

Do not despair: there is life after constructivism¹

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Prologue

On Monday 16 October 1989 Trevor Pinch and I were driving on the freeway Interstate 880 through Oakland, California. The world in which we were living was self-evident and without ambiguities (at least after we had managed to get into the right lane and thus avoid being forced onto the Bay Bridge and into San Francisco). We hardly noticed the road, while passing over its Nimitz section. We did not notice the pillars of the Cypress Structure, as the double deck freeway was locally called; we did not notice the houses down by the freeway; nor were we particularly interested in its history.

The next day, 17 October 1989 at 5:04 p.m., the earth trembled. I was thrown off my feet and onto the bed on a 6th floor hotel room in Berkeley. An earthquake had hit. The Interstate 880 and its Cypress Structure collapsed. The unambiguous, self-evident world through which we had been cruising the day before, was ruptured. Before our eyes, when glued to the TV-set and frantically making notes, all of the elements which had made up the Interstate 880 were revealed – as indeed they were to the general public. Its technical components were uncovered – everybody learned that the concrete pillars in that structure were only reinforced with vertical steel rods without an additional spiral rod. Its political elements were revealed – Washington politicians started to use words like 'blame' and 'investigation.' Its economic elements were uncovered – some engineers claimed they had known about the weakness of the structure, but that funds had been lacking to carry out the planned reinforcement. Its social elements were revealed – a man stood up from the audience and accused the expert panel in a direct TV broadcast: 'I was the first to start helping those people in their cars, I live in those houses you know, I live in those houses you always drive by, looking down upon us; but nobody came to me and asked how it was, though I was the first there; and you always drive by, looking down upon us; you always drive by, looking down upon us'.²

The Quake did an effective job in revealing the constitutive elements in this sociotechnical world – it did to the Cypress Structure what students of

technology are trying to do to bicycles, missile guidance, subway systems, electric power networks, steel, computer software. Can students of socio-technical change, while causing less damage, be as effective as the Quake?

Introduction

Over the last ten years technology studies have experienced a veritable boom – economic studies of technical change and integrated sociological-historical studies are the most visible bodies of work. In this paper I will concentrate on the latter, realizing that the important question of how to relate these two disciplinary contributions is thus left aside for the moment.³

In a rough and whiggish historical sketch, the integrated historical-sociological studies of technology can be depicted as a child of two parents: the (mainly American) history of technology and the (mainly European) sociology of scientific knowledge. An international workshop in 1984 has been mentioned as the birthplace of the child.⁴ As most children, at that moment it was promising but not much more than promising. The main thrust of the workshop papers was programmatic, although the published versions were already more empirically grounded. An informal research programme could be distinguished consisting of three approaches – the systems approach, the actor-network approach and the social-constructivist approach. From a distance (either geographically, from America; or disciplinary, from philosophy or economics) these three lines within the programme were often collapsed onto another and simply labelled as 'social constructivism.' To answer the question whether this new research programme was able to generate fruitful empirical research, a second workshop was held in 1987 and the answer to this question was unambiguously 'yes.'⁵ Now the question is raised 'Where to go from here?' – towards some kind of post-constructivism, or perhaps to more constructivism?

In this paper I will start with a brief assessment of the present state of the art in sociological-historical studies of technology. Is there 'something rotten in the state of technology studies?' I will then specifically address the question of explanations, come briefly to the issue of practice and theory and conclude by suggesting an answer to the question 'Where do we go from here?'

State of the art – State in despair?

The sociological-historical studies of technology may be producing an increasing number of case-studies, but there nevertheless are some persis-

tent problems that, some commentators seem to think, threaten to incapacitate the whole endeavour.⁶ I will briefly discuss four of these problems – relativism, reflexivity, theory and practice.

Two problems with the *relativist* elements in recent social studies of technology are often mentioned. The first relates to ontological relativism, the second to normative relativism. As I will discuss in the next section more extensively, the pleas for relativism in technology studies are however primarily methodological. I tend to agree with Collins (1985) that epistemological, or ontological, relativism cannot be confirmed or falsified by empirical studies. Thus social-constructivist studies of technology do not imply any ontological position. The normative problem, as for example formulated by Russell (1986), stems from the idea that the plea for methodological relativism implies a form of political relativism, for example with respect to questions of the societal impact of technology, the deskilling of labor by technical innovations, or the democratic control of technology. My reaction to this accusation is similar to Voltaire's when he was accused of letting all norms and values to be eroded because he proclaimed that God does not exist. Voltaire reportedly replied that the fact that God is dead, did not mean that everything was now allowed – it only meant that things were not allowed for different reasons than the biblical. Also on the basis of relativistic studies of technology it is possible to argue for political and ethical positions with respect to technological choices.⁷

The problem of *reflexivity* has primarily been formulated with respect to science studies and can be summarized as follows. Modern students of science deconstruct the special character of scientific knowledge. To do so, they need to maintain a privileged stance for the knowledge their own studies produce, and hence they refute their basic claim. They saw the branch on which they sit, and they saw it between their seat and the tree.⁸ I must confess that I have no satisfying answer to the reflexivists' critique. Neither the implication to restall scientific knowledge into its old glory, nor the implication to be mute for the rest of my scientific life seems acceptable. Probably the solution to the problem is to be found not in general terms, but in special treatments of the *specific* case at hand.⁹ Insofar the reflexivists continue to issue *general* statements about science and technology studies, I propose to elect them to the honorable position of jester at the court of science and technology studies: making us laugh and weep and think at the same time, while not committing themselves to dirtying their hands by making necessary decisions.

The problem of *theory* has been on the agenda of recent sociological-historical studies of technology from the beginning. One of the criticisms we formulated against the history of technology was that while historians

typically did open the 'black box' of technology to investigate the contents of technology (as opposed to, for example, economic and philosophical studies of technology), they almost never got out of that black box again to compare with other case-studies and thus form a generalized understanding of processes of technical change. Now that we have a growing body of empirical case-studies, the question how to make theoretical generalizations becomes very pressing indeed. I will devote the central part of my paper to this problem.

The problem of *practice* may be particularly Dutch. Science and technology studies in The Netherlands did not so much emerge from the academic disciplines of mainstream sociology, history or philosophy. Rather, their origin lies in the Dutch 'science and society' movement which resulted in the early 1970-s in the establishment of critical STS programmes in most science and engineering faculties.¹⁰ By the end of the 1970-s an increasing need was felt for a more empirical and theoretical foundation of the critical STS research and teaching. Seen in this perspective, the science and technology studies of the 1980-s are an academic detour to collect ammunition for the struggles with political, scientific and technological authorities. Of course, one may define this academic path not as a detour but as the right route – then there is no 'problem of practice.' But if one feels still bound to the old STS ideals, as I do, the question becomes pressing whether the detour has not been long enough by now; whether we cannot start to relate present findings in science and technology studies to political issues of democratic control of science and technology? I will briefly discuss this problem at the end of my paper.

So, is our State in Despair? Are the problems of relativism and reflexivity stifling our movements, albeit in an interesting project? Or is the problem of theory turning our endeavour into merely story-telling, and thereby into a far less ambitious project? Is, finally, the problem of practice demonstrating that the project is not only unambitious, but even completely useless? I think not. The problem of relativism has been dealt with by Bloor and Collins years ago. The problem of reflexivity we can live with and even benefit from. And the problems of theory and practice can be addressed head-on. I will now turn to this task, building on three case-studies – the bicycle, Bakelite and fluorescent lighting.¹¹

Towards a theory of sociotechnical ensembles

The three steps mounting up to a proposal how to attack the problem of theory will be the following. First I will, using the bicycle case, argue for the need to analyse technical change as a social process. Key concepts are 'rele-

vant social group' and 'interpretative flexibility.' At a philosophical level, supporting the proposed analysis, the principle of symmetry plays an important role. Second, the case of Bakelite is used to develop the theoretical concept of 'technological frame.' I will discuss what requirements a theory of technical change should meet and how 'technological frame' does fit those conditions. Third, drawing on the application of the concept of 'technological frame' in the fluorescent lamp case, I will argue that we have moved now so far that the original definition of *technical artifacts*, with which I started this work, is too narrow. Instead, I will propose to take *socio-technical ensembles* as the unit of analysis. At the philosophical level this means a shift from only the Principle of Symmetry to also endorsing the Principle of Generalized Symmetry.

The development of the bicycle shows how impossible it is to explain the course of events and the development of designs by referring to intrinsic properties of the artifacts. The high-wheeled Ordinary could be argued to be a dangerous, non-working machine and thus prone to loose out in the market place. This is however not what happened. The Ordinary also was a well-working Macho machine, attractive to a specific group of users. This became clear by focusing on the social groups relevant for the bicycle development. I described the various bicycles through the meanings attributed to them by these relevant social groups.

Using these relevant social groups as entrance for the description, it is possible to demonstrate the interpretative flexibility of artifacts. This concept of 'interpretative flexibility' is central to the social constructivist project, and indeed to most of recent social and historical studies of technology. Demonstrating the interpretative flexibility of an artifact mounts up to showing that one seemingly unambiguous 'thing' (a technical process, or some material contraption of metal, wood and rubber like in the bicycle case) is better to be understood as several different artifacts. Each of the different artifacts hidden within that seemingly one 'thing' can be traced by identifying the meanings attributed by the relevant social groups. The concept of 'interpretative flexibility' is crucial in countering technical determinism. Indeed, to recognize the interpretative flexibility of artifacts is synonymous with refuting technical determinism.¹² Hence the concept's key role in the social studies of technology – only when technical development can be considered as being not autonomous and not driven by purely internal dynamics, can it be subjected to social analysis. The use of the concept 'interpretative flexibility' thus is so much as the *raison d'être* of the social studies of technology, the justification of its existence.

The concept 'interpretative flexibility' finds its philosophical and methodological basis in the Principle of Symmetry. This principle was

formulated by Bloor (1973, 1976) for the social studies of science. Bloor argued that, in order to analyse scientific belief systems, the sociologist of scientific knowledge should be impartial as to the truth or falsity of beliefs. True and false claims were to be analysed symmetrically – that is, with the same conceptual apparatus. Thus it was to be avoided that the acceptance of one (presently considered true) claim was explained by its truth content, for example in terms of a better correspondence with nature, while the acceptance of another (presently considered false) claim was explained by referring to, for example, the social circumstances of its conception. 'Nature' should not enter the explanatory endeavour as *explanans*; rather, it was to be the *explanandum*. 'Nature' was considered to be not the cause of scientific beliefs, but the result.¹³ Pinch and Bijker (1984) extended this principle to the analysis of technology by arguing that working and non-working machines were to be analysed symmetrically. The working of a machine should not be the *explanans*, but should be addressed as the *explanandum*. The working of a machine was not considered as the cause of its success, but as the result of its being accepted in relevant social groups.

Along these lines I have described the history of bicycles. This case-study was then used to extract a general model for describing cases of technical development. To have such a descriptive model is necessary if a set of comparable case-studies is to be described with the aim of making them into a basis for the development of generalizations. The descriptive model should allow the analyst to get into the black boxes of the various case-studies, but also to subsequently get out of the box again to compare the description of one case with the descriptions of others. Thus the model should strike a fine balance between getting down to the nuts-and-bolts-level of technology and staying at enough an analytical distance to allow for cross-case-study comparisons.

The Social Construction of Technology (SCOT) model was developed to meet these requirements. I shall briefly summarize its main characteristics, partly introduced in the previous paragraphs. In the SCOT model, *relevant social groups* form the starting point. Artifacts are, so to say, described through the eyes of the members of relevant social groups. The interactions within and among relevant social groups constitute the different artifacts, some of which may be hidden within the same 'thing.' In that case, the *interpretative flexibility* of that 'thing' is revealed by tracing the meanings attributed to it by the various relevant social groups. With reference to a general methodological adagium – that instability is more revealing about a system's characteristics than stability – it was specified that in tracing those meanings we should concentrate on the *problems* and associated *solutions* that relevant social groups see with respect to the artifact. Such a description

would then result in mapping-out increasing or decreasing *degrees of stabilization*. An artifact does, in this descriptive model, not suddenly leap into existence, as the result of a momentous act by a heroic inventor; rather, it is gradually constructed or deconstructed in the social interactions of relevant social groups.

In a subsequent case-study I used this SCOT model to describe the development of Celluloid and Bakelite. The main purpose of that study was to move one step further than the thick descriptions as provided by the descriptive model. Assuming that we are now able to generate an empirical base of different case-studies in terms which allow us to make cross-case-study comparisons and generalizations, the next task is to develop a conceptual framework for making such generalizations. What can be said about the characteristics that such conceptual framework requires? I will discuss three such characteristics, related to respectively (1) the 'seamless' character of the 'web of technology and society', (2) the change/continuity dimension, and (3) the actor/structure dimension.

It is impossible to make *a priori* distinctions between, for example, the technical, the social and the scientific. Did Baekeland's condensation reaction result from a scientific fact (as he claimed himself and was decorated for (Baekeland, 1913))? Or was it the result of successful technical tinkering (as we may now think, knowing that Baekeland's explanation has been superseded by macromolecular theories)? Or was it neither a scientific, nor a technical accomplishment, but first of all a social and economic one – negotiating competitors into partners during patent litigation and building networks of manufacturing companies to use the new material? This characteristic of technical development has been described with the metaphor '*seamless web*' (Hughes, 1986; Bijker, Hughes and Pinch, 1987b). The web of modern society is not made up from distinct pieces of scientific, technical, social, cultural and economic cloth – rather, whatever creases we see are made by the actors or by the analyst.¹⁴ Another way of expressing the same is to observe the activities of engineers and to recognize that a successful engineer is not purely a technical wizard, but an economic, political and social one as well. A good technologist is a 'heterogeneous engineer' (Law, 1987).

The consequence of the previous observation is that we require our theoretical concepts to be as heterogeneous as the actors' activities and as seamless as the web to which the concepts will be applied. If this would be otherwise, the old distinctions would be led in by the back door of generalization, after having been kicked out through the front door by the descriptive model. Our conceptual framework should thus not compel us to make any *a priori* choices as to the social or technical or scientific character of the specific patterns it will make visible to us.

The second and third requirements relate to the change/continuity and the actor/structure dimensions. The social-constructivist approach, as advocated above, stresses the contingent character of technical development. Through demonstrating the interpretative flexibility of a technical artifact we show that an artifact can be understood as being constituted by social processes, rather than by purely technical. This seems to leave more latitude for alternatives in technical change than when the constraints would be purely technical. Moreover, by breaking down classical distinctions, as argued in the previous paragraphs, the old theoretical vocabulary to discern fixed patterns of dependent and independent variables has to be discarded. This seems to be a historian's delight, as much as a sociologist's curse: no structuralist explanations for human action but free reign for the individual actor.¹⁵

The other side of the coin is however that the heterogeneous engineer seems to be an actor without a history of her own: since there are no constraints, there are no limits to the spectrum of possibilities; everything is possible, change is all there is, and permanence has disappeared. The social-constructivist analysis may be able to account for technical change, but is it unable to explain constancy in history? Do rupture and revolution have a place in the analysis, while flow and evolution do not? Here the approach seems to turn into (some) historian's curse and (some) sociologist's delight.

Our conceptual framework should enable us to explain *change* in history as well as the lack of it – *continuity* in history. The preliminary work for this issue of change/continuity is provided in the SCOT descriptive model by the concepts of 'stabilization' and 'closure.' The 'degree of stabilization' was introduced as a measure of the acceptance of an artifact by a relevant social group. The more homogeneous the meanings attributed to the artifact, the higher is the degree of stabilization. The concepts of 'closure' and 'stabilization' are closely linked. Originally 'closure' was introduced in the sociology of scientific knowledge (SSK) to denote the ending of a scientific controversy with the emergence of consensus in the scientific community. SSK studies have shown how with the closure of a controversy, an immediate rewriting of the controversy's history takes place. As soon as consensus emerges, the interpretative flexibility of scientific claims ceases to exist and Nature is invoked as the cause of consensus and not as the result.¹⁶

It is important to recognize that consequently this process of closure is almost irreversible – almost, but not completely. Nowadays it is difficult to think of air tyres as other than unambiguously normal parts of bicycles. When you have a punctured and flat tyre you are of course reminded of the technical features of 'keeping the air on the right side of the rubber', but this does not make you think about solid tyres – only about technically better air

tyres (and about your repair kit, left home). It is, in other words, hardly possible to envisage the world as it existed before the closure of the controversy. This seems to introduce a static element in social-constructivist accounts of technology. Is the process of closure a flip-flop mechanism, digitizing the continuous flow of time? It is primarily to counter this problem, that I introduced the concept of 'degrees of stabilization' of an artifact. Following the histories of the various artifacts, we thus see growing and diminishing degrees of stabilization. By using the concept of stabilization in this way, I could argue that the invention of the Safety Bicycle can be understood not as an isolated event (for example in 1884), but as an eighteen-year process (1879-1897). This process was traced by noting the dropping of modalities in contemporaneous writings about the safety bicycle.

So, the social-constructivist analysis does highlight the contingency of technical development (by demonstrating the interpretative flexibility of an artifact) and thus stresses the possibilities for change, but is also able to describe how this freedom of choice is narrowed down by closure and stabilization processes. These stabilization processes have a dual character: they include irreversible processes of closure which impose a step-like character onto technical change, but they are also continuous in-between, as is described by growing and diminishing degrees of stabilization. This is the second requirement to be met by whatever conceptual framework we are going to adopt: to combine these two elements – the contingent interpretative flexibility and the constraining stabilization, or the change and the permanence, or the step-like and the continuous. This requirement is difficult to meet. The typical way to tackle such a task is to give a static description and then add the time dimension to it – leaving the concepts intrinsically static. Such a method would try to explain the ability of a bicyclist to ride upright by drawing on a model of the bicycle as a pair of scales which is balanced by the bicyclist by equating the left and right hand forces.¹⁷ The equilibrium of a rolling bicycle can only be understood by using intrinsically dynamic concepts such as 'angular momentum.'

The third requirement, relating to the *actor/structure dimension*, builds on the same aspects in the descriptive SCOT model. The emphasis on the socially constructed character of artifacts, through demonstrating artifacts' interpretative flexibility, stresses the contingent character of technical change. Does this imply that anything is possible; that each configuration of artifacts and social groups can be built-up or broken down at will; that there is no end to interpretative flexibility and to the generation of new alternative artifacts and subsequent different design lines within one material contraption? This, of course, cannot be: a theory of technology proposing such a view of our technological society evidently underestimates the

solidity of a society and the stability of technical artifacts. Indeed, this is where the concepts 'closure and stabilization processes' enter the stage again. After having demonstrated the interpretative flexibility of an artifact, the second step in the SCOT model is to investigate how one of the artifacts eventually does stabilize and how others destabilize and disappear from history. By this stabilization process a new structural environment for further technical development emerges. This should be the third requirement: to combine in a theoretical analysis the contingency of technical development with its being structurally constrained, or, in other words, the strategies of actors and the structures by which they are bound, or Free Will and Fate.

The concept of 'technological frame' is proposed as theoretical concept, meeting all three requirements I have formulated. First, a technological frame is heterogeneous in the sense that it does not exclusively belong to the cognitive or the social domain.¹⁸ Part of a technological frame are exemplary artifacts as well as cultural values, goals as well as scientific theories, test protocols as well as tacit knowledge. Second, technological frames are no fixed entities – they are being built up as part of the stabilization process of an artifact. It is the interactive character of 'technological frame' that makes it into an intrinsically dynamic concept. A technological frame is not residing internally in individuals, nor externally in nature – a technological frame is largely external to any individual, yet wholly internal to the set of interacting individuals in a relevant social group. Thus a technological frame needs continuously to be sustained by interactions, and it would be very surprising if its characteristics remained unchanged. Third, technological frames provide the goals, the thoughts, the tools for action. They enable thinking and action like Wittgenstein's (1953) 'form-of-life' does. A technological frame offers both the central problems and the related strategies to solve them, as I showed for the Celluloid frame. But at the same time the building-up of a technological frame will constrain the freedom of members of the relevant social group. A structure is being created by interactions, which will in turn constrain further interactions. Within a technological frame not everything is possible anymore (the structure-centered aspect), but the remaining possibilities are more clearly and readily available to all members of the relevant social group (the actor-centered aspect).

In my third case-study I applied the concept of 'technological frame' to the fluorescent lamp. I showed how the *intensity* fluorescent lamp was designed in what economists would call its diffusion stage; how the actual designers were managers at a business meeting rather than engineers at their drawing boards; how the technological frames of General Electric and the electric utilities shaped the lamp; how the 'stuff' of this invention was economics

and politics, as much as electricity and fluorescence. It is time now to transcend the dichotomy between the social and the technical. Accepting this distinction was necessary to argue explicitly against technical determinism, to demonstrate interpretative flexibility, to argue indeed for the non-existence of seams between the social and the technical in the web of modern society. But having climbed that way, we can throw away this ladder and take a fresh look around us.

We now see a landscape of sociotechnology. All relations we see are both social and technical. Purely social relations are to be found only in the imaginations of sociologists, among baboons, or possibly on nudist beaches; and purely technical relations are to be found only in the wilder reaches of science fiction. The technical is socially constructed, and the social is technically constructed – all stable ensembles are bound together as much by the technical as by the social. Where there was purity, now there is heterogeneity. Social classes, occupational groups, firms, professions, machines – all are held in place by intimately linked social and technical means. The landscape we see now, is different from the one described when discussing the bicycle case. A Principle of General Symmetry is substituted for the Principle of Symmetry; technical artifacts are replaced by sociotechnical ensembles as unit of analysis; and the sociology of technology seems to move imperialistically into the domain of general sociology.

The sociotechnical is not merely an intimate combination of social and technical factors – it is something *sui generis*. Sociotechnical ensembles, rather than technical artifacts or social institutions, will be our unit of analysis. And sociotechnical processes will constitute the patterns discerned by our theoretical concepts. The technical and the natural do not enter through the back door since they do not exist anymore in our vocabulary. Each time 'machine' is written as short-hand for 'sociotechnical ensemble', we should, in principle, be able to sketch the (socially) constructed character of that machine. Each time 'social institution' is written as short-hand for 'sociotechnical ensemble', we ought to be able to spell out the technical relations which go into making that institution into a stable set-up. Society is not determined by technology, nor is technology determined by society. Both emerge as two sides of the sociotechnical coin, during the construction processes of artifacts, facts and relevant social groups.

The Principle of General Symmetry extends Bloor's Principle of Symmetry, discussed at the beginning of this section. This symmetry principle advocates that true and false beliefs (or, in the case of technology, successful and failing machines) are to be analysed in the same terms. Callon (1986) extended this principle to another level: the construction of

science and technology on the one hand and the construction of society on the other hand should be analysed within the same framework. Neither technical reductionism (where society is explained by a reduction to technical development), nor social reductionism (where the technical is considered to be determined by the social) should be our method. Linked to this principle was the plea to give symmetrical roles to human and non-human actors in case descriptions. This proposal has been and still is the subject of fierce debates.¹⁹ The debate does potentially divide students of sociotechnology into two camps – an Anglo-Saxon and a French. For the first camp, it mounts up to a heresy against the best of Winchian (1958) tradition in the social sciences to allow machines as actors into the story. For the latter camp, the analyses within Bloor's symmetry scheme are hardly more than internal accounts and do not provide insight into such crucial questions as the relation between micro events and macro-societal developments.

While this philosophical debate will rage for a while, we have to proceed along the more mundane paths of generalizing on the basis of empirical case-studies. But how can we proceed? Does the Principle of General Symmetry imply that no explanatory reduction may be made, that description displaces explanation? Is the analysis of sociotechnology restricted to 'how' questions? Are questions about why some sociotechnical combinations become obdurate and institutionalised while others do not, impossible to answer because of their complexity? Latour, for example, has proposed to elide the classical 'why' questions.²⁰ The job of the investigator is not, he argued, to discover causes, for there are no causes. Rather it is to unearth the heterogeneous operations, strategies and concatenations and to expose their contingency.

But there is another route possible. This route accepts the need to use part of the sociotechnical web as a relatively stable blackcloth for the events happening in the forefront. Thus for specific questions some parts of the sociotechnical world are assumed to be fixed and the development of other parts can be set against that blackcloth. For example, in the case of the fluorescent lamp I was primarily interested in the construction of the lamp, and not in the (re-)construction of General Electric. This does not mean however that General Electric is not as much a sociotechnical ensemble as the fluorescent lamp, nor that its properties are immanent rather than constructions.²¹ But this is not enough. I have to move one step further, lest I would be paying only lip-service to recognizing the seamless character of the sociotechnical web while in practice continuing with, for example, the classic sociology of institutions or history of technology. This further step involves the creation of new seams, or rather pleats, in the web by ironing it with the 'technological frame' concept.

Previously used theoretical frameworks have to be cast aside since they assume intrinsic properties as *explanans* where, from the here proposed perspective, we are looking at such facets as being constructed, as the *explanandum*, as to be explained. Theories which set out, for example, to explain technical development on the basis of the interests of the relevant parties assume those interests as given. The same applies to Marxist-inspired theories about class or power relations.²² Let me briefly focus on 'power' as explanatory concept. Could it have been of any help in explaining the fluorescent lamp case? For example, the situation around the commercial release of the fluorescent lamp is ambiguous. One could say that General Electric's hand was forced by the combination of World Fairs, fear for a scarred public image and the threatening competition by Claude Company's high voltage neon discharge lighting. On the other hand, General Electric was able to 'nurse' fluorescent lighting past the barricades which were thrown up by the utilities. But in doing so, they had to make concessions as to the specific artifact which they were going to manufacture – the intensity lamp instead of the efficiency lamp. How is 'power' to be invoked as an explanatory concept? Is General Electric Company more powerful than the utilities? Or the other way around? To formulate the problem like that is begging the question: instead, what we should try to explain is the distribution of power as emerging together with technological frames and sociotechnical ensembles.

So, I do want to make generalizations about processes occurring in various case-studies of sociotechnical change. But how do we escape the *cul-de-sac* of a catch-all concept that is routinely applicable in all circumstances, a sedative for curiosity and a substitute for thought? How do we distinguish patterns in the sociotechnical web without invoking the old, as immanent interpreted, properties 'technical', 'social' or 'scientific'? Dissecting such patterns will inevitably introduce new asymmetries.²³ These have to be accepted; and they can be accepted since they do not have the ontological status of the previous distinctions.

The theoretical model I am proposing has been roughly outlined before (Bijker, 1987a).²⁴ I will briefly summarize it here. The concept of 'technological frame' is used to reorder the sociotechnical landscape. As a first-order analysis, three different configurations can be distinguished – when *no* clearly dominant technological frame is guiding the interactions; when *one* technological frame is dominant; when *more* technological frames are at the same time important for understanding the interactions related to the sociotechnical ensemble that is being studied. In each of these configurations, different processes of technical change are typically found.

The first configuration (and here the case of the early history of the bicycle

provides an example) occurs when there is no single dominant group and there is, as a result, no effective set of vested interests. Under such circumstances, if the necessary resources are available to a range of actors, there will be many different innovations. Furthermore, these innovations may be quite radical.²⁵ More than in the other configurations, the success of an innovation will depend upon the formation of a constituency, a group that comes to adopt the emerging technological frame.²⁶ Strategies of enrolment are crucially important for actors in this configuration.

In the second configuration, one dominant group is able to insist upon its definition of both the problems and the appropriate solution of those problems. Under such monopolistic circumstances innovations tend to be conventional (work in the Celluloid era is illustrative). Problems may arise from functional failure (Constant, 1980), and the solutions are judged in terms of their perceived adequacy to solve such failures.

In the third configuration, when there are two or more entrenched groups with competing divergent technological frames, arguments that carry weight in one of the frames will carry little weight in the other. Under such circumstances criteria external to the frames in question may become important as appeals are made over the heads of the other social group to third parties. In addition, innovations that allow the amalgamation of the vested interests of both groups will be sought. Such innovations (the construction of the intensity fluorescent lamp is an example) are, so to speak, doubly conventional because they have to lodge within both technological frames.

Return from the academic detour: the turn towards practice

Let us now turn to the problem of practice, which, I have argued earlier in this paper, should be as high on the agenda as the problem of theory. If I am in favor of addressing the problem of practice, this is not to say that we are to turn to straightforward policy studies. We should not sell out to the powerful and forget about our (Dutch) background of being in critical opposition to those authorities.

The most obvious role I see for technology studies in practice is an analytical one. The deconstructive capacity of our work can be effectively used to show interpretative flexibility, to suggest alternative technological choices, to debunk the sociotechnical ensembles constructed by the powerful. Not many of our studies have been presented with this explicit aim, but the work by, for example, Ashmore, Mulkay and Pinch (1989), Latour (1987), Collins (1990), MacKenzie (1990), Mack (1990) and Blume (1991) can be read in this way.

These scholarly works are however not the only examples. If we take this task serious, we should explicitly pay attention to questions of the public understanding of science and technology, to an analysis of the social construction of control (Bijker, 1989b), and to instruments providing possibilities of control to the general public. Much of Brian Wynne's recent work (1983, 1988) has been explicitly directed towards such goals. Collins (1987) addressed the problem of the public image of science and technology as it is constructed in the media. Bijker (1981) and Collins and Shapin (1983) discussed how secondary school science education could contribute to a public image of science and technology which would be more inviting to a democratic participation in public discussions on issues of technological and scientific controversy, than the present image of science is. And we should not be afraid to engage in even more unorthodox and less academic projects. Examples of such projects are the 'Technological Culture' project in Amsterdam (Schwarz, 1990) and the 'Eurometrics' project. The latter aims at organizing a series of interlinked exhibitions in all twelve countries of the European Community in 1993 – exhibitions which, among other things, will demonstrate the scientific and technological work going into 'taking the measures of Europe', into the standardization and harmonization of Europe. The 'Technological Culture' and the 'Eurometrics' projects both build explicitly on recent studies of science and technology.²⁷

Conclusion

This conference has been organized because 'the shift to an American setting [as contrasted to the increased European input over the past decade] should allow for the kind of critical appraisal of social constructivism that is badly needed.'²⁸ Issues that were raised in the original conference proposal included: the possible need for reassessing technological determinism as 'a viable and fruitful perspective on technology and society'; and the possible need for a 'model that allows "the substance" or "content" of technology independently to shape subsequent political, economic and social choices.' More specifically, this final session was labelled as 'Post-constructivism' and devoted to answer the question 'Where do we go from here?'

My answer may be clear by now. Technological determinism is too viable a vision to be flirted with (see the Epilogue, below). If technical determinism will be as prevalent as I think it presently still is, the image of technology will continue to be dominated by elements of 'autonomy', 'internal dynamics' and 'being beyond control.' Such an image of technological change does not stimulate citizens' participation in processes of democratic control of technology. A similar point has been made about the need for the general

public having a more constructivist image of science (Bijker, 1981): if scientific facts are dictated by Nature – rather than constructed by human – any scientific controversy (for example about the risk of radioactive radiation) will lead to the conclusion that one of the debating parties is right and the other is wrong; the good guys against the bad guys. The reaction 'let them sort that out among themselves; I don't want to have anything to do with that' is then very understandable. Likewise, if we do not build up a social-constructivist image of technological development, stressing the possibilities and the constraints of change and choice in technology, a large part of the public is bound to turn away and to let technology really get out of control.²⁹

My suggestion in this paper has been to pursue the 'social-constructivist' programme and to extend it both in perspective – sociotechnology rather than technology should be our subject matter – and in depth – theoretical explanations should now be developed on the basis of the rich empirical research of the past decade.

Epilogue

The Earthquake of 17 October 1989 seemed to have been effective in revealing the composing elements in the sociotechnical world of the Interstate 880. But one week later we could already witness the covering up, the closure of the black box, the camouflage of the socially constructed character of Technology, Nature and Society. I quote from the *The New York Times*:

'From the beginning, California has been the American symbol of opportunity, freedom, renewal, sunny paradise and human dominion over a land that was as beautiful as it was terrible. Dams and aqueducts brought water into the deserts, where vast cities and farms blossomed. (...)

In just 15 seconds on Tuesday evening, nature sought to restore a bit of its equilibrium. A powerful earthquake knocked down a freeway in Oakland.'³⁰

All interpretative flexibility had vanished after one week – natural and technical determinism were the central guiding posts again.

Let us hope that the studies of sociotechnical ensembles, as called for in this paper, will have a more lasting effect. If so, we have no reason to despair: there is life after constructivism – more constructivism.

Noten

1. Dit verhaal is gepresenteerd op de conferentie 'Technological Choices: American and European Experiences', 12-14 april 1990, Indiana University, Bloomington, IN., U.S.A. De bedoeling van de conferentie was een evaluatie te maken van recent techniekonderzoek zoals dat in de jaren tachtig in Europa tot ontwikkeling is gekomen. Het ging hierbij, aldus de subsidieaanvraag aan de National Science Foundation, vooral om een evaluatie van het sociaal-constructivisme: 'In the Academy as elsewhere, however, "new" is not always "better", and the time seems ripe for a critical appraisal of recent initiatives that are loosely gathered under the umbrella of "the social construction of technology." What is genuinely new in the sociology and history of technology, and what is mere rediscovery?' Mijn paper stond als laatste op het programma, in de sessie 'Post-constructivism: Where do we go from here?' Geprikkeld door deze context, is de toonzetting nogal polemisch uitgevallen. De versie die nu in *Kennis en Methode* wordt gepubliceerd is vrijwel identiek aan de gepresenteerde; er zijn slechts enkele Nederlandse referenties aan toegevoegd. Ik dank de Indiana University, de Mellon Foundation, de National Science Foundation (DIR-8921057) en de Society for the Social Studies of Science voor financiële steun.

2. This quote is not transcribed from a recording but reconstructed on the basis of my notes. The social gap revealed here is part and parcel of the highway system. The lower class people, not owning a car, have to live near the city center. The freeways which carry the middle class citizens between their suburban homes and down-town workplace cross over the living quarters of the poor.

3. For a comprehensive and daring view of the present state of the art in economic technology studies, see Dosi *et al.* (1988). Blume (1991) has developed a framework which aims at the sociological and economic perspectives.

4. See Bijker, Hughes and Pinch (1987a, 1987b) for the papers of this workshop and an account of its history. Bijker (1987b) gives a review in Dutch.

5. See Bijker and Law (forthcoming) for the papers of this workshop.

6. See Latour (1989) for a similar argument.

7. See Pinch and Bijker (1986), De Vries (1989) and Bijker (1990).

8. See for more sophisticated discussions on reflexivity: Woolgar (1988a), Woolgar (1988b), Ashmore (1989).

9. Ashmore, Mulkey and Pinch (1989) have investigated the possibility of applying social sciences (see also Bijsterveld en Mesman, 1990). They study two cases. The first is health economics. The second case is – and this constitutes the reflexive turn – their own sociology of knowledge (in studying health economics). This project has convinced me of the possibility to incorporate in specific projects some elements of the reflexive programme. See also Pinch, Ashmore and Mulkey (forthcoming).

10. See Bijker (1988) for a brief account of this development. The establishment of the famous Dutch 'science shops' was part of this same development.

11. For the bicycle, see Pinch and Bijker (1984); for Bakelite see Bijker (1987a); for the fluorescent lamp see Bijker (forthcoming). In this paper I will not present empirical details of these studies.

12. See for an introduction to the issue of technical determinism the 'Introductory essay' by MacKenzie and Wajcman (1985) and for a comprehensive discussion of various shades of technical determinism MacKenzie and Spinardi (1988).

13. For a discussion on the Principle of Symmetry, see Laudan (1981) and Bloor (1981). See also Collins (1985).

14. The metaphor of the seamless web breaks down if we focus on the *actors* instead of the *analysts*. Actors label specific activities differently. It is exactly this process of actors making distinctions which we analysts should study, rather than assuming *a priori* our own distinctions.

15. Zie ook Hagendijk 1986) en Amsterdamska en Hagendijk (1990).

16. The classic discussion of this phenomenon is given by Latour and Woolgar (1979) in their 'splitting and inversion model.' Collins (1981) discussed the implications for historical studies of science. Bijker (1989a) and Misa (forthcoming) reworked the concept in order to make it fit for the present purposes. See also Woolgar (1988a), especially chapter 4.

17. This is the model which anybody with secondary school physics as his background is bound to use. To such an observer, the task of keeping a bicycle upright is strikingly difficult. This explains the amazement of people in the 1860-s, seeing bicyclists for the first time.

18. This is one of the important differences with '(technological) paradigm' (Kuhn, 1970; Gutting, 1984) and 'frame of meaning' (Collins and Pinch, 1982; Carlson, forthcoming).

19. See for example Amsterdamska (1990), Collins and Yearly (1990) and Latour (1989, forthcoming).

20. See Latour's (1984, 1988) programmatic plea for irreductionism.

21. This does not imply that we let realism sneak in through the back door again. Working through a window of constructivism when analysing the building-up of the various interlinked elements of sociotechnical ensembles, is an antidote against imputing immanent properties to the backcloth.

22. See, for example, Russell (1986) and Russell and Williams (1987).

23. Another attempt to generalize beyond individual cases is presented by Latour, Mauguin and Teil (1990). The pleat which is ironed into the seamless web of sociotechnology by their graphical analysis runs along the border between programmes and anti-programmes. See also Akrich and Latour (forthcoming).

24. See for a discussion of other theoretical attempts along the same route the introduction by Bijker and Law (forthcoming). See also Misa (1989) who pleaded for a meso-level theory of sociotechnical change.

25. See Hughes (1987) for a discussion of radical and conventional inventions.

26. See Staudenmaier's (1985) use of the concept of 'constituency' in the history of technology.

27. For further information, contact the European Coordinator of the Eurometrics Project – Chantal Latour, Projet Eurométrie, 60 Bd. St.-Michel, 75272 Paris (Cedex 06). Nederlands coördinator is Dr. Marcel van den Broecke, Stichting PWT, Postbus 171, 3500 AD Utrecht.

28. Cf. the conference proposal by Thomas Gieryn (draft of May 1, 1989): 4.

29. This is of course not to say that we should deny the solidity and momentum of technological systems. That might result (via invoking too optimistic expectations, to causing desillusions) in an equally contra-productive cultural-political climate. It is exactly with this point in mind that I stressed, in the main body of this paper, the need for a theoretical framework that pays due respect to both the actor and the structure perspective.

30. Robert Reinhold, 'Fault Lines. California Struggles With The Other Side Of Its Dream', *The New York Time. The Week in Review*, 22 October 1989, section 4.

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