technology criticism - does not therefore mean continuing "scientification" of technology, but grounding its indispensable socio-political components on a rational social analysis. Because I do not have the time to elaborate such an analysis here, I will confine myself to a brief indication. Technologies and socio-technical systems are entitled to be called "rational", if they satisfy three criteria of rationality simultaneously:

a) They must be based on valid knowledge about those parts of reality which can be objectivated, i.e. the material part (nature) and the functional forms of human action. This criterion is disproportinately emphasized in our science-imbued society. In this respect much knowledge is already available. I do not want to imply, however, that empirical scientific research should be stopped now. On the contrary. Agreeing with Marcuse we can expect (and advocate) that different social conditions will induce other kinds of scientific research, following different paradigms and different finalization strategies [29]). Much of our current knowledge could turn out to be useless, if not untrue.

b) They should be based on universal norms with regard to social life, that is to say: norms to which in principle every participant would give his free approval, because they would place no one in a privileged situation relative to others. It may not be too bold to state that production technologies, which are designed one-sidedly by management, without anything resembling a democratic authorization from the side of the employees, do not satisfy this criterion.

c) They should be based on authentic, non-manipulable need interpretations, that is to say: conceptions of the "good life" which are the outcome of autonomous, non-blockaded forms of individual and social self-determination. Hardly reconcilable with this criterion is the permanent bombardment of passive consumers through the mass media with product-oriented personality ideals and life-styles developed by commercial interests.

Technology criticism, then, aims at two things:

1. To make visible all those choices in the technological design process which cannot be founded on internal scientific grounds or for which a scientific grounding should not be sought, in as far as they have a normative relevance.
2. To examine and to discuss the rational character of these normatively relevant choices, in order to assure that theoretically testable statements are knit together by correct interpretations of what is needed for a just society and the satisfaction of authentic human needs.
   Power relations which are not legitimated, short term and group interest, figuring as stopgaps in theoretical lacunae, should be replaced by universal and reasonable need interpretations.

Finally, I think that I have also made clear what relevance technology criticism might have for technological practitioners. We have seen that they - although they are hardly aware of it - tinker not only with material objects and processes determined by natural laws; they tinker just as well with human values. A technologist is a broker between the desirable and the possible, in search of the attainable. Neither the one, nor the other is a datum to him. But by thus describing him, we have recovered his true character. Someone who compromises between the desirable and the possible? That must be a politician! We should therefore subject the technologist as an *undercover* social reformer to the same rules as apply to the politician: his choices must be tested in a public debate by the criterion of a reasonable and inspiring perspective on the future.

NOTES

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