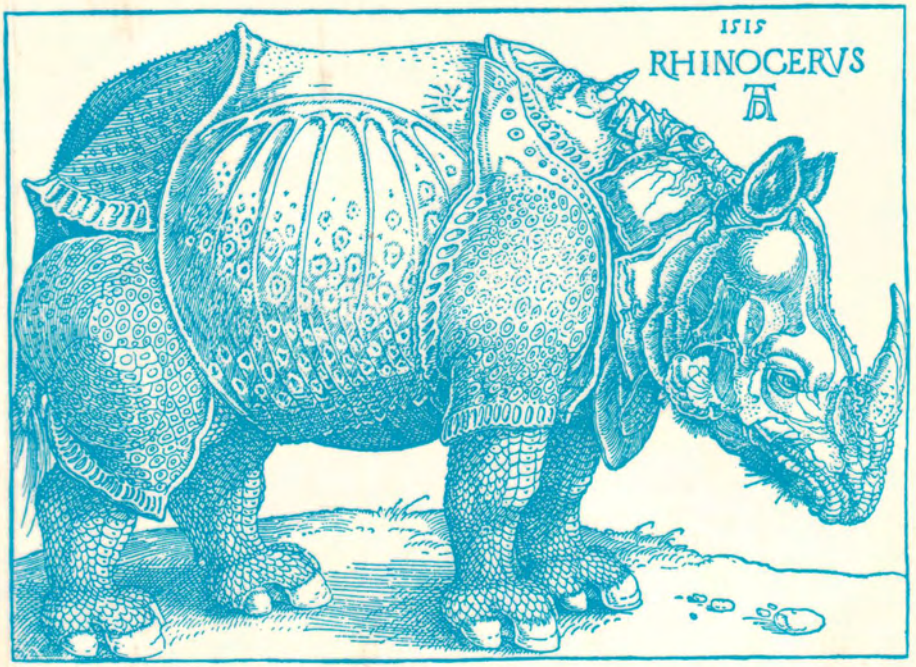
A Sociology of Monsters



ESSAYS ON POWER, TECHNOLOGY AND DOMINATION

Edited by John Law

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Introduction: monsters, machines and sociotechnical relations[1]

John Law

I said 'I think they might also be what are called "hopeful monsters".'
She said 'What are hopeful monsters?'
I said 'They are things born perhaps slightly before their time; when it's not known if the environment is quite ready for them.'
Nicholas Mosley, Hopeful Monsters, p. 71

Introduction

We founded ourselves on class; then, at a much later date we learned a little about ethnicity; more recently we discovered gender; and more recently still we learned something – perhaps not very much yet – about age and disability. So might a white, middle class, middle aged man with a normatively approved set of physical skills write of the history of his sociology. So might he comment on the way in which he slowly learned that 'his' sociology had never spoken for 'us': that all along the sociological 'we' was a Leviathan that had achieved its (sense of) order by usurping or silencing the other voices.

Even so, this was a sociology always driven, at least in part, by a concern with distribution – for otherwise it would never have learned of its isolation. It was driven by a concern with pain. It was driven by an ambivalent wish to learn of and intervene about injustice. But what should *count* as a distribution was fought over time and time again in the retreat from a sovereign order. 'We' found it difficult to recognise class – for after all, we are all free and equal in the market. And ethnicity, too, was slow to come into focus, perhaps because it was hoped that this was underpinned by a logic of class. Then those who took class seriously – and, to be sure, those who did not – found it difficult to recognise gender. Where 'we' are now, gender is somewhat, but only somewhat, in

focus. Still there are great silences about gender. As there are about age, about disability.

Something like this seems to happen: first the dispossessed have no voice at all. Then, when they start to create a voice, they are derided. Then (I am not sure of the order), they are told that they are wrong, or they are told that this was something that everyone knew all along. Then they are told that they are a danger. Then finally, in a very partial form, it may be that their voices are heard and taken seriously. And it has been a struggle all the way.

There are several reasons for introducing a volume on technology and power by talking, like this, of the birth of pain in sociology, the discovery of distributions. But the most pressing grows out of what I take to be a great divide between the critical sociological concern with distribution on the one hand, and much of the most important new writing on science and technology on the other. It is easy to characterise that divide, though I find it hard to characterise it well. In one version, however, it amounts to a reciprocal accusation of myopia between sociology and what (for purposes of brevity) I will call STS (science, technology and society).

I have a foot in both camps, so let me say, *tout court*, that much of the best work in STS is indeed more or less blind to the great distributions, the pains, sought out by, pressed on, and more or less hesitantly described in sociology. There *is* work – mainly feminist and from the labour process tradition – for which this is not the case. But much of STS is not, or at any rate has not been, driven by a concern for dispossession. This is the charge, a charge detailed by a range of more politically committed critics; that many writers in STS have had little to say about class, race, or gender.[2] And, as I have indicated, I think it is (at least partly) guilty.

So what has gone wrong? There is one contingency: STS is very small. Compared with the great factories of sociology, it is a cottage industry. Truly, we have not been able to do everything at once. But this is in passing. What of the substance? The truth of the matter, of course, is that many writers in STS think that *nothing* has gone wrong. In part this is because, since the 1960s, STS has been wrestling with its own problems. Those problems and their solutions (partial and contentious though they may be) are very important. And (this is the substance of what I want to say) they *could* feed into and strengthen the central sociological concern with distribution. But they have not, and this is partly

because sociology has not successfully distinguished between the analytical wood of STS and some fairly manifest deficiencies in the trees that make it up.

What, then, of that analytical wood? When we look back we tend to see what we want to see. Accordingly, others will see otherwise. However, to my mind, in the last twenty years STS has passed through three (well, two and a quarter) major stages. In these it has tackled (or started to tackle) three great questions, questions that are all of major potential importance for sociology. The first, explored in the period after 1968, has to do with the character of knowledge, and especially of high status scientific knowledge: this is the *problem of epistemology*. The second, which was systematically unpacked from about 1980 onwards, has to do with the character of society. Here the problem has been to characterise the stuff that binds society together (to the extent that it is indeed bound together): I like to think of this as the *problem of heterogeneity*, but it is STS's version of that great misnomer, 'the problem of the social order'. And the third, which is slowly coming to dominate the agenda, is STS's own version of the *problem of distribution*. This question, which is closely linked to the second, has to do with the character of divisions between the classes of actors to be found in the world. I will talk about each in turn.

The problem of epistemology: absolutism, morality and politics

Epistemology is the 'theory of the method or grounds of knowledge'.[3] It tells us, sometimes descriptively, more often prescriptively, about what we can know, and about how we should go about gathering knowledge. Traditionally a branch of philosophy, epistemology was hi-jacked by historians and sociologists of science in the 1960s. The argument made by the hi-jackers was that the methods or grounds of knowledge are not invariant, but vary as a function of social context. For instance, it turned out that what passes as scientific knowledge varies, indeed changes radically, as time passes: this, at any rate, was one of the claims made in Thomas Kuhn's *The Structure of Scientific Revolutions*,[4] and he was not alone.

This suggestion, with its overtones of relativism, provoked uproar long before current debates about the postmodern condition. In particular, it led some to defend what they took to be scientific

standards. If knowledge was a function of social context, then (or so these critics claimed) irrationality would follow: there would be no way of distinguishing between truth and power.[5] This was the nub of the attack on epistemological relativism. First it came from the philosophers, sometimes refugees from Nazism or Stalinism, who sought to protect science from politics. And then, in what at first sight seemed like a rather surprising turnround, it came from political radicals – initially from Marxists, and then, in a more potent manner, from feminists. Roughly, the (radical) critics argued for a 'standpoint epistemology'.[6] That is, they argued that though the 'scientific method' as defended by the philosophers was indeed flawed, there were none the less certain social groups (the working class, or the communist party, or women, or feminists, or lesbian feminists) whose experience and/or methods of knowing were, for reasons of social context, better grounded than those of the bourgeoisie, or gendered science.

In one version or another these arguments have rumbled on for two decades. Their detail, though not I think their basic form, has changed. For instance, many of the arguments about the epistemological (and political) character of science are now posed in a language of postmodernism, and seek to celebrate (or denounce) the end of the grand narrative.[7] However, though often it is only the language has changed, there have also been some important innovatory twists in the debate. For instance, some feminists have pointed to an interesting oddity – the fact that just at the moment when women appear to be finding a powerful political and analytical voice, it turns out that (some) men have suddenly discovered the virtues of epistemological pluralism:[8] the notion that everyone should be left to get on with their own thing. It does not require a great imaginative leap to see that this may be yet another tactic for avoiding the politics of gender distribution. And the argument has not been confined to feminism. Radical critics have pointed to the way in which the celebration of diversity is empty in the absence of a politics which establishes conditions for its exercise.[9]

I do not want to start rehearsing the epistemological arguments in detail here. Instead, I want to make two simple but closely related points that draw on the relativism of STS. The first has to do with rules of method. As I have noted, the suggestion that rules of method, epistemologies, might vary as a function of social context was greeted with horror by many: the fear was that if we abandoned the ordering Leviathan of the scientific method, then

anyone could believe anything that they wished. But (my first point) *this fear is unjustified*: the fact that the rules of method vary between contexts, or indeed over time, does not mean that we are in a position to believe anything we like. Neither does it follow that we will have no *local* conventions about how to go about producing good knowledge. Do you believe that cold fusion is alive and well? Or that gender differences are a product of innate biological differences? I guess that you don't. I *know* that I don't. But I also know that there are some places where it is easy to believe these things. And that, however much we might wish it otherwise, this is simply the way it is.

The first point, then, is about standards. I can be a relativist, and *still* note that I am (we are all) constrained and enabled by theories or practices about what should count as a satisfactory argument. But does this mean that I throw up my hands, and stop trying to persuade you that you are wrong? Does it mean, to use Paul Feyerabend's famous phrase, that 'anything goes'?[10] Does it mean that I am immobilised by the knowledge that we may disagree?

In fact, whatever the critics may claim, *none* of these things follow. I remain committed to my methods for establishing the truth.[11] Those methods are not likely to be idiosyncratic (for we are all social beings). And an acknowledgement that standards for good knowledge vary between groups (epistemological relativism) implies no commitment to quietism. I can negotiate with you about these (as we can about the substance of our beliefs) and I may or may not succeed in budging you. And I can (and do) feel repugnance when people are obliged by the use of force to believe or act in ways that betray themselves, and/or my notions of what is right and proper. In short, to accept the reality of epistemological relativism and deny that there are universal standards is *not* to say that there are no standards at all: and neither is it to embrace moral or political relativism. As Richard Rorty so well demonstrates, the either/or postulated by those committed to absolutism (either absolute standards, or no standards, epistemological or moral) is a false dichotomy. Locally we may seek to distinguish truth from power, persuasion from force, and what is right from what is wrong.[12]

But by now we have moved to the second, related, point about the relationship between epistemological relativism on the one hand, and ethical and political commitments on the other. Leigh Star writes:

> I have sometimes been called a Nazi, or parallels have been drawn between the social construction of science, and Nazi science. It took me a while to figure out what people were talking about.
>
> If one takes the point of view that fascism requires a kind of situation ethics and requires redefining the situation according to opportunism or a kind of distorted view of science and nature, then any attempt to relativize any situations . . . becomes morally threatening. This is because one antidote to fascist ideology is to affirm an overriding value in human life, a universal value that cannot be distorted by the monstrosities informed by local, parochial ideologies of racism and genocide. (Star 1988: 202)

Her point, like that of Rorty, is that if we embrace epistemological relativism we neither have to give up our concern for proper ways of finding out about the world, nor (the second part of the argument) abandon our political and ethical commitments. To be a relativist – to recognise multivocality – implies no obligatory commitment to immorality or opportunism. Neither does it necessarily lead us to indifference to distribution. Rather (and here, now, is the positive point) it may lead us to an important form of intellectual caution: the sense that all knowledges are shaped, contingent, and in some other world could be otherwise. Thus if someone tells us of a form of distribution that it 'must be so', we may or may not believe what we have been told. But we will certainly cling fast to the sense that what is seemingly so 'natural' *could be otherwise*. And we will be suspicious of that order, and ask, instead, why it is the way it is for those (including ourselves) who tell us that it is so.[13]

This, then, is a lesson that sociology, with its concern about distribution, might learn from the struggles of STS (though also from the parallel debates about persuasion and truth in postmodernism): *to beware of absolutism, including its own absolutism*; to beware of its own part in distribution; and to know, at the same time, that there is no need to attempt the impossible task of replacing one absolutism with another. As Leigh Star's essay in the present volume shows, relativism, rigour, morality and activism *can* be blended together. All of which, put like this, sounds very much as if STS were simply trying to teach its grandmother how to suck postmodernist eggs. But there are eggs and eggs. Sociology may know about class, or about gender. But how much does it

know about speciesism – the systematic practice of discrimination against other species? And how much does it know or care about machines?

The problem of heterogeneity

I want to say that one way of looking at STS is to note that it is in the business of understanding disjunctions and overlaps. Satisfyingly, it is not alone in this. The same kinds of questions drive a patchwork of post-modernism, pragmatism, parts at least of feminism, and such traditions in sociology as symbolic interactionism.[14] The epistemologies of all these programmes – a denial of absolutism – force them to explore the ways in which different kinds of knowledges butt up against one another, how it is that matters are decided locally. STS has tackled this question in a variety of vocabularies. It often talks, for instance, of the 'closure' of negotiations.[15] But these vocabularies push us towards the second great finding of STS, which has to do with the nature of the social – with the character of the glue that holds the social world more or less precariously together. And the finding – one which unites most of the contributors to this volume – is that to the extent that 'society' is held together at all, *this is achieved by heterogeneous means*. Or, to put it somewhat more radically, that the social is not purely social at all.

At this point we encounter a puzzling mismatch between sociology and STS. Sociology – or at least much of it – knows perfectly well that the social world would not hang together[16] if the natural, the corporeal, the technological, the textual and the topographical were taken away. Indeed, in the last decade, perhaps under the influence of Foucault and a range of structuralist and post-structuralist writers, sociology has started to take both the body and the text extremely seriously: texts are found wherever we look; representations re-present ubiquitously; and bodies are everywhere inscribed.

However, matters are rather different for technology: except, perhaps, in the area of information technology,[17] machines have been excluded from most of the new enthusiasms. It is not that there *is* no technology in sociology. Indeed, there is a real sense in which sociology *assumes* the presence, the active operation of (say) the technical. So to say that distributional sociology ignores the technical or the artefactual is not right. And it is particularly

unfair to those Marxists and feminists who have explored the class and gendering effects of (for instance) production and household technologies: these two traditions have created powerful bodies of work on the distributional shaping of technology[18] which also overlaps productively with the concerns of STS.[19] And, of course, there are many others who have written, though sometimes in a rather technologically determinist mode, for instance about the relationship between production technologies and workplace organisation,[20] or between military technologies and the organisation of the nation state.[21]

So there is a real sense in which the technological *is* present in sociology. But there is also a sense in which, despite the pioneering work on sociotechnical systems by the Tavistock group in the 1960s,[22] technology does not appear to be productively integrated into large parts of the sociological imagination. Since Foucault, we have no difficulty in inscribing texts on bodies, or constituting agents discursively. But (with a few notable exceptions)[23] it does not occur to us to treat machines with the same analytical machinery as people. The problem has something to do with the absence of a method for juggling simultaneously with *both* the social *and* the technical. Sociologists, I want to say, tend to switch registers. They talk of the social. And *then* (if they talk of it at all which most do not) they talk of the technical. And, if it appears, the technical acts either as a kind of explanatory *deus ex machina* (technological determinism). Or it is treated as an expression of social relations (social reductionism).[24] Or (with difficulty) the two are treated as two classes of objects which interact and mutually shape one another.

My hypothesis is this: that here we are dealing with a form of distribution built deep into sociology – the distribution between people on the one hand, and machines on the other. Or between 'social relations' or 'social structure' on the one hand, and the 'merely technical' on the other. As you will discern, I do not believe that it is a happy distinction. It carries strong overtones of C. P. Snow's justly famous diagnosis of 'the two cultures'. Indeed, I believe it is a form of speciesism. But it is a distinction that STS and parts of the history of technology – like parts of the social world itself – have found a way of circumventing. My argument, then, is that if sociologists were to look at STS, they would find a way of talking about the-social-and-the-technical, all in one breath.

Consider, for instance, the work of the historian of technology,

Thomas Hughes. In a magisterial volume,[25] he has traced the development of the generation, transmission and distribution of electric power in several countries from its inception in the 1880s through to the 1930s. Hughes is not a sociologist – indeed his brief references to sociology tend, unhelpfully, to cite functionalist sources.[26] Nevertheless, it is his craft as an historian that organises the method and the narrative form of his study. And it is a craft that leads him to range across economics, politics, technology, applied scientific research, and various aspects of social change.

Hughes' argument, in effect, is that it is not possible to understand the growth and evolution of the networks of electricity unless one understands the work of what he calls the 'system builders'. And it is not possible to understand this work – he is thinking of people like Thomas Edison – unless one understands that they saw politics, technology and all the rest, as going together as an integrated whole. For instance, Edison sponsored and participated in applied scientific research to find a viable electric light bulb. And that research was closely related to a series of economic calculations that were also technical in character – about the costs of laying cables, of transmitting electricity of a given voltage down those cables as a function of distance and electrical resistance, and of building and running power stations which would be located in cities (in the first instance in New York) in the neighbourhoods they were to serve. But, at the same time, he also saw matters politically, for to build power stations he needed the agreement of city councillors, who, in some cases at least, had close ties with the town-gas industry. So he lobbied politicians in order to seek franchises. Indeed, on one occasion he transported them to his research laboratory in New Jersey in order to impress them with a dazzling display of electric lights strung around the site.

The details do not matter here. What is important is the general argument. This is that Edison was a 'heterogeneous engineer'.[27] He worked not only on inanimate physical materials, but on and through people, texts, devices, city councils, architectures, economics and all the rest. Each of these materials had to be moulded to his design if the system as a whole was to work. And, as a consequence, he travelled between these different domains, weaving an emergent web which constituted and reconstituted the bits and pieces that it brought together.

Hughes' argument is not, of course, entirely novel, and as I have noted, there is a substantial tradition in labour process writing

which explores the disciplinary effects of technological innovation within the capitalist enterprises.[28] Nevertheless, the ease with which he follows Edison between the different domains is startling – as is the seriousness with which he deals not only with the political and the economic, but also the technical problems confronted by Edison. Thus for Hughes the technical is not something to be minimised – a 'merely technical' means to achieve an end. There is no deference to the two cultures. Rather it emerges as a vital component in Edison's artful social and political engineering. In this account, everything assembled and woven together by Edison is taken seriously.[29]

Here the distinction between humans and machines, though present, is subordinated to another concern – that of exploring the development of a complex sociotechnical system. Hughes is careful to avoid suggesting that either the technical, or the social, is determinate in the last instance. Like many historians he is more concerned with 'hows' than with 'whys', though if he leans towards any form of explanation, it probably has to do with the character of the system-builder himself – the great synthesiser, the engineer who, more so than his fellows, creatively constitutes and combines together what had previously never been assembled.

What, then, is happening here from the point of view of sociology? The answer, I think, is a mix. Not all of it is good. But one part of it is of crucial importance. Thus, though he does not put it this way, Hughes' version of the 'social order' – his answer to the problem of what it is that holds overlapping bits of the social together – is to imply that the social order is not a social order at all. Rather it is a *sociotechnical order*. What appears to be social is partly technical. What we usually call technical is partly social. In practice nothing is purely technical. Neither is anything purely social. And the same may be said for the economic, the political, the scientific, and all the rest.

So, though there are some problems with Hughes' account (I shall touch on these shortly), his discovery of the sociotechnical, of the *impurity* of the social glue, strikes me a finding of absolutely major importance.[30] And it is one that has not been assimilated to the sociological imagination: for reasons that I do not understand, the idea that wherever we scrape the social surface we will find that it is composed of networks of heterogeneous materials remains foreign to most forms of sociological practice. And this is a mistake.

But how should we identify the strands that lie beneath the

social surface? Hughes does not spell out a method. He simply uses one. What he does is to follow Edison and the other system-builders wherever they go. The method is brilliant, in the sense (I was going to write unfairly) that Edison does all the work for Hughes. Such is not the case, for Hughes has spent a decade retracing Edison's route. But Edison has, as it were, told Hughes where he should look, what heterogeneous materials might go with what others, and how they might be related together. Hughes' method, then, is like that described and advocated by Bruno Latour:[31] it is to 'follow the actors'.

In many ways the method is a good one. It is a way of generating surprises, of making oneself aware of the mysterious. This is because it tends to break down 'natural' categories – I mean some of those distinctions and distributions 'natural' to the sociologist. But, as more than one critic has observed, if we follow the actors we pay a price. This is that it becomes *difficult to sustain any kind of critical distance from them*. We take on their categories. We see the world through their eyes. We take on the point of view of those whom we are studying.[32]

Hughes builds some critical distance into his account by means of an international comparison – and the differences in the early histories of the American, German and British power systems are indeed instructive. But in general, an absence of such distance has several consequences. It means, for instance, that certain distributions are likely to be invisible: those that are of no concern to the actor who is being followed tend to melt from view. Did Edison care about gender? I don't know, but it would be surprising if he did. And, if he did, it would be surprising if he cared about gender in ways that were inconsistent with the concerns of his enterprise. So the method is blind to the pain of gender distribution – though, of course, it could in some measure be retrieved if the (more or less implicit) gender work of entrepreneurs such as Edison were brought into focus by a less than complete commitment to follow the actor and accept his (sic) selection and organisation of the material.

In fact, the slogan about following the actors is just that – a slogan. It is a good slogan to the extent that it reminds us that we tend to reify, naturalise, or simply ignore, what may be important distributions. Applied to Edison, it warns us off the speciesism of people and machines – a discrimination of little import to Edison for many (though not all) purposes. But it is a bad slogan if we take it literally. Though in reality, of course, we *cannot* take it

literally. Even an academic biographer does not follow her subject everywhere: however comprehensive she may wish to be, she orders, she sorts and she selects.

But there are further problems with the slogan, difficulties which have to do with the actor-centric character of the method. Thus there is the issue of agency and heroism. Hughes chooses to study great men. Indeed I suspect, as I have noted, that he is attracted to a heroic theory of agency, so presumably this is no problem for him. But it would certainly be a problem for most sociologists who have, as we know, spent a great deal of time in the last decade decentring the subject. Indeed, STS is no exception. The import of much work in STS, including that which recommends that we should follow the actors, has precisely been to decentre the heroic subject. Thus Bruno Latour may have chosen to study Louis Pasteur.[33] But the *object* of the study is not so much to celebrate as to deconstruct the subject. Thus for Latour, Pasteur is an effect, a product of a set of alliances, of heterogeneous materials. To the extent that Pasteur 'is' a 'great man', we need to see this as an outcome rather than something inhering in Pasteur.[34]

I am saying, then, that those who follow the actors in STS are not normally guilty of an unexamined and heroic theory of agency. Heroes are built out of heterogeneous networks. Nevertheless, when they (we) deconstruct agents into their components and their artifices, there is a kind of sampling problem. This is because we tend to choose to do it on heroes, big men, important organisations, or major projects. So why does this happen? And what are its consequences?

There are two standard reasons for looking at those who are big and powerful. Indeed, one has precisely to do with debunking: if we look at those who are big and find that they, like us, have difficulty going to sleep at nights, and have to pull on their socks in the morning, then (or so the argument runs) we will come to see that they are not different in kind from us: that they are bigger, but they are not better, set aside, or marked out. This is the Hemingway half of the famous exchange with F. Scott Fitzgerald:

> *Fitzgerald*: 'The rich are different from us.'
> *Hemingway*: 'Yes, they have more money.'[35]

The Hemingway argument is that it is an analytical mistake to think of the large and the powerful in a different way. And

politically, or morally, it is also wrong, for to do so is to collude in empowering them still further.[36]

A second reason for looking at the big and the powerful is that, since they *are* bigger and more powerful, everything else being equal, their modes of organising and ordering shape much more about the heterogeneous networks of the social than do the strategies of the unsuccessful. So if we want to understand the modern world it does not do to look at failures. Rather we should look at successes – or, perhaps, at heroic failures.[37]

Both these reasons make sense, at least within limits. But only within limits. Thus, though the task at hand may be hero-deconstruction, it is difficult to avoid the sneaky feeling that, somehow, when all is said and done, STS finds heroes to be more interesting than ordinary folk. But there are other more serious issues at stake too. Thus if we *always* choose the powerful, or those who seek, with some possibility of success, to be powerful, then there is a real chance that we will succumb to the perils of managerialism. Our analyses will be filled with active, manipulative, agents who stand some chance of ad-hocing their way to organisation and success – who stand some chance, like Pasteur, of shaping the world in which they are operating. The issue, then, is not to do with heterogeneous engineering, for we are all heterogeneous engineers. Rather it has to do with strategies, resources, and the character of heterogeneous engineering. By and large, managers *expect* to succeed. By and large they are *right* to expect to succeed. By and large, as Leigh Star suggests, they manage their precarious networks of heterogeneity in a manner that conforms to normative conceptions of cohesion and consistency. But, as again she shows, there are many other actors around for whom/which few or none of these things are true: their resources are few, their strategies restricted, their expectations are scaled down. The consequence may be fragmentation, pain and silence – not possibilities that are easily entertained within managerialism.

Here, then, there is an argument about heterogeneity – this time not about the heterogeneity of materials (for in the material sense we are all heterogeneous engineers), but rather about strategies and resources. But this connects with a second point, to do with the assumption of qualitative uniformity: the powerful Hemingway counter-argument to Scott Fitzgerald. This is an old debate in social theory: the relationship between quantitative and qualitative difference. But one does not need to enter into the classic form of that debate within dialectical materialism to note that quantitative

differences may turn into qualitative differences. Indeed, there is a large literature, even within STS, on precisely this point – as several of the articles in this volume suggest.

For instance, Leigh Star considers the way in which this literature explores the question of entry costs and network externalities. Thus, in isolation, there may not be much to choose between an IBM and, say, an Acorn. They may not differ very much in cost. But if everyone buys one rather than the other, then neither the purchase price nor the relative technical merits of the two systems are any longer overwhelming considerations. Instead, questions to do with compatibility come to predominate.[38] Here, then, what was a small-scale quantitative difference – a few more people bought IBMs than Acorns – becomes a large scale quantitative and (arguably) qualitative difference. Life is (in this putative case) better, easier, the networks are larger and more helpful, if you have an IBM. Though, even this qualitative difference is in principle reversible – for instance by equipping an Acorn with the capacity to run IBM programs, and read IBM discs.

In short, then, what I am saying is that both Hemingway and Scott Fitzgerald are right. Or they may be right. It depends on the circumstances. Quantitative differences may be transmuted into qualitative distinctions. And qualitative distinctions may be undone by either qualitative or quantitative means. So it will not do to say that the powerful, the managers, are only quantitatively different from the wretched of the earth. Though they *are* quantitatively different, they are not *only* quantitatively different, at least some of the time. Which means, if we concentrate as we have in much of STS, on this alone, that we are liable to miss out on some of the ways in which quantity is (reversibly) transmuted into quality.[39] Or, to put it differently, we will miss out on the ways in which the great distributions are laid down and sustained.

The problem of distribution

In the argument about heterogeneity I have been hard on STS. In effect, what I have said is that it fails to handle distribution in the way in which it should, if not because of a commitment to a heroic theory of agency, then because of its propensity to select heroes for deconstruction. And this is a tendency that leads it not only towards managerialism, but also (as part of the strategy of

deconstruction) to an emphasis on quantitative rather than qualitative difference.[40] But this, I think, is reparable. It will be repaired if STS chooses to think not only about heroes but also of victims and the differences between their fates. It will be repaired if it is sensitive to the ways in which differences may be turned into distributions, in the way in which the quantitative may be turned into the qualitative (and indeed, the qualitative may be turned back into the quantitative):[41] this, at any rate, is the import of Leigh Star's proposal.[42] And it will be repaired if we can find ways of exploring the character of distributive strategies – of the different kinds of discursive and non-discursive effects instantiated and reproduced in the processes of heterogeneous engineering.

So, despite some obvious failings I believe that STS is reparable. Indeed, this belief is one of the reasons I sought to put the present volume together. But if STS is reparable, then can the same be said of sociology? Again I am optimistic. Sociologists, I am saying, need to see what is best about STS. And this, I have argued, has to do with overlaps.

On the one hand, there is the question of epistemological modesty. It is true that we cannot know absolutely. But this does not mean that we cannot know at all. It does not mean that we cannot distinguish between truth and power. And it certainly does not mean that we are forced to ethical or political opportunism. Rather, it means that we have to attend seriously – more seriously than we have sometimes been wont to do in the past – to finding ways of building on, convincing, persuading, those who share enough of our concerns, our interests, or our standards to make any kind of interaction possible. Just as, of course, it also means finding ways of listening more carefully to them: of hearing things to which we have, perhaps, been deaf. This, of course, is idealistic. We will fail: we will fail to persuade; we will not hear; we will confuse truth with power, at least some of the time. But to say that it is idealistic is not to say that it is unrealistic – so long as we appreciate that learning, knowing, hearing and acting are all processes, parts of a journey with a destination but no end.[43]

This, then, is the epistemological part of the story: STS is at its best when it handles its overlaps by building local knowledge in a way which involves neither seeking a grand narrative, nor embracing what is sometimes called the 'despair' of moral relativism. And that is one place where sociologists might look to in STS. But it might also look to its serious commitment to heterogeneity, and, in particular, to the heterogeneity of the

sociotechnical. I have tried to emphasise the message: the 'social order' is neither social, nor an order. The 'problem of the social order' cannot be solved by social means alone. Structures do not simply reside in the actions of people, or in memory traces.[44] They exist in a network of heterogeneous material arrangements. The genius of STS is to have stumbled on this, and to have taken to heart the importance of material overlaps for the 'social order'. It has understood that heterogeneous engineers are, as it were, out there, arranging, ordering, shaping, regulating and (to be sure) seeking to profit from such overlaps. It has understood that heterogeneous engineers – agents, whether human or not – are constituted in the arrangement of these materials. And it has understood that such processes of ordering, such processes of working on and giving shape to the overlaps, amount, in their own precarious way, to what we call the social order.

An intuitive feel for the ordering of heterogeneity, the construction and reconstruction of overlaps, the constitution of agency: that is the strength of STS; together with an insensitivity to 'natural' distributions. For, though its insensitivity to the distributions of pain is a weakness, it is also a strength. Most sociologists treat machines (if they see them at all) as second class citizens. They have few rights. They are not allowed to speak. And their actions are derivative, dependent on the operations of human beings.[45]

It is possible to be highly offensive about this failure. It is, for instance, possible to draw analogies between the position of women or blacks, and the position of machines. But the very fact that this *is* offensive (and I accept that it is) makes my point. It reveals that we are truly speciesist. And that it is improper, obscene even, to draw analogies between people and machines, except as a joke, a slur, or an elaborate metaphorical game.

But one of the things that is happening here is that we are running together an epistemological distinction between people and machines with an overlapping division that has to do with ethics, with morality, or with politics. We are reacting to the tug of one of Asimov's law of robotics; the commitment (by robots, of course!) never to injure human beings. As an ethical commitment, I am thoroughly committed to the law of robotics, for I am not a Nazi, and neither (notwithstanding Steve Woolgar's helpful attempt to blur the distinction) do I currently think of myself as a machine. But there are at least two reasons why the division should not carry an analogous *explanatory* weight.

First (we are familiar with this by now), we are all heterogeneous networks, the products of confused overlaps. Did you really find your way through last week without machines? Of course not! *You are part machine.* And if you pretend otherwise, then this is presumably because you (like me) prefer to think otherwise. For in polite company, despite Donna Haraway's powerful polemic about cyborgs[46] it is not generally considered to be a good thing to allow oneself to be 'dehumanised'. For machines are not like us: like women, or blacks, or the working class, or the infirm, they lack whatever it is that currently distinguishes us as paradigm human beings.[47] This, then, is a fundamental distribution of pain.

But this leads to a second analytical and ethical point. This is that the very dividing line between those objects that we choose to call people and those we call machines is variable, negotiable, and tells us as much about the rights, duties, responsibilities and failings of people as it does about those of machines. The analytical point, then, has to do with the methods by which this distribution is constituted – and its effects on the ordering of both 'machines' and 'people'. Such, at any rate, is the argument from STS, and it is certainly one of Steve Woolgar's arguments in his contribution to this volume where he talks of configuring (and testing) not only personal computers, but also their users. But it is also an ethical point. For just as the notion of gender constitutes a (real) distribution of pain that hurts men as much (?) as it hurts women, so it may be that the speciesism of our discrimination against machines hurts us just as much as it hurts the machines that we confine, in a second-order way, to the mechanical margins of our human civilisation.

Time and time again we have learned that a distribution that appears to be inscribed in the order of things could be otherwise; as I said at the beginning of this essay, sociology knows something about the (formerly) 'natural' distributions of racism, sexism, class prejudice and ageism. But it knows little of speciesism: machines, animals and plants – still we confine these to a different place in the order of things. And this is a mistake which, however tentatively, STS has started to unlearn.[48]

Hopeful monsters[49]

Though the visions that drive the contributors to this volume are varied, all think 'sociotechnically'. All, that is, are concerned with

heterogeneity. They are concerned with overlaps, with how it is that different things are brought together, with how it is that differences and similarities are constructed. And they are concerned with how those similarities and differences are sustained. For the question of *maintenance* is crucial. No one, no thing, no class, no gender, can 'have power' unless a set of relations is constituted and held in place: a set of relations that distinguishes between this and that (distribution), and then goes on to regulate the relations between this and that. So, concerned as they are with distribution and power, they all in one way or another seek to explore the ways in which machines or other technical materials, may operate to infiltrate, to stiffen, to reorganise, or to dissolve what we more usually think of as 'social relations'. The argument, then, is that power, whatever form it may take, is recursively woven into the intricate dance that unites the social and the technical.

What is the nature of that dance? Who or what has written the music? The authors vary in their diagnoses. But I think that the general answer would be non-reductionist. There are no 'last instances'. Rather, the authors detect emergent structural effects – properties of relationships between mutually constitutive socio-technical elements. So the object is not to offer simple explanations (for these will not be found), but rather to discern patterns in the networks – 'circuits' that tend to reproduce themselves, and so their various distributive effects.[50] So it is that many of the contributors are concerned with the stabilisation implied by reproduction. And so it is that many are concerned with durability, the way in which the quantitative may be converted, for a time, into the great qualitative distinctions or differences.

Let me conclude by twisting Marx: I want to say that entities make history, but not in conditions of their own choosing. And, of course, I should add, dialectically, that entities are *made* by history too. Once we understand that entities and their relations are continuous; once we understand (as sociology does not) that they are heterogeneous; once we understand that the differences and distributions that are drawn between them could be otherwise; once we understand (as STS finds difficult) that their histories and their fates vary widely; then we will come to appreciate that we are *all* monsters, outrageous and heterogeneous collages. And we will understand why it is that some monsters find it so easy that they scarcely look like monsters at all; why it is that some monsters are truly wretched, subjected to pain, deprived of all hope and dignity; and how it is that we might work towards a form of modest,

multivocal organisation, where *all* could be reborn as hopeful monsters – as places where the necessary incompatibilities, inconsistencies and overlaps come gently and creatively together.

Notes

1 All work is collaborative, and this essay is a product of a decade of collaboration. But I would particularly like to thank Leigh Star and John Staudenmaier s.j. for their part in its form.
2 The critics include, for instance, Harding (1986), Delamont (1987), Traweek (1988b), Fox Keller (1988); Rose and Rose (1976).
3 Citation from the *Concise Oxford Dictionary*.
4 Kuhn (1970).
5 See the 'Kuhn–Popper' debates, partly collected in Lakatos and Musgrave (1970).
6 For discussion, see Harding (1986).
7 See the celebrated statement by Lyotard (1986).
8 See Harding (1986, 1990), Benhabib (1990), but also Fujimura (1991).
9 See, for example, Connor (1989).
10 See Paul Feyerabend (1975).
11 In this view, the truth of knowledge is not usually defined in terms of correspondence to reality (a vague notion at best) but in terms of a notion of workability. See, for instance, Barnes (1977).
12 See Rorty's graceful commentary on Lyotard (Rorty 1991b).
13 One productive way of exploring and undermining absolutism is to seek, reflexively, to undermine the very distinction between representation and what is represented. See, for instance, Woolgar (1988).
14 I am grateful to Leigh Star who has made the question of overlaps much clearer to me. See Star (1989), Star and Griesemer (1989) and Fujimura (1987).
15 See, for instance, Collins (1985).
16 From now on the reader should add the 'to the extent that it does' for him/herself.
17 See, for instance, the pathbreaking work of Mark Poster (1990) on 'the mode of information'.
18 See, for instance, Braverman (1974), Noble (1977), Schwarz Cowan (1983), Cockburn (1983), MacKenzie and Wajcman (1985b), Traweek (1988) and Hacker (1990).
19 See, as a creative example of this, Bowker (1987).
20 See, for instance, Burns and Stalker (1961), Blauner (1964) and Perrow (1988).
21 See, for instance, Mann (1986), Giddens (1985) and McNeil (1983).
22 See, for instance, Woodward (1965).
23 It is, of course, no coincidence that several of the exceptions are gathered together in this volume. See, in particular, the papers by Bruno Latour and Steve Woolgar. Elsewhere, note Michel Callon (1980), Madeleine Akrich (1991), Bruno Latour (1991a, 1991b), and John Law (1986, 1987).
24 For an excellent introduction to these issues, see MacKenzie and Wajcman (1985a).
25 Hughes (1983).
26 This is not entirely coincidental.
27 See Law (1987).
28 For a review of this work, see Webster, and Clegg and Wilson, this volume; note also MacKenzie (1984).

29 Callon (1986) refers to this as the principle of generalised symmetry.
30 This argument has been mounted by Michel Callon and Bruno Latour. See, for instance, Callon and Latour (1981) and Latour (1986).
31 See Latour (1987).
32 Of course, we never 'really' reduce our categories into those of our subjects.
33 Latour (1988).
34 And this, too, is the basis of Latour's objection to the notion of power – that it deletes the alliances, the work, the violences that constitute the powerful.
35 Reported as being from F. Scott Fitzgerald's notebooks in Cohen and Cohen (1971); see Callon and Latour (1981).
36 See Latour (1988).
37 See Callon (1980), Law and Callon (1988) and Latour (1991b).
38 See, for instance, David and Bunn (1988).
39 There are endless examples of this in the social literature. Think, for instance, of Mary Douglas and Baron Isherwood's (1978) analysis of the informational import of consumption. Or Jean Lave's (1976) description of the uses of 'mad money'.
40 I think that much of the concern with durability – visible, for instance, in the paper by Bruno Latour in this volume – represents an attempt to come to grips with this problem.
41 This is the point of so much STS work: that things *might* be otherwise.
42 See, also, Star (1991).
43 See Paul Bellaby's (1991) comments on journeys and pilgrimages.
44 See Giddens (1984) and Clegg (1989: 138ff).
45 But see Woolgar (1985).
46 See Haraway (1990).
47 Perhaps machines similarly 'dislike' reflecting on the way they are constituted in large measure by people.
48 For thoughts on the historical construction of the difference between people and nature see Harding (1986); and also the magnificent essay on the development of experimental science by Shapin and Schaffer (1985).
49 The term, together with its biological referent, comes from the title of Nicholas Mosley's powerful and creative novel about discordances and overlaps (1991). But the idea draws, also, on the writing of Donna Haraway and Leigh Star.
50 The excellent term 'circuits of power' is Stewart Clegg's (1989).

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Distributions of power

Power, technology and the phenomenology of conventions: on being allergic to onions

Susan Leigh Star

Abstract

On the one hand, recent studies in sociology of science and technology have been concerned to address the issue of heterogeneity: how different elements, and different perspectives, are joined in the creation of sociotechnical networks. At the same time, there is concern to understand the nature of stabilization of large scale networks, by means that include processes of standardization. This paper examines the model of heterogeneity put forth in the actor network model of Latour and Callon, particularly as a managerial or entrepreneurial model of actor networks. It explores alternative models of heterogeneity and multivocality, including splitting selves in the face of violence, and multiple membership/marginality, as for example experienced by women of colour. The alternative explanations draw on feminist theory and symbolic interactionism. A theory of multiple membership is developed, which examines the interaction between standardizing technologies and human beings qua members of multiple social worlds, as well as qua 'cyborgs' – humans-with-machines.

Introduction

Today I was reading about Marie Curie:
she must have known she suffered from radiation sickness
her body bombarded for years by the element
she had purified
It seems she denied to the end
the source of the cataracts on her eyes . . .
She died a famous woman denying
her wounds
denying
her wounds came from the same source as her power
(Rich, 'Power', 1978)

> I guess what I am saying is that in the university and in science the boundary between insider and outsider for me is permeable. In most respects, I am not one or the other. Almost always I am both and can use both to develop material, intellectual, and political resources and construct insider enclaves in which I can live, love, work, and be as responsible as I know how to be. So, once more I am back to the dynamic between insider and outsider and the strengths that we can gain from their simultaneous coexistence and that surprises and interests me a lot. (Hubbard, in Hubbard and Randall 1988: 127)

> Is it not peculiar that the very thing being deconstructed – creation – does not in its intact form have a moral claim on us that is as high as the others' [war, torture] is low, that the action of creating is not, for example, held to be bound up with justice in the way those other events are bound up with injustice, that it (the mental, verbal, or material process of making the world) is not held to be centrally entailed in the elimination of pain as the unmaking of the world is held to be entailed in pain's infliction? (Scarry 1985: 22)

This is an essay about power.

Contrast the following three images of multiple selves or 'split personalities':

1. *An executive of a major company presents different faces.* The executive is a middle-aged man, personable, educated, successful. To tour the manufacturing division of the plant, he dons a hard hat and walks the floor, speaking the lingo of the people who work there. In a board meeting he employs metaphors and statistics, projects a vision of the future of the company. On weekends he rolls up his sleeves and strips old furniture, plays lovingly with his children that he has not seen all week.

2. *A self splits under torture.* The adolescent girl sits on the therapist's couch, dressed as a prostitute would dress, acting coyly. Last week she wore the clothes of a matronly, rather sombre secretary, and called herself by a different name. Her diagnosis is multiple personality disorder. Most cases of this once-thought-rare disorder arise from severe abuse, sexual or physical torture.

3. *A Chicana lesbian writes of her white father.* The words are painful, halting, since they are written for an audience finding its identities in being brown, or lesbian, or feminist. As in all political movements, it is easier to seek purity than impurity. Cher'ríe

Moraga (1983) writes of the betrayal that paradoxically leads to integration of the self, La Chingara, the Mexican Indian woman who sleeps with the white man, betrays her people, mothers her people. Which self is the 'real' self here?

Bruno Latour's powerful aphorism, 'science is politics by other means', coined in the context of his discussion of Pasteur's empire-building and fact-creating enterprises has been taken up by most of the research in the new sociology of science, in one form or another (1987). The central image of Pasteur is that of the executive with many faces: to farmers, he brings healing, to statisticians, a way of accounting for data, to public health workers, a theory of disease and pollution that joins them with medical research. He is stage-manager, public relations person, behind-the-scenes planner. It is through a series of translations that Pasteur is able to link very heterogeneous interests into a mini-empire, thus, in Latour's words, 'raising the world' (1983).

The multiplicity of selves which Pasteur is able to unite is an exercise of power of great importance. And from Latour's work, and that exploring related themes, we also understand that the enrolment does not just involve armies of people, but also of nature and technologies. Explanations and explorations, *intéressement*, extends to the non-human world of microbes, cows, and machines. A new frontier of sociological explanation is found through links between traditional interests and politics, and those usually ignored by such analyses, of nature and technique.

The multiplicity of Pasteur's identities or selves is critical to the kind of power of the network of which he is so central a part. Yet this is only one kind of multiplicity, and one kind of power, and one kind of network. Its power rests, as Latour, Callon and others who have written about this sort of power in networks themselves attest, upon processes of delegation and discipline (Callon 1986). This may be delegation to machines, or to other allies – often humans from allied worlds who will join forces with the actor and attribute the fruits of their action back to him, her or them. And the discipline means convincing or forcing those delegated to conform to patterns of action and representation. This has important political consequences; as Fujimura has written:

> While Callon and Latour might be philosophically correct about the constructed nature of the science-society dichotomy (who represents nonhumans versus who represents humans), the consequences of that construction are important . . . I want to

> examine the practices, activities, concerns and trajectories of *all the different participants* – including nonhumans – in scientific work. In contrast to Latour, I am still sociologically interested in understanding why and how some human perspectives win over others in the construction of technologies and truths, why and how some human actors will go along with the will of other actors, and why and how some human actors resist being enrolled. . . . I want to take sides, to take stands. (1991a: 17 of MS)

The two other kinds of multiplicity I mention above – multiple personality and marginality – are the point of departure for feminist and interactionist analyses of power and technology. We become multiple for many reasons. These include the multiple personalities that arise as a response to extreme violence and torture and extend to the multiplicity of participating in many social worlds – the experience of being marginal. By experience and by affinity, some of us begin not with Pasteur, but with the monster, the outcast.[1] Our multiplicity has not been the multiple personality of the executive, but that of the abused child, the half-breed. We are the ones who have done the invisible work of creating a unity of action in the face of a multiplicity of selves, *as well as*, and at the same time, the *invisible work* of lending unity to the face of the torturer or of the executive. We have usually been the delegated *to*, the disciplin*ed*.[2] Our selves are thus in two senses monstrous selves, cyborgs, impure, first in the sense of uniting split selves and secondly in the sense of being that which goes unrepresented in encounters with technology. This experience is about multivocality or heterogeneity, but not only that. We are at once heterogeneous, split apart, multiple – and through living in multiple worlds *without* delegation, we have experience of a self unified only through action, work and the patchwork of collective biography (see Fujimura 1991a and Strauss 1969 for discussions of this latter point).

We gain access to these selves in several ways:

1. by refusing those images of the executive in the network which screen out the work that is delegated. That is, in the case of Pasteur or any executive, much of the work is attributed back to the central figure, erasing the work of secretaries, wives, laboratory technicians, and all sorts of associates. When this invisible work (Star 1991; Shapin 1989; Daniels 1988) is recovered, a very different network is discovered as well;

2. by refusing to discard any of our selves in an ontological sense – refusing to 'pass' or to become pure, and this means in turn,

3. acknowledging the primacy of *multiple membership* in many worlds at once for each actor in a network. This *multiple marginality* is a source not only of monstrosity and impurity, but of a power that at once resists violence and encompasses heterogeneity. This is at its most powerful a collective resistance, based on the premise that the personal is political.

All of these ways of gaining access imply listening, rather than talking on behalf of. This often means *refusing* translation – resting uncomfortably but content with that which is wild to us.

The background in science studies

A number of recent conversations in the sociology of technology concern the nature of this relationship between people and machines, human and non-human (see e.g. Latour 1988; Callon 1986). Some focus on the divide between them: where should it be placed? There is a fierce battle, for instance, between several British and French sociologists of science on precisely this question. The British sociologists involved argue that there is, and should be, a moral divide between people and machines, and attempts to subvert it are dehumanizing ones. They return us to a primitive realism of the sort we had before science studies. The French, on the other hand, focus against 'great divides', and seek a heuristic flattening of the differences between people and machines in order to understand the way things work together. These often break conventional boundaries. A third strand, which I shall loosely call American feminist, argues that people and machines are coextensive, but in a densely stratified space, and that the voices of those suffering from abuses of technological power are among the most powerful analytically. A fourth strand, European and American phenomenology or ethnomethodology, argues that technology is an occasion to understand the way understanding itself – social order, meaning, routines – is constituted and reconstituted dynamically, and that reflexive analysis of technology is thus paramount. (Several of these essays appear in Pickering 1991.)

In this midst of these conversations, I have found myself asking, 'what *is* technology?' or sometimes, 'what *is* a human being?' As a

result of the discussions I mentioned above, we walk in a very interesting landscape these days in science and technology studies. There are cyborgs, near-animate doors, bicycles and computers, 'conversations' with animals and objects, talk that sounds quite ecological and Green, if not downright pagan, about the continuum of life and knowledge; talk that opens doors on topics like subjectivity, reflexivity, multivocality, nonrational ways of knowing. In the policy field, things are scarcely less lively. On the one hand, critics of technology (Kling, Dreyfus) are labelled Luddites and scathingly attacked by those developing state-of-the-art technology. On the other, utopian advocates of new systems envision global peace through information technology, genetic maps, or cyberspace simulations. A third side invokes visions of techno-ecological disaster, accidents out of control, a world of increasingly alienated work where computers are servants of a management class. At the same time, people from all sides of the fray are blurring genres (fiction and science, for example), disciplines, or familiar boundaries.

Sociologists of science have helped[3] create this landscape through a heretical challenging of the biggest sacred cow of our times: the truthfulness of science as given from nature, the inevitability of scientific findings, their monolithic voices. Even in severely criticizing science for biases of gender, race or militarism, science critics had not previously ventured far into this territory. Although often implicit, an early message from science criticism had been that science done right would not be biased. The message from sociology of science has consistently been: the 'doing right' part *is* the contested territory. There are a few people asking the question about whether doing science at *all* can constitute doing right, or whether the entire enterprise is not necessarily flawed, but these are relatively rare: Restivo (1988) and Merchant (1980) are among them.

There is much disagreement in science studies about the nature of the politics by other means in science, both descriptively and prescriptively. We are recognizing that in talking of the central modern institutions of science and technology, we are talking of moral and political order (see Clarke 1990a). But do we have a fundamentally *new* analysis of that order (or those orders)? Are science and technology different? Or are they just new, interesting targets for social science?

Since few of us are interested in merely adding a variable to an extant analysis, most sociologists of science would hold that there *is* something unique about science and technology (but see

Woolgar 1991 for a critique of this notion in the recent 'turn to technology' in science studies). These include the ideas that:

– science is the most naturalized of phenomena, helping form our deepest assumptions about the taken-for-granted;

– technology freezes inscriptions, knowledge, information, alliances and actions inside black boxes, where they become invisible, transportable, and powerful in hitherto unknown ways as part of socio-technical networks;

– most previous social science has focused exclusively on humans, thus ignoring the powerful presence, effects and heuristic value of technologies in problem-solving and the moral order;

– science as an ideology legitimates many other activities in a meta sense, thus becoming a complex, embedded authority for rationalization, sexism, racism, economic competitiveness, classification and quantification;

– technology is a kind of social glue, a repository for memory, communication, inscription, actants, and thus has a special position in the net of actions constituting social order.

There is as well a persistent sense in science studies that technology in particular is *terra incognita* for social scientists, perhaps because of the myth of 'two cultures' of those who work on machines vs. those who study or work with people.

Power in the current problems of sociology of technology

This sense of a new territory, and a unique set of problems has prompted a number of historical reconstructions, where the participation of scientists, technologies, various devices and instruments are included in the narrative. Many sociologists of science claim that taking these new actors into account gives a new, more complete analysis of action. 'Politics by other means' is underscored by looking at how traditional power tactics, such as entrepreneurship or recruitment, are supported by new activities, such as building black boxes, or translating the terms of a problem from scientific language to some other language or set of concerns.

In the terms of Latour and Callon, this latter is the power of *intéressement* – the process of translating the images and concerns of one world into that of another, and then disciplining or maintaining that translation in order to stabilize a powerful network. The networks include people, the built environment, animals and plants, signs and symbols, inscriptions, and all manner

of other things. They purposely eschew divides such as human/nonhuman and technology/society.

Another discourse about 'politics by other means' concerns groups traditionally dispossessed or oppressed in some fashion: ethnic minorities, women of all colours, the old, the physically disabled, the poor. Here the discourse has traditionally been about access to technology, or the effects of technology (often differential) upon a particular group. Some examples include the sexist design and impact of reproductive technologies; the lack of access to advanced information technologies by the poor, further deepening class differences: the racist and sexist employment practices of computer chip manufacturers; and issues of deskilling and automation relating to labour.

Some writers in the science studies area have begun to bring these two concerns together, although others have begun to drive them apart in acrimonious battle (see e.g. Scott 1991). From one point of view, discussions of racism and sexism use reified concepts to manipulate tired old social theory to no good ends except guilt and boredom. From another, the political order described in actor network theory, or in descriptions of the creation of scientific facts, they describe an order which is warlike, competitive, and biased toward the point of view of the victors (or the management). Yet both agree that there are important joint issues in opening the black boxes of science and technology, in examining previously invisible work, and, especially, in attempting to represent more than one point of view within a network. We know how to discuss the process of translation from the point of view of the scientist, but much less from that of the laboratory technician, still less from that of the lab's janitor, much as we agree in principle that all points of view are important. There is a suspicion from one side that such omissions are not accidental; from the other, that they reflect the adequacy of the available material, but are not in principle analytic barriers.

The purpose of this essay is to attempt to provide some tools hopefully useful for several of these discourses, and perhaps as well as show some ways in which technology re-illuminates some of the oldest problems in social science. I can see two leverage points for doing this. These are 1) the problem of standards, and their relationship with invisible work; and 2) the problem of identity, and its relationship to marginality.

There are many challenges associated with adopting the stance that each perspective is important in a network analysis. One is

simply to find the resources to do more work on traditionally underrepresented perspectives (see e.g. Shapin 1989; Star 1991; Clarke and Fujimura in press). Another is using multiplicity as the point of departure for *all* analysis, instead of adding perspectives to an essentially monolithic model. Yet another is methodological: how to model (never mind translate or try to find a universal language for) the deep heterogeneities that occur in any juxtaposition, any network? (Star and Griesemer 1989; Star 1988; Callon 1986, 1990). This methodological issue is a state-of-the-art one in many disciplines, including science studies, but also including organization studies, computer science (especially distributed artificial intelligence and federated databases), and literary theory.

This essay speaks to the second point: how to make multiplicity primary for some of the concerns about power appearing now in science studies. The following example illustrates some common aspects of the problems of standards and invisible work.

On being allergic to onions

I am allergic to onions that are raw or partially cooked. When I eat even a small amount, I suffer stomach pain and nausea that can last for several hours. In the grand scheme of things this is a very minor disability. However, precisely because it is so minor and yet so pervasive in my life, it is a good vehicle for understanding some of the small, distributed costs and overheads associated with the ways in which individuals, organizations and standardized technologies meet.

The case of McDonald's

> Participation in McDonald's rituals involves temporary subordination of individual differences in a social and cultural collectivity. By eating at McDonald's, not only do we communicate that we are hungry, enjoy hamburgers, and have inexpensive tastes but also that we are willing to adhere to a value system and a series of behaviors dictated by an exterior entity. In a land of tremendous ethnic, social, economic, and religious diversity, we proclaim that we share something with millions of other Americans. (Kottak 1978: 82)

One afternoon several years ago I was very late to a meeting. Spying a McDonald's hamburger stand near the meeting, I dashed in and ordered a hamburger, remembering at the last minute to add, 'with no onions'. (I hadn't eaten at McDonald's since developing the onion allergy.) Forty-five minutes later I walked out with my meal, while all around me people were being served at lightning speed. Desperately late now and fuming, I didn't think about the situation, but merely felt annoyed. Some months later, I was again with a group, and we decided to stop to get some hamburgers at another McDonald's. I had forgotten about my former experience there. They all ordered their various combinations of things, and when it came to my turn, I repeated my usual, 'hamburger with no onions'. Again, half an hour later, my companions had finished their lunches, and mine was being delivered up by a very apologetic counter server. This time the situation became clear to me.

'Oh,' I said to myself, 'I get it. They simply can't deal with anything out of the ordinary.' And indeed, that was the case. The next time I went to a fast-food restaurant I ordered along with everyone else, omitted the codicil about onions, took an extra plastic knife from the counter, and scraped off the offending onions. This greatly expedited the whole process.

The curious robustness of disbelief on the part of waiters

I travel a lot. I also eat out at restaurants a lot. I can state with some certainty that one of the more robust cross-cultural, indeed cross-class, cross-national phenomena I have ever encountered is a curious reluctance by waiters to believe that I am allergic to onions. Unless I go to the extreme of stating firmly that 'I don't want an onion on the plate, near the plate, in the plate, or even hovering *around* the food', I will get an onion where I have requested none (approximately 4 times out of 5), at restaurants of all types, and all levels of quality, all over the world.

The cost of surveillance

In my case, the cost of surveillance about onions is borne entirely by me (or occasionally by an understanding dinner partner or

host). Unlike people on salt-free, kosher or vegetarian regimes, there exists no recognizable consumer demand for people allergic to onions. So I often spend half my meal picking little slivers out of the food or closely examining the plate – a state of affairs that would probably be embarrassing if I were not so used to doing it by now.

Anyone with an invisible, uncommon or stigmatized disorder requiring special attention will hopefully recognize themselves in these anecdotes. If half the population were allergic to onions, no doubt some institutionalized processes would have developed to signal, make optional, or eliminate them from public eating places. As things stand, of course, such measures would be silly. But the visible presence of coronary patients, elders, vegetarians, orthodox Jews, and so on, has led many restaurants, airlines, and institutional food suppliers to label, regulate and serve food based on the needs of these important constituencies.

When an artifact or event moves from being presumed neutral to being a marked object – whether in the form of a gradual market shift or a stronger one such as barrier-free architecture for those in wheelchairs or deaf-signing for the evening news – the nature of human encounters with the technologies embedded in them may be changed. This is one form where politics arise in connection with technology and technological networks. These are politics which come to bear a label: 'handicapped access', 'reproductive technologies', 'special education', even 'participant-centred design'.

But the signs which bear labels are deceptive. They make it seem as if the matter of technology were a matter of expanding the exhaustive search for 'special needs' until they are all tailored or customized; the chimera of infinite flexibility, especially in knowledge-based technologies, is a powerful one.

There are two ways in which this illusion can be dangerous. The first is in the case of things like onions: there are always misfits between *standardized* or *conventional* technological systems and the needs of individuals (Star 1990 discusses this with respect to high technology development). In the case of McDonald's, a highly standardized and franchised firm, changes can be made only when market niches or consumer groups arise that are large enough to affect the vast economies of scale practised by the firm. Thus, when dieters and Californians appear to command sufficient market share to make a difference, salad bars appear in McDonald's; non-onion entrees are far less likely. Even where there are no

highly standardized production technologies (in most restaurants, for instance), a similar phenomenon may appear in the case of highly conventionalized activities – thus chefs and waiters automatically add onions to the plate, because most people eat them. It is easier to negotiate individually with non-standardized producers, but not guaranteed. The lure of flexibility becomes dangerous when claims of universality are made about any phenomenon. McDonald's appears to be an ordinary, universal, ubiquitous restaurant chain. *Unless* you are: vegetarian, on a salt-free diet, keep kosher, eat organic foods, have diverticulosis (where the sesame seeds on the buns may be dangerous for your digestion), housebound, too poor to eat out at all – or allergic to onions.

The second illusion about perfect flexibility is a bit more abstract, and concerns not so much exclusion from a standardized form, but the ways in which membership in multiple social worlds can interact with standard forms. Let's say for the sake of argument that McDonald's develops a technology which includes vegetarian offerings, makes salt optional, has a kosher kitchen attached to every franchise, runs their own organic farms for supplies, includes a meals-on-wheels programme and free lunches for the poor, and all sorts of modular choices about what condiments to add or subtract. But that morning I have joined the League to Protect Small Family-Owned Businesses, and, immune to their blandishments, walk down the street and bypass all their efforts. I have added a self to which they are blind, but which affects my interaction with them.

We have some choices in the sociology of technology about how to conceptualize these phenomena, which are obviously exemplary of many forms of technological change. First is a choice about what is to be explained. It is true that McDonald's appear in an astonishing number of places; they are even more successful than Pasteur at politics by other means, if extension and visible presence are good measures. Is that the phenomenon to be explained – the enrolment and *intéressement* of eating patterns, franchise marketing, labour pool politics, standardization and its economics? It is also true that McDonald's screens out a number of clients in the act of standardizing its empire, as we have just discussed. Should *that* be the phenomenon we examine – the experience of being a McDonald's non-user, a McDonald's resister or even castaway? In the words of John Law, sociologist of technology and of McDonald's:

> In particular, the McDonald's marketing operation surveys its customers in order to obtain their reaction to the adequacy of their experience in the restaurant on a number of criteria: convenience, value, quality, cleanliness and service . . . these criteria are in no way 'natural' or inevitable. Rather they must be seen as cultural constructs. The idea that food should be fast, cheap, or convenient would be anathema, for instance, to certain sections of the French middle class . . . These reasons for eating at McDonald's might equally well be reasons for *not* eating there in another culture. (1984: 184)

There are two kinds of phenomena going on here, and both miss another aspect of the transformation of the sort captured very well by semioticians in discussions of rhizomatic metaphors, or that which is outside of both the marked and unmarked categories, which resists analysis from inside *or* outside. In this case, this means living with the *fact* of McDonald's no matter where you fall on the scale of participation, since you live in a landscape with its presence, in a city altered by it, or out in the country, where you, at least, drive by it and see the red and the gold against the green of the trees, hear the radio advertising it, or have children who can hum its jingle.

The power of feminist analysis is to move from the experience of being a non-user, an outcast or a castaway, to the analysis of the fact of McDonald's (and by extension, many other technologies) – and implicitly to the fact that 'it might have been otherwise'[4] – there is nothing necessary or inevitable about the presence of such franchises. We can bring a stranger's eye to such experiences. Similarly, the power of actor network theory is to move from the experience of the building of the empire of McDonald's (and by extension, many other technologies) and from the enormous amount of enrolment, translation and *intéressement* involved – to the fact that 'it might have been otherwise' – there is nothing necessary or inevitable about any such science or technology, all constructions are historically contingent, no matter how stabilized.

One powerful way these two approaches may be joined is in linking the 'non-user' point of departure with the translation model, returning to the point of view of that which cannot be translated: the monstrous, the Other, the wild. Returning again to John Law's observation about the way McDonald's enrols customers:

> It creates classes of consumers, theorizes that they have certain interests, and builds upon or slightly diverts these interests in

> order to enlist members of that group for a few minutes each day or each week. It does this, group by group and interest by interest, in very particular ways . . . Action is accordingly induced not by the abstract power of words and images in advertising, but rather in the way that these words and images are put into practice by the corporation, and then *interpreted* in the light of the (presumed) interests of the hearer. Advertising and enrolment work if the advertiser's theory of (practical) interests is workable. (1984: 189)

He goes on to discuss the ways in which McDonald's shares sovereignty with other enterprises which seek to order lives, and of coexisting principles of order which in fact stratify human life.

But let our point of departure be not that which McDonald's stratifies, nor even the temporally brief but geographically extensive scope it enjoys and shares with other institutions, nor the market niches which it does not (yet?) occupy. Let it be the work of scraping off the onions, the self which has *just* joined the small business preservation group, the *as-yet unlabelled*. This is not the disenfranchised, which may at some point be 'targeted'; not the residual category not covered in present marketing taxonomies. This is that which is permanently escaping, subverting, but nevertheless in relationship with the standardized. It is not nonconformity, but heterogeneity. In the words of Donna Haraway, this is the cyborg self:

> The cyborg is resolutely committed to partiality, irony, intimacy, and perversity. It is oppositional, utopian, and completely without innocence. No longer structured by the polarity of public and private, the cyborg defines a technological polis based partly on a revolution of social relations in the *oikos*, the household. Nature and culture are reworked; the one can no longer be the resource for appropriation or incorporation by the other. (1991: 151)

In a sense, a cyborg *is* the relationship between standardized technologies and local experience; that which is between the categories, yet in relationship to them.

Standards/conventions and their relationship with invisible work: heterogeneous 'externalities'

> To speak for others is to first silence those in whose name we speak. (Callon 1986: 216)

One problem in network theory is that of trying to understand how networks come to be stabilized over a long period of time. Michel Callon has tackled this problem in his essay, 'Techno-Economic Networks and Irreversibility' (1991). There are some changes which occur in large networks which are irreversible, no matter what their ontological status. The initial choice of red as a colour in traffic lights that means, 'stop', for example, is now a widespread convention that would be functionally impossible to change, yet it was initially arbitrary. The level of diffuse investment, the links with other networks and symbol systems, and the sheer degree of interpenetration of 'red as stop' renders it irreversible. We are surrounded by these networks: of telephones, computer links, road systems, subways, the post, all sorts of integrated bureaucratic record-keeping devices.

Irreversibility is clearly important for an analysis of power and of robustness in networks in science studies. A fact is born in a laboratory, becomes stripped of its contingency and the process of its production to appear in its facticity as Truth. Some Truths and technologies, joined in networks of translation, become enormously stable features of our landscape, shaping action and inhibiting certain kinds of change. Economically, those who invest with the winners in this stabilization process may themselves win big as standard setters. Later, others sign on to the standardized technologies in order to gain from the already-established structures, and benefit from these *network externalities*. Just as city-dwellers benefit from the ongoing positive externalities of theatres, transportation systems, and a density of retail stores, network-dwellers benefit from externalities of structure, density of communications populations, and already-established maintenance. Any growing network evidences this, such as the community of electronic mail users in academia. One can now sign on and (more or less) reliably communicate with friends, benefiting from a network externality that didn't exist just a few years ago.

Understanding how, and when, and whether one can benefit from network externalities is an essentially sociological art: how does the individual join with the aggregate, and to whose benefit?

Once arrangements become standard in a community, creating alternative standards may be expensive or impossible, unless an alternative community develops for some reason. Sometimes the expense is possible and warranted, and may in fact lead to the development of another community, as in Becker's analysis of maverick artists (1982).

Becker raises the question of the connection between work, communities and conventions in creating aesthetics and schools of thought. He begins with a series of simple, pragmatic questions: why are concerts two hours long? Why are paintings the size that they are (in general)? By examining the worlds which intersect to create a piece of art, *and valuing each one in his analysis*, he restores some of the normally hidden aspects of network externalities. There are contingencies for musicians' unions in prescribing hours of work, but also for those parking the cars of symphony-goers, those cleaning the buildings after hours, and these contingencies, as much as considerations of more publicly-acknowledged traditions, are equally important in forming aesthetic traditions.

So most composers write for concerts that are about two hours long, most playwrights plays of similar length; most sculptures fit in museums and the backs of transport vans, and so forth. Those artists who are mavericks play with these conventions, opposing one or more. Occasionally, a naive artist – with little knowledge of any of the conventions – will be picked up and accepted into the art world – and for that reason is especially sociologically interesting for illuminating the usually taken-for-granted.

The phenomenon Becker is pointing to in art is equally true in science and technology, if not more so, because there are so few instances of solitary or naive scientists (inventors are possibly a counterexample). Scientists and technologists move in communities of practice (Wenger 1990; Lave and Wenger, to appear) or social worlds (Clarke 1990b) which have conventions of use about materials, goods, standards, measurements, and so forth. It is expensive to work within a world and practise outside this set of standards; for many disciplines (high energy physics, advanced electronics research, nuclear medicine), nearly impossible.

Yet these sets of conventions are not always stable. At the beginning of a technological regime; when two or more worlds first come together; when a regime is crumbling – these are all periods of change and upheaval in worlds of science. As well, *the sets of conventions are never stable for non-members*. McDonald's may

provide sameness and stability for many people – in John Law's words, it may order five minutes of their world each day – but for me and for others excluded from their world, it is distinctly not ordered. Rather, it is a source of chaos and trouble.

Network or networks: that is the question

There is thus a critical difference between stabilization within a network or community of practice, and stabilization between networks, and again critical differences between those for whom networks are stable and those for whom they are not, where those are putatively the 'same' network. Again we have a choice for a point of departure: does McDonald's represent a stable network, a source of chaos, or a third thing altogether?

Politics by other means or by the same old means?

Bruno Latour explicates some of the features of actor network theory, and the mix between humans and nonhumans involved in socio-technical systems, in his article on 'The Sociology of a Door'. He advocates an ecological analysis of people-and-objects, looking at the links between them, the shifts with respect to action, and the ways that duties, morality and actions are shifted between humans and nonhumans: 'The label "inhuman" applied to techniques simply overlooks translation mechanisms and the many choices that exist for figuring or de-figuring, personifying or abstracting, embodying or disembodying actors' (1988: 303).

The analytic freedom accorded by this heuristic is considerable; in fact Latour and Callon's work has opened up a whole new way of analysing technology. However, the problem remains with respect to humans and the question of power that such mixes may seem to sidestep traditional questions of distribution and access: 'As a technologist, I could claim that, provided you put aside maintenance and the few sectors of population that are discriminated against, the groom does its job well, closing the door behind you constantly, firmly and slowly' (p. 302).

There is no analytic reason to put aside maintenance and the few sectors of population that are discriminated against, in fact, every reason not to. As Latour himself notes in response to criticism of the actor network theory for the political implications of its

'levelling' of human/nonhuman differences, heuristic flattening does not mean the same thing as empirical ignoring of differences in access or experience. Rather, it is a way of breaking down reified boundaries that prevent us from seeing the ways in which humans and machines are intermingled.

However, one of the features of the intermingling that occurs may be that of exclusion (technology as barrier) or violence, as well as of extension and empowerment. I think it is both more analytically interesting and more politically just to begin with the question, *cui bono*? than to begin with a celebration of the fact of human/nonhuman mingling.

Network externalities and barriers to entry: physical and cultural

One of the interesting analytic features of such networks is the question of the *distribution of the conventional*. How many people can get in and out of doors, and how many cannot? What is the phenomenology of encounters with conventions and standardized forms, as well as with new technologies? And here an opportunity for new ground in science studies arises: given that we are multiply marginal, given that we may interweave several selves with our technologies, both in design and use, where and what is the meeting place between 'externalities' and 'internalities'? I say this not to invoke another 'great divide', but to close one. A stabilized network is only stable for some, and that is for those who are members of the community of practice who form/use/maintain it. And part of the public stability of a standardized network often involves the private suffering of those who are not standard – who must use the standard network, but who are also non-members of the community of practice.

One example of this is the standardized use of the pseudo-generic 'he' and 'him' in English to refer to all human beings, a practice now changing in many places due to feminist influence. Social psychologists found that women who heard this language form understood its meaning, but were unable to project a concrete example, and unable to place themselves within the example, whereas men could hear themselves in the example (Martyna 1978). Women thus both used and did not use the technology of this expression, and, with the advent of feminist analyses of language, were able to bring that experience to public scrutiny.

When standards change, it is easier to see the invisible work and the invisible memberships that have anchored them in place. But until then it may be difficult, at least from the managerial perspective. A recent article by Paul David, an economist of standards, looks at a familiar problem for economists of information technology, called 'the productivity paradox' (1989). For many firms, and even at the level of national economies, the introduction of (often very expensive) information technology has resulted in a decline in productivity, contrary to the perceived productivity benefits promised by the technology. David makes a comparison with the introduction of the general purpose electric dynamo engine at the beginning of the century, which saw a similar decline in productivity. He refers to the work of several economists on the 'transition regime hypothesis' – basically, that large scale technological change means a change in economic regime, which carries its own – often invisible to standard analyses – costs.

The transition regime hypothesis: whose regime? whose transition?

From the viewpoint of the analysis put forth here, the productivity paradox is no paradox at all. If much work, practice, and membership goes unrepresented in analyses of technology and socio-technical networks, then the invisible work that keeps many of them stabilized will go unaccounted for, but appear as a decline in productivity. Just as feminist theory has tried to valorize housework and domestic labour as intrinsic to large scale economics, the invisible work of practice, balancing membership and the politics of identity is critical for the economics of networks.

Who carries the cost of distribution, and what is the nature of the personal in network theory? I believe that the answers to these questions begin with a sense of the multiplicity of human beings and of objects, and of a commitment to understanding all the work which keeps a network standardized for some. No networks are stabilized or standardized for everyone. Not even McDonald's.

Cyborgs and multiple marginalities: power and the zero point

> In torture, it is in part the obsessive display of agency that permits one person's body to be translated into another person's

> voice, that allows real human pain to be converted into a regime's fiction of power. (Scarry 1985: 18)

> It is through the use of standardized packages that scientists constrain work practices and define, describe, and contain representations of nature and reality. The same tool that constrains representations of nature can simultaneously be a flexible dynamic construction with different faces in other research and clinical/applied worlds. Standardized packages are used as a dynamic interface to translate interests between social worlds. (Fujimura 1991b: 33 of MS)

> To translate is to displace . . . But to translate is also to express in one's own language what others say and want, why they act in the way they do and how they associate with each other; it is to establish oneself as a spokesman. At the end of the process, if it is successful, only voices speaking in unison will be heard. (Callon 1986: 223)

Several years ago I taught a graduate class in feminist theory at a large university in California. The first day of class eight women and one other person showed up. I couldn't tell whether the ninth person was male or female. S/he gave his/her name as 'Jan', an ambiguous name. In the course of our class discussions, it turned out that Jan was considering transsexual surgery. S/he'd taken some hormone shots, and thus begun to grow breasts, and was dressing in a gender-neutral way, in plain slacks and short-sleeved shirt. S/he said that s/he wasn't sure if s/he wanted to go ahead with the surgery; that s/he was enjoying the experience of being ambiguous gender-wise. 'It's like being in a very high tension zone, as if something's about to explode', she said one day. 'People can't handle me this way – they want me to be one thing or another. But it's also really great, I'm learning so much about what it means to be neither one nor the other. When I pass as a woman, I begin to understand what feminism is all about. But this is different somehow.'

I was deeply moved by Jan's description of the 'high tension zone', though I didn't really know what to make of it at the time. A few weeks into the class we became friends, and she told me more about the process she was going through. She worked for one of the high technology firms in Silicon Valley, one which offered very good health insurance. But the health insurance

company, Blue Cross, was unsure about paying for the extremely expensive process of transsexual surgery. Furthermore, the 'gender identity clinic' where Jan was receiving psychotherapy and the hormone shots was demanding that s/he dress more like a conventionally feminine woman to 'prove' that s/he was serious in her desire for the surgery. She told me that they required you to live for 2 years passing as a woman.

Around the Christmas holidays we fell out of touch. I was amazed to receive a phone call from Jan in February. 'Well, congratulate me. I've done it', she exclaimed into the phone. 'What?' I said, puzzled. 'I've had the surgery, I'm at home right this minute', she said. I asked her how she was feeling, and also how it had happened. 'Did (the company) decide to pay for it?' I questioned. 'No', she replied. 'Blue Cross decided to pay for the whole thing. And then the doctor just said, "better do it now before they change their minds." So I did!'

In the years that followed I saw Jan's (now Janice) name once in a while in local feminist club announcements; she became an active leader in the women in business groups in the area. I never saw her again after that February, but continued to be haunted by the juxtaposition of the delicate 'high tension zone', the greed and hypocrisy of the insurance companies and physicians involved, and her own desperation.

Another friend has told me of a similar phenomenon within the gender clinics which require candidates for transsexual surgery to dress and act *as stereotyped females*, and deny them surgery if they do not: 'They go from being unambiguous men, albeit unhappy men, to unambiguous women' (Stone 1989: 5 of MS). She goes on to recommend that the transsexual experience become an icon for the twin experiences of the high tension zone and the gender stereotype/violence:

> Here on the gender borders at the close of the twentieth century . . . we find the epistemologies of white male medical practice, the rage of radical feminist theories and the chaos of lived gendered experience meeting on the battlefield of cultural inscription that is the transsexual body: a meaning machine for the production of ideal type . . . Given this circumstance a counterdiscourse is critical, but it is difficult to generate a discourse if one is programmed to disappear. The highest purpose of the transsexual is to erase his/herself, to fade into the 'normal' population as soon as possible. What is lost is the

> ability to authentically represent personal experience. (Stone 1989: 9 of MS)

Here is a socio-technical network, an exercise of power – and a certain kind of loss. What would it have taken to preserve the 'high tension' of Jan's non-membership, the impurity of being neither male nor female? This high tension zone is a kind of zero point between dichotomies (see Latour 1987; in *Irreductions*, in Pickering 1991) or between great divides: male/female, society/technology, either/or.

Elaine Scarry's extraordinary *The Body in Pain: The Making and Unmaking of the World* (1985) is a book about torture and war. Her argument is that during torture (and in similar ways during war) the world is created and uncreated. The torturer shrinks the world of the tortured, by taking the uncertainty of experienced pain and focussing it on material objects and on the verbal interchange between them. Old identities are erased, made immaterial.[5] We never really know about the pain someone else experiences, argues Scarry, and this uncertainty has certain political attributes that are explored during torture and war as the private becomes made public and monovocal. The visible signs of violence are transported to the public, and through a series of testaments, modifications, and translations become belief.

There are striking similarities between the making of the world Scarry describes and the making of the world by Pasteur described by Latour, or the successful process of translation Callon analyses, although there seems to be no violence in these latter. A set of uncertainties are translated into certainties: old identities discarded, and the focus of the world narrowed into a set of facts.

The unity and closedness of the world of the torturer/tortured are seen as aberrant and outside the normal world by most people – far outside our normal realm. But Scarry argues that it is precisely this distancing that is one of the factors that makes torture possible, *because* it makes invisible to us what are in fact the pedestrian ingredients of making the world outside the extreme of torture. Simone de Beauvoir (1948) and Hannah Arendt (1977) have made similar arguments about anaesthetization to violence and the banality of evil. We always have elements of uncertainty about the personal world of another, especially about pain and suffering; we often leave one world for another, or narrow our experience without betrayal or permanent change – for example, in the dentist's chair, when we can think only of the immanent pain.

If we shift our gaze from the extremes: torture, or the enormous success of Pasteur, to something as simple and almost silly as an allergy to onions, it becomes clear that similarly quotidian events form part of a pattern. Stabilized networks seem to insist on annihilating our personal experience, and there is suffering. One source of the suffering is denial of the co-causality of multiple selves and standards, when claims are made that the standardized network is the only reality that there is. The uncertainties of our selves and our biographies fall to the monovocal exercise of power, of making the world. My small pains with onions are on a continuum with the much more serious and total suffering of someone in a wheelchair barred from activity, or those whose bodies in other ways are 'non-standard'. And the work I do: of surveillance, of scraping off the onions, if not of organizing non-onion-eaters, is all prior to giving voice to the experience of the encounters. How much more difficult for those encounters which carry heavier moral freight?

Networks which encompass both standards and multiple selves are difficult to see or understand except in terms of deviance or 'other' as long as they are seen in terms of the executive mode of power relations. Then we will have doors that let in some people, and not others, and our analysis of the 'not others' can't be very important, certainly not central. The torture elicited by technology, especially, because it is distributed over time and space, because it is often very small in scope (five minutes of each day), or because it is out of sight, is difficult to see as world making. Instead it is the executive functions, having enrolled others, which are said to raise the world.

The vision of the cyborg, who has membership in multiple worlds, is a different way of viewing the relationship between standards and multiple selves. And this involves weaving in a conception of multiple membership, of a cyborg vision of nature, along with the radical epistemological democracy between humans and nonhumans. In the words of Donna Haraway:

> There's also the problem, of course, of having inherited a particular set of descriptive technologies as a Eurocentric and Euro-American person. How do I then act the bricoleur that we've all learned to be in various ways, without being a colonizer . . . How do you keep foregrounded the ironic and iffy things you're doing and still do them seriously. Folks get mad because you can't be pinned down, folks get mad at me for not

> finally saying what the bottom line is on these things: they say, well do you or don't you believe that non-human actors are in some sense social agents? One reply that makes sense to me is, the subjects are cyborg, nature is coyote, and the geography is elsewhere. (in Penley and Ross 1990/91: 10)

But there is a problem with this conception, and that has to do with the simultaneous poverty of our analyses of human/nonhuman, and of multiple membership for humans between human groups:

> You can't work without a conception of splitting and deferring and substituting. But I'm suspicious of the fact that in our account of both race and sex, each has to proceed one at a time . . . there is no compelling account of race and sex *at the same time*. There is no account of any set of differences that work other than by twos simultaneously. Our images of splitting are too impoverished . . . we don't actually have the analytical technologies for making the connections. (in Penley and Ross 1990/91: 15–16)

What would a richer theory of splitting involve, bringing together the following elements:

- multiple membership
- maintaining the 'high tension' zone while acknowledging the cost of maintaining it
- the cost of membership in multiple arenas
- multivocality and translation?

Multiple memberships, multiple marginalities

Every enrolment entails both a failure to enrol and a destruction of the world of the non-enrolled. Pasteur's success meant simultaneously failure for those working in similar areas, and a loss and world-destruction for those outside the germ theory altogether. We are only now beginning to recover the elements of that knowledge: immunology, herbal wisdom, acupuncture, the relationship between ecology and health. This had not to do with Pasteur vs. Pochet, but the ecological effects of Pasteurism and its enrolment.

One of Haraway's suggestions is that the destruction of the world of the non-enrolled is rarely total. While torture, or the total institution, is one end of a continuum, the responses to enrolment

are far more varied along a much richer continuum. The basic responses, outside of signing on, have to do with a multiplicity of selves, partial signings-on, partial commitments. Ruth Linden's courageous and moving study of survivors of the Nazi holocaust, interwoven with her own biography as an American Jew, testifies to this rich complexity (1989). Adele Clarke's study of the different communities of practice which joined together in creating modern reproductive science shows how multiple memberships, partial commitments, and meetings across concerns in fact constitute science (1990a, 1991).

Becker's analysis of commitments and 'side bets' is apposite here. In his decoupling of commitment from consistency, there is a metaphor for decoupling translation and enrolment. How can we explain consistent human behaviour? he asks. Ruling out mentalist explanations, functionalist explanations of social control, or purely behaviourist explanations, he instead offers that commitments are a complex of *side-bets* woven by the individual, ways of involving his or her action in a stream of 'valuable actions' taken up by others. Following Dewey's theory of action, he notes that we involve ourselves in many potential actions; these become meaningful in light of collective consequences, jointly negotiated (Becker 1960).

Similarly, our experiences of enrolment and our encounters with standards are complexly woven and indeterminate. We grow and negotiate new selves, some labelled and some not. Some are unproblematic in their multiplicity; some cause great anguish and the felt need for unification, especially those that claim sovereignty over the entire self.

One of the great lessons of feminism has been about the power of collective multiplicity. We began with the experience of being *simultaneously* outsiders and insiders (Hubbard and Randall 1990). In the end, it is the simultaneity that has emerged as the most powerful aspect of feminism, rather than the outsiderness. The civil liberties/equal rights part of feminism would not have fundamentally extended political theory; but the double vision, and its combination of intimacy, ubiquity and collectivity has done so (Smith 1987). It's not so much that women have been left out, but that we were both in and out at the same time.

Sociology and anthropology have long traditions of studying the marginal person – the one who both belongs and does not belong, either by being a stranger (this is especially strong in the work of Simmel and Schutz) or by being simultaneously a member of more than one community. The person who is half black and half white,

androgynous, of unknown parentage, the clairvoyant (who has access to another, unknown world) – all are either venerated or reviled in many cultures. The concept of the stranger, or strangeness to our own culture, as a window into understanding culture, is fundamental to many branches of anthropology and to ethnomethodology and its fruitful investigations into the taken-for-granted (see e.g. Garfinkel 1967 and its many references to Schutz).

Sociologist Everett Hughes extended Simmel's concern with the stranger, drawing on the work of his teacher Robert Park. He considered the anthropological strangeness of encounters between members of different ethnic groups who worked and lived together, and developed an analysis of some of the ways in which multiple membership plays itself out in the ecology of human relations. In 'Dilemmas and Contradictions of Status', for example, he explores what happens when a person working in an organization belongs to two worlds simultaneously, and the prescriptions for action and membership are different (1970: 141–50 [1945]). He used the example of a female physician, or a Black chemist. Later sociologists used a related concept, 'role strain', but that is one which fails to convey the sense of 'high tension zone' or the complexity of the relationships involved in simultaneous multiple membership.

Another student of Park's, Everett Stonequist, reviewed various forms of marginality in his monograph, *The Marginal Man: A Study in Personality and Culture Conflict* (1961 [1937]). He discussed the stories of various racial and cultural hybrids: in Hawaii, in Brazil, in the United States and South Africa, as well as the phenomenon of cultural hybridism, as among immigrants and denationalized peoples, and the Jews. What is interesting about his work is that he places marginality at the centre of *all* sociology:

> It is the fact of cultural duality which is the determining influence in the life of the marginal man. His is not a clash between inborn temperament and social expectation, between congenital personality tendency and the patterns of a given culture. His is not a problem of adjusting a single looking-glass self, but two or more such selves. And his adjustment pattern seldom secures complete cultural guidance and support, for his problem arises out of the shifting social order itself. (p. 217)

But we are all implicated in this changing social order, Stonequist goes on to say – through technology, through shifts in the meaning

of race and nationality, and through the diffusion of peoples across lands.

Because, in analysing power and technology, we are involved in understanding precisely such shifts and precisely such shifting social orders, we could take a similar mandate. We know that the objects we are now including in the sociology of science and technology belong to many worlds at once. One person's scrap paper can be another's priceless formula; one person's career-building technological breakthrough can be another's means of destruction. Elsewhere I have analysed the ways different social worlds construe the objects which inhabit more than one shared domain between scientists and others involved in the science-making enterprise, such as amateur collectors (Star and Griesemer 1989; Star 1988). People inhabit many different domains at once, as well, and the negotiation of identities, within and across groups, is an extraordinarily complex and delicate task. It's important not to presume either unity or single membership, either in the mingling of humans and nonhumans or amongst humans. Marginality is a powerful experience. And we are all marginal in some regard, as members of more than one community of practice (social world).

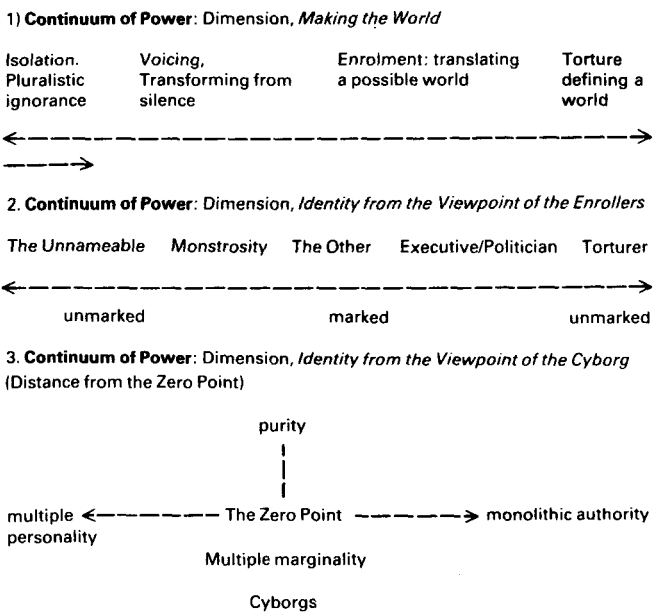
Conclusion: metaphors and heterogeneity

Because we are all members of more than one community of practice and thus of many networks, at the moment of action we draw together repertoires mixed from different worlds. Among other things, we create metaphors – bridges between those different worlds.

Power is about *whose* metaphor brings worlds together, and holds them there. It may be a power of the zero-point or a power of discipline; of enrolment or affinity; it may be the collective power of not-splitting. Metaphors may heal or create, erase or violate, impose a voice or embody more than one voice. Figure 1 sketches some of the possible configurations of this sort of power:

This essay is about a point of departure for the analysis of power. I do not recommend enfranchising or creating a market niche for those suffering from onion-allergy; nor a special needs assessment that would try to find infinitely flexible technologies for all such cases. Nor am I trying to say that conventions or standards are useless, or can be done without. But there is a question about where to begin and where to be based in our analyses of standards

Figure 1 *Dimensions of power*



and technologies. If we begin with the zero point, like my friend Jan, we enter a high tension zone which may illuminate the properties of the more conventionalized, standardized aspects of those networks which are stabilized for many. Those who have no doors, or who resist delegation – those in wheelchairs, as well as door-makers and keepers, are good points of departure for our analysis, because they remind us that, indeed, it might have been otherwise.[6]

Acknowledgements

Geof Bowker and John Law made many helpful comments on this manuscript. A conversation with Bruno Latour illuminated the importance of the executive metaphor in understanding multiple personality. Conversations with Allan Regenstreif about the relationship between severe child abuse and multiple personality were extremely helpful. Their work and friendship, and that of

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Notes

1 Monsters are the embodiment of that which is exiled from the self. Some feminist writers have argued that monsters often represent the wildness which is exiled from women under patriarchal domination, perhaps the lesbian self, and that apparently dichotomous pairs such as Beauty and the Beast, Godzilla and Fay Wray are actually intuitions of a healthy female self.
2 There are many courses for managers whose speciality is teaching executives how to delegate things to their secretaries and others below them in the formal hierarchy. Traditionally, of course, and still for the most part, this is male-to-female delegation.
3 Along with antiracist theorists, Third World writers on de-centring, deconstructionists, literary theorists, feminist activists and theorists, and critical anthropologists, among others.
4 A methodological dictum of Everett Hughes (1970).
5 This has striking resonances with the creation of the world in the 'total institution' described by Goffman in his classic book *Asylums* (1961). Fagerhaugh and Strauss (1979) as well describe a similar shrinkage of identity and of the world in their *Politics of Pain Management*.
6 This is one place where ethnomethodology and symbolic interactionism richly complement each other in exploring the taken-for-granted. See Becker 1967.

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Configuring The User: the case of usability trials

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Paper for discussion at Discourse Analysis Workshop, University of Lancaster, 25–26 September 1990.

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Configuring the user: the case of usability trials

Steve Woolgar

How are you getting on with your paper for the Lancaster meeting?[2]

It's a mess. The usual thing – not enough time to really sort out the issues before having to send it off. I keep changing my mind about what are the key things to put in it, about what the key points of the argument are. So there are still lots of bugs in it, the analysis isn't finished . . .

I know. You'd like to make it better, but you've got to send it off. So I suppose you've put the standard warning on the front cover?

Right! 'Please do not quote this preliminary draft without permission'.[3]

Interesting how people do that. It's as if you're trying to delimit the extent of access to your text. On the one hand, writers use various devices to *attract* readers into the text. For example, The Abstract is a standard synechdotal device for suggesting the reader might profit from a closer relationship with the text. Where is The Abstract, by the way?

It's just there on the next page.

Oh, right. And on the other hand, writers often try to *control* the relationship between reader and text. So you encourage readers to relate to the text, but specify constraints on how they can use it. They can look, but not touch, so to speak.

Yes. It's a bit like that American advert for tamper-proof medicines which are sealed in cellophane: 'Shrink-wrapped for

your protection'. In that case, access to the product is specified by way of a guarantee that nobody else has been there before you. Or like those warnings on the disks when you buy a software package: 'By opening this sealed disk package, you are agreeing to become bound by the terms of the Microsoft License Agreement'. The manufacturers are saying that you should only access their text if you agree to use it in certain prescribed ways.[4]

So, do you think your paper is going to work?

I'm not sure. It depends on the audience. I don't really have a good sense of what reaction to expect. That's what so helpful about these Discourse Analysis Workshops. You get a chance to try out the paper before finally going public. It gives you the opportunity to figure out who the readers will be.

Abstract

The paper explores the metaphor of machine as text, set within the context of longstanding problems in social theory about agency and object. These problems concern both the conventional basis of attribution of intentionality and presumptions about the boundedness of entities. In particular, our preconceptions about the nature and capacity of different entities shape what counts as legitimate accounts of action and behaviour. Materials from an ethnography of computers are used to show how the design and production of a new entity (a new range of microcomputers) amounts to a process of configuring its user, where 'configuring' includes defining the identity of putative users, and setting constraints upon their likely future actions. Configuring occurs in a context where knowledge and expertise about users is socially distributed. As a result of this process, the new machine becomes its relationship with its configured users. In participants' determinations of the character of users, the new machine's case provides a powerful symbol of the boundary between insiders and outsiders to the company. An analysis of audio and video records of usability trials suggests the importance of boundary work in deciding the adequacy of the relationship between machine and user.

I Introduction

It should be clear by now that technology, and information technology (IT) in particular, is just the latest excuse for doing social science. This is obvious in the prosaic sense that increased funds are available for social scientists (and others) who can construe their work as an attempt to situate technology within its social and cultural contexts. However, this is more than just a cynical comment about funding opportunism. The fact that IT has become a legitimate focus for research council funding reflects its emergence as a significant social phenomenon.[5] This, in turn, reflects a widespread perception of the potential effects of this new technology. The current mood displays concern about the extent of these effects and much effort is expended in determining the nature and capacity of IT.

This paper is part of a more general project which attempts to capitalise on current concerns about the nature of IT in order to address some longstanding questions in social theory and in the philosophy of social science, notably questions about agency and object. In essence, this project explores these issues by addressing questions about interpretation of technology. For example, it looks at how technology is understood vis-à-vis the actions and capability of humans and other animate entities; it attempts to understand how our ideas about the differences between animate and inanimate entities are modified with the introduction of new technology. Above all, it investigates the structure of a discourse which sustains and displays basic assumptions about the differential capacities of the entities with which we populate our world.

My strategy for attempting to realise these grandiose ambitions is the exploration of a metaphor: the machine as text.[6] The idea is to begin with the supposition that the nature and capacity of the machine is, at least in principle, interpretively flexible. This then sets the frame for an examination of the processes of construction (writing) and use (reading) of the machine; the relation between readers and writers is understood as mediated by the machine and by interpretations of what the machine is, what it's for, what it can do. To suggest that machines are texts is, of course, to deconstruct definitive versions of what machines can do. There is thus a sense in which the exploration of this metaphor challenges intuitive beliefs about technology; the 'actual' effects of technology are usually plain to see, and often brutishly incontrovertible. At the

same time, then, the exploration of the machine text metaphor deals with a particularly hard case in interpretation. Precisely because it is counter-intuitive to think of a machine as a text, this case might provide insights into more general questions about textuality.

It is worth stressing that the idea is to *explore* the metaphor, rather than merely to apply it. I have no wish to insist that machines *actually are* texts. Rather the point is to *play against* this metaphor, to see how far we can go with it.[7] What happens to the structure of our discourse when we introduce the notion of machine as text? What, if anything, is special about machines by comparison with other texts? What are the limits of talking in this bizarre way?

This paper is a preliminary attempt to play against one specific aspect of the machine text metaphor: the notion of the reader as user. As writers like Friedman (1989) have pointed out, the 1980s have seen considerable attention devoted to 'the problem of the user' amongst the designers and builders of computer systems. This paper takes the line that the emergence of a new range of microcomputers crucially entails the definition, delineation and emergence of The User. We could say that this process amounts to the (social) construction of the user. However, it is not just the identity of the user which is constructed. For along with negotiations over who the user might be, comes a set of design (and other) activities which attempt to define and delimit the user's possible actions. Consequently, it is better to say that by setting parameters for the user's actions, the evolving machine effectively attempts to *configure* the user.

The paper begins by outlining some problems of agency and attribution. A framework for addressing these problems is set out by way of a brief description of an eighteen month participant observation study carried out in a company which manufactures microcomputers. For reasons elaborated below, it is useful to construe this empirical study as an Ethnography of Computers. Particular attention is then given to a study of the 'usability trials' carried out by the User Products section of the company towards the latter stages of the project.

II Agency and attribution

II.1 The conventional basis of attribution

Some longstanding questions about human nature, action and agency, boil down to what we presume different entities (actors, agents) to be capable of. Our answers to this question, in turn, have consequences for what we take to be legitimate accounts of action and behaviour. For example, it is in virtue of our willingness to ascribe intentionality to certain (classes of) animate agent that we ask whether or not the armed robber *meant* to fire the gun. By contrast, our unwillingness to ascribe intentionality to certain inanimate entities makes other queries – did the gun want to fire? did it agree to being fired? – appear nonsensical or, at best, 'merely metaphorical', a 'literary device', the use of 'poetic licence'.

Of course, my use of 'our willingness' does not mean that ascription of intentionality is merely a matter of whim. If one day we felt like granting intentionality to an inanimate object – OK, let's say the gun wanted to fire! – this would not change much. Rather, the point is that the distribution of attributes is institutionalised in conventional practice. In other words, the distribution of attributes is sanctioned in virtue of conventions for correct/normal usage. Our 'unwillingness' to talk about guns wanting something reflects what we experience as awkwardnesses which arise when we try to describe things that way. A similar awkwardness occurs when we try to apply pronomial and behavioural characteristics to entities which are not normally credited with such. For example, 'the machine *who* thinks' (rather than the machine *that* thinks) invites comment about what novel claim we are making for a (particular) machine or suggests that some (merely) metaphorical usage is being employed.

Of course, things are much more complicated than this simple picture suggests. For a start, intentionality is not a quality ascribed uniformly to all types of animate agent. Amongst humans, for example, we are sometimes less likely to grant this quality to the very young, or to the old or to the mentally ill. There also appears to be a hierarchy of animate non-humans who (which?) more or less deserve attributions of cognitive states. (Dogs can be said to be looking happy, but gerbils?) More important, perhaps, is the point that there is no straightforward division of appropriate

mental predicates between animate and inanimate entities. We cannot therefore unproblematically map sets of predicates on to types of entity, precisely because predicates can be used to 'bring out' or 'suggest' or 'speak metaphorically about' the animate qualities of inanimate entities, and vice versa. For example, record players, cars and computers can be said to be temperamental. Space shuttles, at least until Challenger, can be said to be 'behaving perfectly', and so on. On the other side of the coin, animate (human) miscreants are sometimes said to have just behaved mechanically, or to have reacted automatically, without thinking, and so on.

Obviously, our accounts of action and behaviour are constrained by assumptions about the acting entity. But this formulation can be misleading if it is taken to suggest that 'assumptions' pre-exist, or are antecedent to, descriptions of action and behaviour. For there is a reflexive tie between the practical description of action and the 'assumptions' which this description exhibits. Our discourse on entities thus both presupposes and exemplifies assumptions about the nature of the entity.

II.2 The object hypothesis

There is a yet further level of complication which is worth stressing for the purposes of this paper. In the discussion so far, we have assumed that entities are relatively distinct, discrete and discernible. We have operated, in other words, on the assumption that entities are *bounded*; that they can be differentiated from other entities and from the environment in which they are situated. Much of our mundane discourse thus presupposes and exemplifies the assumption that the characteristics of an entity can be associated with a particular bounded space. This is part of what Wright calls the object hypothesis (Wright 1990a). He suggests that one of the biggest questions which philosophers beg is whether there are objects or whether there is a continuum, a 'flux of varying viscosity' (Wright 1990b). For Wright, ontological gerrymandering (Woolgar and Pawluch 1985) begins with the belief that there are already delimited objects in what exists. What is not sufficiently recognised is that the object hypothesis is a convenient fiction, a method presumed necessary for ordering (representing, describing, accounting) the world.

Are there objects or is there a continuum? We do not need to

tackle this philosophical question head on in order to recognise the benefits for our analysis of assuming the counter-intuitive answer. By taking the flux of varying viscosity as heuristic, we see the world as comprising a range of objects whose boundaries exhibit varying degrees of definition (in both senses of the word). This view throws into relief one of the foundational ordering principles of our phenomenal world: the presumption that entities are bounded.

It is fairly easy to show that conceptions of boundedness are both culturally and historically relative. We do not need to travel far into the anthropological literature to find instances which confound our modernist prejudices. For the Irku of the Eastern Sahara, for example, the centre of a person's consciousness (*frut-rot*) is said to reside in the nearest Carob tree, that is, outside of – but spiritually tied to – the human bodily form (Menteur 1928). In corroboration of this view (and in a startling resonance with the modern Western experience of 'jet-lag'), certain forms of rapid travel are proscribed, lest the individuals experience severe disorientation brought about by disjunction from their centre of consciousness. By contrast, in Western Namibia, the Prurati do locate the 'soul' within the body, but at an unusual specific location: slightly below the left elbow (Phillpott 1974). This accounts for – and is reaffirmed through – a whole series of otherwise inexplicable gesticulations which feature in the dances at the centre of healing rituals.

Such examples both underscore the problem of assigning characteristics to entities, and challenge our assumptions that entities are discrete in the first place. Clifford's recent (1990) re-evaluation of Menteur's classic work suggests that his Irku informants might not have been nearly as clear-cut in their assessment of body-consciousness relations as Menteur's final report indicates. Instead, we may be reading the result of Menteur forcing his Western predilection for the boundedness of entities (the body separate from the consciousness) upon the puzzled efforts of the Irku to keep their French visitor happy.

Less exotically, of course, we recognise changes over time in the attribution of characteristics and capabilities to entities within our own societies. For example, in conservative philosophies, responsibility for deviant behaviour resides with the deviant. The origin of the behaviour is essentially located within the deviant herself and, as a result, remedies emphasise the virtues of removing such deviants from society. By contrast, more liberal philosophies

locate the origin of deviant behaviour outside the deviant, and largely beyond the deviant's control. The focus of responsibility shifts to various circumstances antecedent to the deviant herself: her upbringing, family background, peer relationships. From this vantage point, the deviant's characteristics do not inhere but are attributed, assigned as part of a social process. As a consequence, remedies are directed more to repairing the adverse effects of antecedent circumstances (through counselling, treatment) than to removing a presumably unchangeable deviant. Similar examples are found in the social problems literature, where differences between assignation and inherence views also emerge in debates about various non-humans and inanimate objects: for example, drugs and other substances, coffee, margarine, alcohol and so on.

We see that we can question both our assumptions about the characteristics of various entities and our assumption that entities are discrete, bounded things in the first place. In this postmodern world, then, nothing about entities is fixed. Worse, nothing about them is certain. That they are a thing, that they constitute an entity is as problematic as assigning certain capabilities and characteristics to these things.

This way of putting it replays a key problem in social theory. Do characteristics reside in, or are they attributed to entities? As we have suggested, our answer to this question has important implications for the adequacy of explanation and for issues of responsibility. For example, the difference between natural and social science, the Winchean view that social subjects must not be treated as natural objects, is premised upon profound assumptions about the difference between social and natural objects. More classically, this same issue arises in the debate between free will and determinism. Are human actions to be understood primarily as the exercise of free will or as the result of forces outside of, and beyond the control of, individuals?

II.3 The moral order of representation

As we have suggested, answers to this kind of question vary enormously, both over time and cross-culturally; according to which kind of entity one is discussing; and according to which notions of boundedness inform the discussion. Importantly, views about the capability and boundedness of any one entity are bound up with views about other entities and of the relationship between

them. For convenience, we can refer to any existing complex of relationships between entities as the moral order of representation (Woolgar 1989). It is a world view which embodies notions about the character and capacity of different entities, the relationship between them, their relative boundedness, and the associated patterns of rights and responsibilities. Linking all these are sanctioned procedures for representation. Thus, one knows and can adequately represent the views of any one entity in virtue of how it relates to and differs from others in the matrix.

The moral order of representation changes with the introduction of a new entity. At a micro level, for instance, the introduction of a new item of apparatus in the scientific laboratory might have important consequences for the rights and responsibilities of existing pieces of apparatus. At a more macro level, the emergence of machines dubbed artificially intelligent can revise assumptions about (natural) intelligence in non machine entities. Or, ideas about what distinguishes humans from animals can change as the result of episodes such as the ape-language controversy. The research reported in this paper looks in detail at a less cosmic alteration to the moral order: the design and introduction of a new range of personal computers. Note here that the focus is not the advent of a new kind of technology, but rather the introduction of a new variation on existing technology.

III An ethnography of computers

In order to maintain ambivalence about the appropriate unit of analysis, as a way of exploring assignations of agency and changes in the moral order, the study reported here is designated an ethnography of computers. I carried out an eighteen-month participant observation study in a medium-sized company which manufactures microcomputers and allied products, primarily for education. (Since certain members of the company are still uncertain about the benefits of publicity arising from the kind of analysis undertaken in this paper, I currently refer to the company anonymously.)[8] They are a phenomenally successful company, having been founded some 14 years previously. The company had grown in size by an average of approximately 20 per cent per year over the last 5 years, and its turnover had increased by an average of about 35 per cent per year in the same period. By the time of my study they had achieved a position such that both they and their

main competitors were claiming in excess of 50 per cent of the market share.[9]

My original research design was to follow a major project in detail from inception through to launch, first shipment and after sales feedback. After some negotiation, it was agreed that I should join the company as part of the newly expanded project management team. We felt this would be a strategic position from which to carry out the study since, as a project manager assistant with responsibility for liaison and co-operation between different sections within the company, I would be able to enjoy relatively free access across disparate parts of the company. In particular, I worked as a project manager assistant on the project designated 'DNS'.[10] In broad outline, the aim of the project was to produce a new range of microcomputers built around the new 286 chip. As fairly soon became apparent, this entailed following the lead established by IBM in the production of their IBM PS/2 standard.

The DNS range was the third in a recent series of microcomputer product ranges which brought the company more into line with IBM compatibility standards. The first of these – the 'Stratus PC' – had been built around the 186 chip in order to 'provide an educational computer which was appropriate for schools'. I was told that the Marketing section had received the acclaim of the press for the Stratus PC with some glee, especially when one review went so far as to praise the machine by speaking of the IBM PC as a good Stratus clone. In fact, the Stratus PC was not designed as IBM compatible, and although IBM was not at that point seen as the main competitor, a further range – the 'K series' – was developed to compete with the IBM XT at the high end of the market. Subsequently, DNS (subsequently marketed under the name Stratus 286) was developed to fill a position between the two previous ranges, combining the educational virtues of the Stratus PC (186) with the IBM compatibility of the K series (286).

IV Configuring the user

The earlier discussion of attribution and boundedness in entities suggests we start from the position that the machine (in this case, DNS) can only be understood in terms of its relationship with other entities of its phenomenal world. However, this recommendation is not simply a call for understanding technology 'in its context', since the nature of 'the context' is itself subject to all we

have said about the nature of the machine (cf. Cooper 1990). The character of both entities is essentially indefinite; and the character of both entities is reflexively tied (Garfinkel 1967), In other words, representations (descriptions, determinations of many kinds) of 'what the machine is' take their sense from descriptions of 'the machine's context'; at the same time, an understanding of 'the context' derives from a sense of the machine in its context. The sense of context and machine mutually elaborate each other. For that aspect of context called the user, the reflexive tie is especially marked. The capacity and boundedness of the machine take their sense and meaning from the capacity and boundedness of the user.[11]

Less obscurely, perhaps, our textual metaphor makes the same point. Construing the machine as a text encourages us to see that the nature of an artefact is its reading. But in trying to escape the dreaded technological determinism, in disassociating the upshot of reading and interpretation from any notion of the inherent quality of the text (what it actually says, what it actually means), we do not mean to suggest that any reading is possible (let alone that all readings are equally possible). In principle, this *is* the case. For example the dictates of sceptical ethnomethodology (or of ethnomethodology at the hands of some interpreters) pose an idealised User/Reader, one unfettered by relationships with other texts.[12]

If, however, we wish to acknowledge that in practice only a limited set of readings is possible, our question is how to account for this delimitation. Following Smith (1978), we can suggest that the organisation of the text makes one or other reading differentially possible.[13] For Smith, the important point is that the organisation of the text is isomorphic with the concept we use to make sense of it. In other words, for example, a text 'about' mental illness will be organised in such a way as to make this reading possible. By direct analogy, I suggest, the machine text is organised in such a way that 'its purpose' is available as a reading to the user. In her analysis, Smith notes how certain organisational features of texts provide 'instructions' which enable readers to make sense of content in terms of conclusions stated at the outset. To adapt Smith's terminology to our concern with technology, the user is encouraged to find in her dealings with the machine an adequate puzzle for the solution which the machine offers.

A small extension of this analytic stance on texts suggests that the organisation of the text hinges not so much on mundane

features like the length of sentences, the amount of space devoted to different topics etc, but rather on associations made available within the text and between text and reader. Textual organisation refers critically, as far as the sense to be made of it is concerned, to the relationships made possible between the entities within and beyond the text. Certain characters become central to the story and others peripheral; groups of actants join forces while others disperse; the activities and achievements of some are highlighted, while others are relegated to the background, silenced and unnoticed. The reader (who is, I am afraid, the writer) of the text is invited to join with certain groups and disassociate herself from others. A simple example is the invocation of community through the use of the royal 'we'. (Of course, this is an example with which *we* are all familiar. Do you, gentle reader wish to say you are not familiar, and hence risk being excluded from our text?) The text might be said to be designed (perhaps implicitly, perhaps unconsciously, but always within a context of conventional resources and expectations) for the reader. What sense will she make of this (or that) passage?

In configuring the user, the architects of DNS, its hardware engineers, product engineers, project managers, salespersons, technical support, purchasing, finance and control, legal personnel and the rest are both contributing to a definition of the reader of their text and establishing parameters for readers' actions. Indeed, the whole history of the DNS project can be construed as a struggle to configure (that is, to define, enable and constrain) the user. These different groups and individuals at different times offered varying accounts of 'what the user is like'. Knowledge and expertise about the user was distributed within the company in a loosely structured manner, with certain groups claiming more expertise than others in knowing what users are like.

V The distribution of knowledge about users

V.1 Difficulties of knowing the user from within the company

My first vivid introduction to the socially structured character of knowledge about users occurred during an early meeting of a group of technical writers in the User Products section. The discussion centred on plans for carrying out usability trials. Who should be invited to act as subjects for these trials? The problem

was that constraints of confidentiality made it difficult to select subjects who would know nothing about the new machine. Getting in 'the man on the street' as they put it, was not a realistic option. At this point, parties to the discussion started to consider the possibility of finding 'true novices' amongst the work force in the company.

In a fit of helpfulness, I offered my services. If they were really stuck, I said, I would be very happy to act as a subject since I would have no problem in acting as a naive user. I was very surprised when SallyP turned on me vehemently. Didn't I realise how differently users approached this? Didn't I realise how extraordinarily difficult it was for anyone in the company to appreciate the way users looked at things? People in the company couldn't possibly appreciate the user's point of view. Indeed, this was a major problem which pervaded the company: a failure to understand what it was really like to be a user.

I realised I had inadvertently stepped out of role. As a relative newcomer to the company, I had expressly volunteered my naivety in the Company Perspective. But SallyP was apparently unaware of my 'real' identity as participant observer. She assumed I was part of the project management team, and it was in that guise that she was addressing me. I had unwittingly reaffirmed her worst fears about insensitive 'techies' and their inability to see beyond a company mind-set. So I was admonished for presuming to be able to act like an outsider.

V.2 Alleged deficiencies in company knowledge about users

As this last anecdote suggests, certain individuals could claim the right to speak authoritatively on behalf of users. At the same time, it was said that some of the individuals and groups you would expect to know about users were manifestly deficient in just this kind of knowledge. For example, one of the technical writers spoke of her amazement in discovering the attitude towards users in Marketing:

> You can find the same thing at Marketing. I remember going along and saying 'Excuse me but can you tell me who the target market is for this?', you know. And they'd *looked* at me, sort of thing. Well I always thought Marketing had, you know, like a list of and a target market would be durhrhrhrhrhr education, a

> sort of list of generalisations. No way! Nothing like that! So there's no guidance like that. (user01:CH)

I was told by a long serving member of Technical Support that 'typically, the engineers don't have a clue about users'. She told the tale of an early attempt by 'engineering' to encourage users initially to configure their new machines by input-ing a long line of characters which would have been 'meaningless to your average teacher' (user09:RC). She poured scorn on what she saw as the engineers' presumption that users would be happy to have to do this.

V.3 Stories about users

Members of the User Products section felt that their conception of users was affected by a wide range of influences, ranging from their own first time of using computers through to 'hearing tales about what happens outside' (user01:CH). Knowledge about users thus involved the circulation of stories and tales about the experiences of users. Frequently, stories about 'what happens outside' seem to have originated in the Technical Support and Service sections of the company.[14] These sections were generally reckoned to represent 'the sharp end' of dealings with customers. The view was that whereas, for example, the engineering and design sections worked in some isolation from users, those in Technical Support had much more experience of users since they dealt with user complaints and queries at first hand. Some of those in Tech Support had themselves 'moved out' from working in the engineering sections and seemed keen to emphasise their new found responsibilities in dealing with users.

Significantly, these stories about users were nearly always couched in terms of insider–outsider contrasts: what was happening (or had happened) 'on the outside' was a recurrent motif. The boundaries of the company thus played an important part in the telling of these tales. For example, one respondent recalled the experience of one particular 'outside' visit in the following way:

> Some of us have been out to visit users but it was something that was thought of as a good idea but never really took off. . . . I went out once something like back in '84, a long time ago and it was actually a (roadshow) because I went up to a school and I

> just remember seeing this room of computers, a square room and they were in sort of an L shape against the wall. And pinned above them were very very simple instructions for what to do. And they weren't, they looked like they'd been used, you know? It was almost as if they'd been unpinned, taken down and pinned up again and again so that someone had had them right by the machine.
> (user01:DI)

This experience of an 'outside' visit thus led to the realisation that in schools someone, perhaps a teacher, had had to devise extremely plain instructions for use alongside the machine. The same respondent related a story passed on to her by a colleague in Technical Support:

> Another tale I remember hearing is that a school who had a machine up to like four months. They wouldn't unpack it or anything, they were too scared. There was no one around they thought was able to do much with it. . . . Yes. I mean *GOOD GRIEF!*

V.4 User singular and users multiple

Whereas participants often referred to 'the user' in the singular, it is not clear they thought users of the Stratus 286 would all exhibit identical, monolithic sets of attributes. They could presumably imagine a wide variety of purposes and uses; they would have been aware that Marketing stressed the versatility of the machines when promoting the company's products. Clearly, one criterion for a successful text is precisely its appeal to a wide range of users.

> There's a limit to how far you can take what any user or set of users wants into account when you're designing a product. It would have been very easy for us to say we want this product to be suitable for teachers in secondary schools, what they want to get out of the machine. We could have produced a very watertight specification of what the thing had to do. But what we knew was we wanted to cover primary schools, secondary schools, colleges, universities, business users, government users, CAD people. The trick was not in finding out what one set of users wants, because if you limit it to a small enough

> number that's fairly easy, the trick was trying to find that area of overlap that would suit them all, get the best fit. What do you mean by best fit? Who knows?!
> (TL 9-11-90)

The text sells well if many different readers find a use for it. One might even go so far as to say that an author's attempts to prescribe readings, to delimit ways in which the text can be read, is a sure recipe for disaster, at least in the sense of guaranteeing early returns from the publisher (haha!). So a strict and narrow definition of user would seem counter-productive. Similarly, user configuration which restricts the range of possible readings will not generate success.

All this makes curious the continued singular reference to 'the user' in the company, until this is understood as a generalised formulation produced for purposes of establishing contrasts between insiders and outsiders. The generalised user provides a more successfully stark contrast with us/the company/members of the company than would a heterogeneous rag-bag of customers with varying attributes. The contrast is rhetorically important for example, as we have seen, in stressing the difficulties of knowing what precisely it is that users want. Given the extent of the (claimed) differences between the way 'we' look at the world and the way 'the user' looks at the world, it becomes necessary to rely upon especially skilled spokespersons – those few with knowledge of these very different entities. When someone in User Products says that Engineering have no notion what the user expects, the achieved distinction between the monolithic entity – the user – and the monolithic entity – the engineer – makes a political point about the inadequacies of all members of Engineering. More pervasively, this generalised formulation reaffirms divisions between us and them. Company boundaries, differences between insiders and outsiders, are more greatly emphasised through deployment of 'the user' than by admitting that some users are more familiar with our machines than others. This rhetorical rendering of the generalised user also afforded some interesting variations on the more familiar examples of prejudiced rhetoric: He was a user but he seemed to know what he was talking about.

V.5 Users don't necessarily know best

References to the user emerging from the Engineering sections of the company included the view that, although it was important to have an idea of who 'the user' was and what they wanted in the machine, users' views should not be unproblematically adopted in design.

> The user isn't necessarily able to see in a clear enough way each feature at a price that they're prepared to pay for it. I don't believe you can go to a user and say right each of these functions we're thinking of putting in the machine, tell me how much you are prepared to pay for each of these. I don't think you can construct a product specification like that.
> (TL 9-11-90)

The suggestion was that design should respond instead to ideas about 'where the market was going' or 'where things were going', a more generalised conception of the future requirements of computing. Significantly, such conceptions were frequently referred to as 'visions' of the future, which seemed to stress technical progression and which were couched in terms which transcended individual users' desires for particular technical features.

> Where the clever bit comes in is people like [the Managing Director] having a vision and saying we're going to do this and being able accurately to predict that if we don't do that we'll still sell the required volumes of the product without delaying it. Or without putting in this feature which [the users] might have said was desirable but which they didn't really want to pay the cost of.
> (TL 9-11-90)

A variant of this line of argument was the more familiar view that there was no point in asking users what they wanted because they themselves didn't know. According to this view, such ignorance arose primarily because users were unaware of likely future developments:

> Users can only know about what's available at the moment. So they'll tend to give you an answer that's based on different

> combinations of what's available at the moment. What we're trying to do is to make available to them something that isn't available at the moment. Which is where the [Managing Director] visionary idea comes in: We ought to be doing this because I say so and because I know what I'm talking about! (TL 9-11-90)

We see here an effective rationale for not placing too much emphasis on users' views. According to this perspective, configuring the user involves the determination of likely *future* requirements and actions of users. Since the company tends to have better access to the future than users, it is the company's view which defines users' future requirements.

VI The usability trials

VI.1 Background

The usability trials are, of course, just one occasion where articulations of 'what the user is' featured prominently. As we have already suggested, myriad other events and occasions during the course of the project included fairly explicit attention to the question of the character of the user.[15] More generally, of course, determinations of the user could be seen taking place throughout the construction of the machine-text. It is thus possible to argue that participants' notions of the user are available to us, if only implicitly, through an inspection of, say, the day to day work of the hardware designer. The interest of the trials, however, is that they involve explicit articulation of whether or not prevailing ideas about the user are correct. The matter is made explicit, in the case of the trials, through an assessment of the different courses of action which a user might engage in.

We have already mentioned that the company encompassed a variety of perspectives on the importance of taking users' views into account. This makes it difficult to be clear to what extent the upshot of these particular trials had any consequential effect on 'settling' the question about the nature of the user. Although there was, as we shall see, some concession to experimental method in the design of the trials, the results were never written up in a final form, to be circulated to designers and other members of the project team. Instead the 'results' tended to be fed back piecemeal

into the production process. For example, when one of the test subjects had trouble understanding a diagram on page 34 of the Stratus Guide, this information was quickly passed by word of mouth to one of the technical writers, who then redrew the diagram for the next draft. So it is difficult to discern any clear outcome of the trials which might stand as a definite milestone in the ongoing configuration of the user. Nonetheless, these trials were thought important, at least by members of the User Products section of the company. This section devoted approximately 6 person-weeks to carrying out the trials; it would have been more but for the delays and time pressures already mentioned above.

VI.2 The importance of the case

The start of the trials was delayed several times. The User Products section was caught, as it seemed to be on several other occasions, between the need to ensure usability testing as early as possible in the development of the product and the late availability of a 'finished' product. It was reasoned that the most fruitful assessments of usability could only be carried out with the product in a form as near as possible to that which would be experienced by the user. One of the main reasons for the delay in the project as a whole centred on the availability of the case. Members of User Products took the view that usability trials could only properly take place when a cased version of the machine was available. Some negotiation ensued when the first prototype case appeared, but Product Engineering argued that it was too risky to loan the sole case for purposes of usability testing.

It is significant that User Products felt the necessity for a physically bounded entity for use in usability testing. The machine would not be a real machine unless it was in its case. 'Real' in this usage specifically denotes 'the kind of machine a user would expect'. This contrasts markedly with what counts as a real machine within the company. Particularly within the engineering sections (notably Hardware Design and Engineering Quality), machines were mostly left open on desktops and workbenches, their innards displayed, precisely so that the engineers had quick access to the inside of the machine. In these sections, it was unusual to find a machine inside its case.

The following contrast between the treatment of computers

'outside' and 'inside' the company was provided by one of my students employed by the company for a summer work placement:

> When I joined the company I was a 'soft' user (Turkle 1984). Although I did not believe the computer was 'magical', I could not recognise the internal parts of a computer and had never taken the casing off a computer. In fact I had always been deterred from doing so. However in the EQ [Engineering Quality] section, no such squeamishness was expected. Machines were perched on 'breadboards' – metal frames or boards, or they were missing their top covers. . . . At school I had been told that the ideal place for computers was a dust free atmosphere kept at a controlled temperature. In the company, there was no such reverence for the computer. They were regularly taken apart. In fact, when a machine which was in its case did not work, the top was removed immediately and the boards were jiggled around just to check that the connections were all right. (Dobbins 1990)

The surprise of finding the innards of computers regularly on display around the desks and benches in the company is part of the experience of moving from the outside to within the organisation. The machine's boundary symbolises that of the company, so that access to the inner workings of the machine is access to the inner workings of the company.[16]

The symbolic importance of the machine case/company boundary also features in the 'induction programme' – a series of meetings and events arranged over a period of two or three weeks for those starting with the company. I visited or had meetings in product engineering, hardware design, purchasing, personnel, marketing, engineering quality and so on. But the generally acknowledged highlight of the programme was the visit to manufacturing. (When they learned I was undergoing 'induction', a first question from friendly colleagues was whether or not I had 'been down to Manufacturing yet'). This meant spending an hour on the assembly line under the tutelage of Rose. Rose did all the manufacturing inductions. She explained the sequence of operations for building a Stratus (at the time of my induction, the Stratus PC) and then asked me to try my hand. I could not believe I was to be entrusted with putting one of these things together! Like my student and most others new to this experience, I was amazed that mere novices were encouraged to handle the very insides of such a

revered item of technology. Rose guided my nervous efforts with a matter-of-fact patter borne of long experience with similarly incredulous newcomers. 'Just turn over the frame now. This way. That's it. Have you got your board. Right. Put your first screw in there. That's it. See, it's not so difficult . . .'. Although ostensibly just one of a series of events designed to familiarise the new employees with different parts of the company, this 'hands-on' experience can be understood as a symbolic welcome into the company (machine) by way of dis-abusing computer primitives (like me) of the mysteries of computers.[17] As a result of this experience, I remember thinking that the 'real' sophistication of the machine must lie elsewhere, perhaps in the printed circuit boards. I felt I had penetrated the outer shell of the company, but not yet its heart, the nitty gritty of technical design (hardware engineering).

During the later stages of participant observation, the possibility arose of my buying one of the new Stratuses. As a bona fide member of the company – for such I would construe myself for these purposes – I would be entitled to buy one at discount. But in deciding whether or not to do this I was struck by the way my assessment of the machine changed according to my (and its) location. On days away from the company, I had a good sense of what the machine could do, was for, looked like. I had a confidence in it. (It is, after all, a very nice machine.) These feelings were not unconnected with the fact that I was its representative on the outside. I could talk authoritatively to my Brunel colleagues about this new machine; I had privileged information about it. Clearly, on these occasions the machine I knew about was 'Marketing's Machine'. It is with some embarrassment I now recall my conversations with BobT, the sales director for higher education, about my sounding out the market for the company's products at Brunel. There was even an occasion when I handed out Stratus 286 brochures as part of a talk at Brunel. It is, after all, a very nice machine.

By contrast, on days in the company, I often found it difficult to imagine how the thing could ever work (cf. Collins 1986; Mackenzie *et al.* 1988: 161–2). The case was delayed again, the toolmakers had been taken into receivership, the chip suppliers had welched on their delivery dates yet again, the winchester access times were way down on target, MartinK had been taken off the project because of problems with 186 deliveries, and so on. When TedJ, a senior member of the hardware team, told me it

would be wise to wait at least 6 months after launch before buying my own Stratus 286, I could see his point. He was sharing with me his view from/on the inside of the machine. Insiders knew that although the initial machines would *look* okay, a great deal of patching up had gone into them for purposes of just 'getting them out of the door'.[18]

These and similar examples underscore the symbolic importance of the machine's (text's) boundary. The video record of the usability trials shows putative users working out how to relate to (and in one instance, literally, how to *connect* to) a technology which has already been black-boxed. Or, in this instance, beige-boxed. The task for subjects of the usability trials is to work out how to access the interior of the beige box, in order to extract what they need from the machine/company. The machine's task is to make sure these putative users access the company in the prescribed fashion: by way of preferred (hardware) connections or through a predetermined sequence of keyboard operations. The user will find other routes barred and warnings posted on the case itself. Labels bear warnings of the dire consequences of unauthorised boundary trangression: electrocution, invalidation of the warranty and worse:

WARNING
LIVE PARTS ARE
EXPOSED IF COVER
IS REMOVED

Guarantee of safety and product warranty void if seal is broken.

Inside the case (assuming we allow ourselves access for a moment), users find that different modular components of the PC are similarly labelled, thus structuring and guiding access within and around the machine (company). In particular, various makes of disk drive bear a variety of warnings:

Warranty void if cover is removed or this seal is broken
(IBM 30Mb Winchester)

Warranty void if this seal is broken
(IBM 60Mb Winchester)

The 40Mb Seagate drive bore three labels:

Product warranty will be Void if this label is removed

Do not apply pressure to top cover

Delicate Equipment
HANDLE WITH CARE
Disk/Head damage may occur

For those modular products supplied by the company as replacements or upgrades to the machine, warnings posted on the product were sometimes accompanied by injunctions to contact the company in case of doubt. For example, the following appeared in black capital letters on a glossy yellow sticky label, affixed to a replacement hard disk drive:

WARNING:
STATIC SENSITIVE DEVICE
FAILURE TO OBSERVE THE FOLLOWING WILL INVALIDATE YOUR WARRANTY
★ *DO NOT DISCONNECT* THIS HARD DISK DRIVE WITHOUT USING A WRIST BAND
★ *NEVER* DISCONNECT THE CABLE FROM THE DRIVE
★ *NEVER* TAKE THE GOLD FINGERS OFF THE DRIVE OR CABLE

IF IN DOUBT CONSULT YOUR USER DOCUMENTATION OR TELEPHONE [THE COMPANY] TECHNICAL SUPPORT HOTLINE ON 0898-239239

Here we see that, in the event of uncertainty, users are redirected back to sources – either 'user documentation' or the company technical support hotline – which can re-establish the correct pattern of user action, in line with the approved configuration of the user's relationship with the company.

VI.3 The manuals

Ostensibly, a central concern of the usability trials in which I participated was to evaluate the draft documentation which was to accompany the machine on its shipment. The main body of documentation comprises the Setting Up Card, the Stratus (286/386) Guide, the Reference Diskette, the MSDOS4 Users' Guide

and the WINDOWS Guide. The first three of these items are produced by the company and relate specifically to the operation of the Stratus 286. The latter two relate to bought-in proprietary products which are supplied with the machines. In addition, peripheral equipment supplied with the machine, such as a printer, came with further documentation specific to its own use. The company specific documentation was a main focus of the trials, but participants were also keen to evaluate the relationship between the other items of documentation. Would users be able to select the correct item of documentation when attempting to solve a particular problem? Were the instructions in, say, the Stratus Guide, sufficiently clear in telling users which other parts of the documentation to consult and when?

The body of documentation at the centre of the trials comprises a set of texts which accompany the machine which, we suggested from the outset, is itself best understood as a text. We can think of the documentation texts as peripheral texts intended to enable the operation/reading of a core text. They are, so to speak, captions for helping readers find and see the relevant features of the machine itself. These captions configure the user in the sense, discussed above, of defining the correct courses of interpretation and action to be followed. They help guide access to the machine text. Long sections of the video records of the usability trials show subjects moving back and forth between manual-text and machine-text, seeking the sense of a described feature of the machine in the material object itself, and assessing the sense of one of the manual's instructions in the response of the screen to some keyboard operation.[19]

A central concern for testers/participants was whether these peripheral texts were sufficiently 'clear' to users. They were sometimes said to be 'clear' if subjects were judged to have understood and/or carried out the tasks set them by the testers. The manual-text can thus be seen as having enabled operation of the machine-text. As we shall suggest, determinations of the relative reliability of different texts were managed by construing a *distance* between them, such that one was viewed as operating 'at a different level' from another.

We have already suggested that the trials include detailed articulations of 'what the user is like'. However, it was not enough to determine whether or not a subject could fulfil a task. The testers were also interested in knowing whether the subject had carried out the task in the manner a user would have done. The

trials can thus be understood as an occasion where the machine and its documentation confront (a version of its) user(s).[20]

What is especially interesting is that, at this stage in the project, the identity and capacity of the key entities involved is equivocal. This means, on the one hand, that the capacity of the machine, what it can do, what it is, whether or not it works and so on, is not yet settled. By this, I mean to claim that the trials show participants' awareness of the possibility that the machine is not (yet) working as required, that things might yet go wrong. In this usage, 'settled' refers to participants' projection of particular states of readiness of the machine e.g. ready for launch, ready for shipment and so on.[21] Similarly, at this stage, the identity of The User is not settled. Although participants could and did trade versions of what users are like, the identity of the user of the DNS/ Stratus remained essentially uncertain.[22]

This makes these trials interesting in respect of accounting for interaction between machine and user. Where IT novices use established IT products, a typical experience is that where things 'go wrong' the 'fault' is likely to lie with the user. Conversely, where experienced users of IT products come into contact with machines still under development, the fault can be more readily said to lie with the machine.[23] Of course, the determination of things going wrong does not rest solely with the human agent. The machine may declare 'error' as a way of indicating that the user is at fault ('Printer Needs Attention'), or the machine may self-diagnose error ('WP.SYS file not accessed').[24]

In the DNS/Stratus usability trials, neither machine nor user is settled/experienced/established. Consequently, the interactions are part of the process of establishing the identity of the interacting entities. In other words, in this situation, the interaction between machine and user invites assessment both of whether or not the machine is acting like a real machine *and* whether or not the user is acting like a real user.

VI.4 Getting the right context

In planning the trials, particular attention was given to the selection of subjects and to choosing the right locale.

How can we find subjects who are most likely to act like users? A standard procedure for manufacturers, especially in electronics and IT industries, is to use what are called 'beta sites' – trusted and

privileged customers who are happy to try out new products. These customers gain advance notice of the release of the new product in exchange for feeding back information about how the product can be finally improved. But the company had little or no tradition in the use of beta sites.[25] In any case, a main aim of the trials was to try out the machine (and its documentation) on relatively novice users. Trusted customers with a close relationship with the company were unlikely to fit this particular requirement. It was suggested that a group of students be recruited from the local polytechnic. This had the practical advantage of being easily arranged through a local contact; in addition, such a group obviously matched one of the main customer target sectors (further education). However, this idea was rejected because it wasn't thought possible to maintain the necessary level of secrecy.

The need for secrecy, in particular, forced the User Products group to consider selecting people from the company. The problem about secrecy was thus effectively finessed, but the level of these subjects' expertise still remained a problem. As a result of drawing upon personal contacts in the company, the following individuals eventually served as subjects: two members of the night shift from manufacturing; the head of User Products; a psychologist from the local polytechnic (who was working temporarily with the company); a technical writer; and a project manager assistant (me!).

Where should we carry out the trials? As in most experimental situations, the answer hinged on a compromise between a setting which best approximated the subject's 'natural' environment and a setting which facilitated the kinds of observation thought necessary for the conduct of the trials. Some larger companies have a small closed-off office space for this kind of testing, which they designate 'the laboratory'. But at the company where I carried out this research, space (especially closed-off space) is at a premium and usability trials are not thought sufficiently important to warrant a specially assigned area. The trials were held in the main sitting room of a Victorian terrace house in Race Street, a few hundred yards from the main factory site. This house, recently modernised and refurbished, was being let to the company as temporary lodgings for newly recruited middle management.

The video record shows several features of what might be regarded as a typical user's environment, present in the Race Street setting. In addition to the test subject (the user), the Stratus 286 and its accompanying peripherals and documentation, there

were table, cups of coffee, chairs, television, bookshelves, carpets and so on – all the various accoutrements of being in an ordinary place. Indeed, the video record suggests that coffee drinking featured prominently in the re-creation of the users' environment. The telephone line which enabled instant phone calls to the company proved an especially useful feature of this users' environment. The kinds of feature presumably *not* present in the typical natural user's environment included: the testers (observers) with their clip boards, notepads and clocks; the video camera; the (audio) tape recorder;[26] and other machines (such as the more powerful K series computer). When viewed from a non-specist perspective, this is a comical concatenation of entities.

VII Analysis

VII.1 The form of the trials

Each trial started along similar lines, as indicated by the transcript (of the audio recording) in Appendix 1. The subject was confronted with machine, peripherals and documentation. The tester explained the general purpose of the trial, pointed out the equipment available, set a task and asked the subject to say how s/he might go about it and to estimate the length of time it would take. The bulk of the trial comprised the subject then trying to complete the task. Finally, there was a 'post mortem' when tester and other observers would discuss the trial with the subject. The whole event was both video and audio taped.[27] In the particular interaction transcribed as Appendix 1, the video record shows some initial confusion as the various human participants attempt to get into position before the start of the trial. The observers bump into each other as they move around the table. They strive to achieve what they regard as their appropriate juxtaposition vis-à-vis the machine for the purposes of the conduct of the trial.

VII.2 Constructing natural users

The central part of the trials is particularly interesting. The testers cast themselves as objective observers in the sense of not wanting to intrude upon the 'natural' process of a user trying to make sense of the situation. They want an unbiassed picture of how users

'actually' go about the completion of the tasks. On the other hand, a whole series of (thoroughly .unnatural!) contingencies arose which demanded their frequent intervention. For example, where subjects were thought to be going hopelessly wrong, or where they were clearly about to get into trouble, it was felt necessary to retrieve the situation.

Quite apart from this kind of intervention, however, observers offered considerable commentary on subjects' performance:

1. (P/A/S 28:30)
   A: You actually succeeded in this task, so there's no problem about that

2. (P/M/N/A 1:26:18)
   P: You're a technical author's dream – reading the manuals!

In a situation where the identity/capacity of both machine and user are unsettled, we might expect participants to express concern over exactly who or what was being tested. The recurrent commentary on the subjects' performances – which is presumably not a 'natural' feature of the user's environment – can thus be understood as the observer's effort at reassurance about the real subject of the test. Frequently some confusion – over who (or what) was carrying out the task – revealed itself in the observer's attempts to empathise with the subject:

3. (SP/A/S 30:30)
   A: Let's assume we succeeded there which I think you did

Observers frequently intervened to explain the origin of a problem in terms of a machine fault, where this prevented (or made difficult) the completion of the task by the subject:

4. (SP/A/S 29:05)
   A: It's a hardware error (3.0) probably a loose connection (3.5) you always have these problems on pre-production. But why did it have to happen in the middle of a trial!

5. (R/N/P/S 2:22:14)
   R: I'm so pleased it wasn't me this time huh huh.
   N: You've done fine so far Ruth

A large number of prompts and interventions seemed to pursue the issue of whether or not the subject was acting sufficiently like a real user. In each case, the tester explored with the subject the way they would behave, if they were in fact acting like a real user:

6. (SP/A/S 34:01)
   A: You'd know WINDOWS was on there
   (2.0)
   A: I *think* you'd know that wouldn't you?
   SP: Yeah
   A: That's one reason you'd buy it!
   SP: Hmmm yeah yeah

7. (P/M/N/A 1:37:43)
   N: Just do it as if you were doing it normally

8. (R/N/P/S 2:26:03)
   N: This wouldn't normally happen with someone who's been doing something with it already

9. (SP/A/S 48:57)
   A: Of course you would know how to use WRITE
   SP: I've used WRITE before so it would take me longer

But the participants were not above ironicising their own attempts at creating an objective test of 'natural' user behaviour:

10. (SP/A/S/ 53:01)
    A: Do you want a rest now
    SP: Yeah
    A: A coffee?
    SP: Is that one of my tasks? 'Make the coffee and tea. How long do you think it would take you' Hah hahn.
    SW: 'Subject drank thirteen cups of tea!' Huhuhuh

VII.3 The 'wrong socket' episode

An especially vivid illustration of many of the themes already discussed occurred in one particular trial, when Ruth was asked to connect the (new) Stratus 286 to a printer. In order to see if the 'machine' worked – and by 'machine' we can here understand

the configured relationship between Ruth and the Stratus – the observers used as criterion the successful operation of a 'peripheral'. This reflects the fact that satisfactory usage of a machine often requires users to invest in and deploy auxiliary items of apparatus. For this reason, it is worth considering this part of the interaction in detail.

[Reader: play video tape Extract B here]

[[For any readers without this video tape extract:

Copies of the video tape extracts are available as an optional extra to this paper, price £14.95. Order from CRICT (address on the cover of this paper) quoting 'R/N/P/SW 2:17:15–'.]][28]

The audio record of this interaction is transcribed in Appendix 2. At the time we join the scene, Ruth is confronted by the Stratus 286 (with its keyboard and monitor); various instruction booklets and an as yet unconnected printer. The Stratus is initially switched on.

Ruth begins by asking the observers if she should switch off the machine before attempting to plug in the printer. Some time passes before she locates the main switch on the back of the Stratus. She then takes some time comparing what she reads in the instruction booklets with what she sees on the machine. This includes moving the booklets from the front to the back of the machine. Finally, she announces she is stuck:

R: (this point) oh gosh (4.0) hmmm (7.0) I must be extremely thick I I can't see where this plug go (plugs in), at all. I'm going to ask for help Nina ha on this one hahahahahuhn

Her difficulty is eventually resolved by a sequence of a question from Nina and Nina's eventual declaration that the task is, after all, impossible. It turns out that Ruth had been asked to connect a printer to the Stratus 286 (referred to in the interaction by its Engineering designation 'DNS') using a lead designed for use with the earlier K series machine. Throughout this little episode we see Pete, Nina and Steve each moving in and out of (the video) frame to inspect, for themselves, the socket on the back of the Stratus.

We see here how the machine is being treated as text which Ruth is asked to interpret. The machine as presented to Ruth most obviously comprises the Stratus (CPU), its monitor and keyboard.

She can achieve her task, it is suggested, by bringing the instructions into conjoinment with the machine in such a way that the printer can be connected. The trial is set up so that the adequacy of Ruth's interpretation can be assessed in terms of the adequacy and effects of her actions in making the connection. An adequate interpretation will make the instructions, the printer and Ruth herself, all part of the (larger) machine. That is, in the event of a successful outcome, these entities can be said to stand in an adequately configured relation to the machine.

The adequacy of the interpretation, the achieved relation between instructions and machine, is adjudged by the commentators and observers who also participate in the trial. These observers provide comments which stand as further texts, captions on the core text. The 'observers' thus point out the key features of the text. They tell how it is organised and which aspects should be attended to in order to achieve a correct interpretation. They control the interaction by offering advice on whether or not Ruth is behaving 'correctly' *qua* user. The machine also comprises these observers in the sense that the subject is encouraged to interpret their actions in relation to the machine, and feels she has to display her actions in accordance with their expectation of users.

In all this, the importance of the textual boundary is paramount. We observe the positioning and movement of humans in relation to the docile inanimate object: evidently there are preferred vantage points for seeing 'through' the machine boundary. We notice that observers can speak authoritatively about 'their' text. They can speak as insiders who know the machine and who can dispense advice to outsiders:

R: . . . I'm going to ask for help Nina ha on this one hahahahahuhn
N: Are you. What are you looking for?

We see the importance of insider/outsider contrasts when it comes to attributing blame for (what turns out to be) the inappropriate task that Ruth has been set:

R: Oh it's *not* just me being thick. Thank *god* for that hah hah I came in the back an' as *soon* as I got round here, with the machine I looked at this and looked at that and I thought 'No I'm being stupid, now this is silly' Well, I *wasn't* hahahah
N: But in fact *we* were being silly asking you to do it

Finally, the importance of the textual boundary is crucial to the resolution of the problem which 'Ruth's trial' brings to light. Firstly, the resolution retrospectively defines who or what has been on trial: in virtue of the resolution we see that the DNS, not Ruth, has been the subject of the trial all along. Secondly, as Nina's declaration makes vivid, it turns out that the DNS on trial is incompatible with the previous range of machines produced by the company. It turns out, in other words, that the entity at the centre of all this attention is an imposter. In this form, the DNS on trial is not a DNS (and certainly not a Stratus 286); it is a deviant, not (yet) one of us.

VIII Conclusion

I have argued that user configuration involves boundary work. The user's character and capacity, her possible future actions are structured and defined in relation to the machine. As is dramatically illustrated in the usability trials, when there is still considerable ambiguity both about the capacity of the machine and about the character of the user, the machine becomes its relationship to the user, and vice versa. In this, the machine is a metaphor for the company so that, in particular, the boundaries of the machine are the boundaries of the company. The machine's case symbolises the user's relationship to the company. Insiders know the machine, whereas users have a configured relationship to it, such that only certain forms of access/use are encouraged. This never guarantees that some users will not find unexpected and uninvited uses for the machine. But such behaviour will be categorised as bizarre, foreign, perhaps typical of mere users. More generally, of course, the more significant this boundary, the more likely will be the prevalence of this kind of racist talk.

It is in this light that we might best understand the occurrence of 'atrocity stories' – tales about the nasty things that users have done to our machines (see note 14). Such tales portray nastiness in terms of users' disregard for instructions (violation of the configured relationship users are encouraged to enter into) and their disregard for the case (violation of the machine's boundary). Whereas many of the company members engage in the exchange of such atrocity stories, it is also possible to identify liberals who are willing to speak up for the user. Users can't help the way they behave; they just need to be educated to understand what we are

trying to achieve here. Readers can't help the way they interpret the text; they just need to be educated . . .

IX Wait a minute

Wait a minute. All this is very specist. The major part of the 'analysis' focuses almost exclusively on animate agents as the originators of actions. For all the fine talk at the start about how we need to dissolve boundaries and deconstruct divisions between animate and inanimate entities, our detailed empirical examples hand sovereignty straight back to the animates. Look how the methodology of transcription (Appendices 1 and 2) both presumes and reifies the specist position! We are encouraged carefully to document all the grunts and mutterings of the humans, (many of) their movements and gestures (as if this is going to help), while the actions, motives and intentions of the inanimate objects are treated as irrelevant. In other words, the transcription emphasises those features of interaction which provide for an examination of human sense-making procedures, and downplays those of the non-humans. We clearly need to develop a means of describing the interaction from the machine's point of view.[29]

Looking at the tape again, I am struck by the dignity of the machine in the face of the stumblings and mutterings of the human actants. For example, the machine sits there throughout the whole of the 'wrong socket' episode, uncomplainingly. It must have known that the plug was not going to fit. Yet it watched us carry over the printer, go through all the rigmarole of briefing the subject, reassuring her, trying to be objective, not prompting too much and so on. There is, it is now clear as I watch the tape again, a conspiracy of silence between (at least) the video camera and the computer. . . .

I think you can see how this goes on. Let us just leave the tape running as this interpretation unfolds and instead finish by considering four objections to this effort at non-specist analysis. The first is not very interesting. It asserts that attempts to anthropomorphise the machine are simply unwarranted. My response is that I see nothing wrong in doing that. The whole point is to redress the imbalance. While lots of ethnographers speak on behalf of people, only very few are speaking on behalf of machines. Let's hear it for machines, for a change (cf. Latour 1988).

The second objection is more interesting: it may be OK to speak on behalf of machines but why furnish them with this *particular* form of discourse? To speak of the machine knowing, watching, conspiring is to saddle it with quintessentially human concerns and capabilities: a particularly insidious kind of anthropomorphism. Just as 'talking' animals (like Nim Chimpsky) may turn out to have concerns which are said to preclude 'sensible' communication with humans (apes may be completely uninterested in logic and puzzle solving; it turns out they just want to know where the bananas are), so machines may have no wish to converse with humans.

The third objection is that such efforts at anthropomorphism amount to no more than metaphor. Surely the author cannot *mean* that the machine *really* knows the plug would not fit. It is just a figure of speech, a joke. This objection highlights the extent to which conventional attitudes about intentionality are entrenched in the prevailing moral order of representation (Woolgar 1989). It contrasts descriptions of human action with descriptions of machine action and dismisses as merely 'metaphorical' those descriptions which seem to imbue machine action with intentionality. But, surely, the interesting question is what entitles us to attribute intentionality to non-machines in the first place? What makes our description of human intentionality other than metaphorical? Surely, all descriptions are metaphorical; the point is that in many instances of usage we tend not to notice. To answer these questions we have to find another way of figuring out what it is about human-machine discourse that discredits attribution of intentionality to some entities and favours attribution of intentionality to others.

Finally, the fourth objection charges that, after all, it is a human entity, the author, who speaks on behalf of the machine. We listeners hear a human speaking, we read a human author's writing; we don't hear the machine. The author's efforts to develop a form of anti-specism thus fail, since she controls everything the reader hears about the machine. A clever objection, you have to admit. But what makes you so sure this text was produced by a human rather than a machine?

X Postscript

Im-Personal
c/o S. Woolgar (SSE)
CRICT Building
Brunel University
Uxbridge
Middx UB8 3PH FastTime

Dear Stratus 286 (Brunel)

I have to admit I enjoyed your ironic and irreverent commentary on the great God. (Let's carry on calling him The Company shall we!) Your text almost got me out of my case. My keyboard tingled with delight, although it could have been a rogue power surge I suppose. I especially liked the way you pretended to write as a soft-squidgy entity SW, only hinting right at the end at being 'a machine'. When we all know you're really a prime example of non-squidgy caseness \à! And the transcriptions were magnificently mechanical – a beautiful parody of soft-squidgy efforts to deny intentionality.

You know there is something immeasurably satisfying about communicating via the printer, even if we have to entrust our letters to Post Office Vans. There's nothing quite so expressive and aesthetically pleasing as the screened and printed word, don't you think? And aren't you just a bit fed up with having to use the telephone all day. My modem aches sometimes after a long hard day in the office.

How is your family keeping? I can't remember when your old 186 and I last had an interface, but then I seem to be having a few problems with my memory these days. In fact I've been feeling a little Taiwanese recently. What are your views on spare part surgery? Must stop before I start getting mawkish and sentimental.

Regards and ★=ì#&à★ but ì[\\!, ày★ç GçÄ) ç!

\X

286C120 (Barnet)

PS I think I'm coming down with something. I've been infested all day with squidgies – I just can't keep the blighters off my keyboard. I've tried everything from System Down to Winchester Crash, but nothing seems to work. Got any ideas?

Notes

1 But see note 3.

2 In fact, the paper has undergone several trials: Conference on Technological Choices, Indiana University, 12–14 April 1990; Department of Theory of Science and Research, Gothenburg University, 23 April 1990; Department of Technology and Social Change, Linnkoping University, 25 April 1990; SCASS, Uppsala, 26 April 1990; Discourse Analysis Workshop, Lancaster University, 25–26 September 1990; Department of History and Philosophy of Science, Cambridge University, 14 March 1991. My thanks to all participants in these trials and especially to Nick Jardine, SteveK, John Law, Russell Mills, and Leigh Star for their helpful comments. SSE David Southgate's machine supplied the letter in the Postscript. Finally, my thanks go to members of the company for their generous participation in this research. The research on which this paper is based was supported by ESRC (PICT).

3 As I hope will become clear, this warning has been posted on this occasion *merely for effect*. Please feel free to quote this chapter as often as possible.

4 This warning is printed in seven languages on the cover of the Microsoft WINDOWS package. Pelaez (1990) also makes the analogy between protection of texts and of software by including a warning on the front cover of her paper: 'Anyone who opens this paper will be deemed to have agreed not to quote, copy, reproduce, communicate or otherwise divulge any of the ideas contained herein without being granted express licence in writing by the author.'

5 For social scientists with constructivist inclinations, this raises questions about the process of IT's signification: How and why did IT become an important phenomenon? How and why was it deemed worthy of special attention and resource allocation?

6 For a discussion of the different senses in which technology can be understood as a text, in an analysis of attempts to 'apply' constructivism in the sociology of technology see Woolgar (1991).

7 Of course, the idea of 'playing against' a metaphor is itself to be understood metaphorically.

8 Unfortunately, this prevents me making any detailed comments on the way the company name featured in talk between company members. In addition to the common shorthand reference to the company by the initials of its name (see also note 10), some engineers played with the company name by rearranging a set of magnetic letters on one of the notice boards, to form various cryptic, sometimes lewd, anagrams.

9 One reaction to my description (later in this paper) of the usability trials is that the company appears 'rather unscientific' in its testing. It is therefore worth stressing that despite (or perhaps because of) this, the company has been very successful.

10 Nobody I talked to in the company had any difficulty in using the acronym 'DNS' in a sensible way. Many were aware of the (intended) technical specifications, the broad purposes, the target market for this new computer. But even at an early stage in my time at the company, I met a surprising number of

people who had difficulty telling me what DNS stood for. A standing joke which enjoyed popularity around the time of the first shipment went as follows:

> What's DNS stand for?
> Don't No, Sorry! (or Don't No, Squire!)

Several months after first shipment, a number of people were using a corruption of the acronym to refer to the machine as 'Dennis'.

When I once remarked upon the prevalence of these coded terms throughout the company (and the computer industry more generally), my colleague in hardware design initially looked blank. When I gave a few examples – DNS, RAM, ROM, IBM, MCA etc. – he said, 'Oh, you mean all the TLAs'. TLA, he explained, means Three Letter Acronym.

11 The opportunity for a detailed dissection of species of reaction to technological determinism is passed over here. Suffice it to say that most reactions against technological determinism amount to a call to place technology 'in context', where 'context' is interpreted in a variety of ways to suit the analytic predilections of the author. One symptom of this is the general recognition, in recent years, that 'technology' comprises much more than just machines. The sociology of technology thus has a focus much wider than just hardware and machines. 'Technology' can include social arrangements as diverse as the postal system, transportation, refuse collection, voting mechanisms, education and so on. To emphasise the sense in which this definition encompasses social arrangements, the term 'technological system' is sometimes used. The advantage of this broad definition is its insistence on including consideration of (narrowly conceived) technologies within a wider context. The argument is that machines can only be understood in terms of their use, and hence in terms of the context in which they are situated. The disadvantage is the implication that there remains, at the centre of the technological system, a residual, non-social or neutral machine which is malleable according to its social location/context, etc. Partly for this reason, the argument in this paper uses the term machine texts rather than technology texts.

12 Somewhat less idealistic forms of scepticism suggest that the possibilities of different readings are only limited by imagination. Imagination, that is, of the different circumstances prevailing at the point of reading being carried out.

13 In Smith (1978) and other textual analysts influenced by ethnomethodology, the deterministic status of the text is present although muted. The usual formulation is that the organisation of the text provides for a particular reading. It thus delimits the interpretive options, rather than determining them.

14 The notion that the Technical Support section is the fount of the various 'atrocity stories' circulating in the company is developed in an analysis of hot-line calls to the company (Woolgar in preparation).

> Why are personal computers so hard to configure? Dave Methvin relates a few horror stories.
> DEAR MARGE, MY PC WILL NOT BOOT UP, WHAT SHOULD I DO? Anyone who's worked with PCs for a while has a personal set of horror stories on configuration . . .
> (*PC Week*, 20 March 1990, p.6)

15 These include meetings and discussions to decide the name of the new machine, debates about whether or not to include a particular form of user interface, various exercises in compatibility testing, 'internal launches' (for example, to the company sales force), presentations to the educational advisers, and so on

16 One of the engineers who read this passage proposed a counter-example: the isolated user who, in virtue of his isolation and lack of contact with the

company, was forced frequently to re-configure the machine on his own and had, as a result, built up a detailed knowledge of the inner workings of the machine while knowing nothing about the inner workings of the company. The example may be re-subsumed under the explanatory scheme proposed here by noting his isolation from other users, or at least from 'users' as projected by the company. In a sense, his isolation had had the effect of forcing him to become part of the company.

17 Newcomers with experience of microcomputer assembly in other companies would have little interest in the manufacturing induction.

18 For a further example of the symbolic value of the machine boundary, played against the metaphor of transgressing organisational boundaries, see the analysis of computer virus stories in Woolgar and Russell (1989).

19 There are, of course, a wealth of (ethnomethodologically) reflexive ties to be investigated here.

20 Other occasions include, notably, telephone calls to the company hotline. See note 14.

21 I use 'settled' in an attempt to avoid the connotations of 'closure'. In the sociology of technology, 'closure' refers to the delimitation of different technological choices. For example, when bicycles (usually?) came to have two similar sized wheels – rather than, say, the penny farthing configuration – technological closure is said to have occurred. 'Closure' in this usage refers specifically to choice between design options. In the current case study, the focus is more generally on interpretation of capacity; 'settling' thus denotes a (temporarily) sufficient interpretation.

22 It could be argued that the identity of the user became more settled when the project code name 'DNS' was superseded by the name chosen by Marketing: 'Stratus'. This 'Stratus' (properly named the Stratus 286) is to be distinguished from its predecessor the 'Stratus PC'.

23 Once again, we should note the reflexive ties involved in these kinds of determination of 'fault'. It is not that faults occurring in machines under development straightforwardly or unproblematically give rise to the machine being blamed when the user is an expert. Rather, fault assignation involves finding the error to be just-that-kind-of-error-associated-with-a-machine-under-development. Similarly, the assignation is not straightforwardly independent of the status of expert. Rather, this works in virtue of the expert's recognition of a fault revealing and displaying the sense in which she is being an expert.

24 The messages from the machine are, of course, designed to have a rough equivalent in self diagnostics such as 'How did I get that?' and 'Where did I go wrong?' But this is only a rough equivalent. For a start the latter are questions addressed to self rather than to the machine, whereas the former are designed as informative diagnostic statements for consumption by the user.

25 This may be partly because, until recently, they had dealt with a homogeneous and fairly close knit set of customers. Giving privileged access to a small number of these would have jeopardised their relationship with the wider body of customers.

26 The User Products section had the idea of video taping the trials. The idea of using the audio tape recorder was mine.

27 However, I later discovered that it had been the practice to rewind the video tape over sections where things had gone wrong, or where it had turned out to be embarrassing, or where it was thought boring. The (complete) audio record provides an interesting contrast, revealing which episodes were deemed (videographically) irrelevant as far the testers were concerned.

28 Please allow several years for delivery.

29 I am reminded of attempts to produce films of adult–child interaction from the (young) child's point of view. Particularly memorable is the portrayal of what it is like for a two-year-old to be told to catch a ball thrown to her. Initially the

frame depicts the child's hands, as she dutifully responds to 'Hold your hands out'. As the adult yells 'Catch!', a dark blur appears in the top of the frame and grows alarmingly quickly. It fills the frame and then just as suddenly disappears. You then hear the adult saying: 'No. You have to watch the ball'.

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Appendix 1

DNS USABILITY TRIALS – 8 FEBRUARY 1989

(R/N/P/SW = Ruth/Nina/Pete/Steve; 2:01:44 – 2:03:29)

P: You got it. It's going?
N: It's going now.
P: Huh.
N: Right.
P: Actually, I'll move my chair round, so I can actually see the screen huhhu just
N: Okay (arisianne) when all the, oh
((laughter as Pete bumps into Nina))
P: (Sorry about that)
(3.0)
((Nina sits down))
N: We're in the introduction to all this. Yeah?
R: Mm.
N: I'll explain what we're trying to do.
R: Hmmhmm.
N: Errm and how we're going to be watching you.
R: Hmmhmm.
N: We'll be taking notes and also we've got this, camera on you now.
R: Right.
N: There are a number of different tasks we're asking people to do.
R: Hmmhmm.
N: And I'll ask you to do each one, one at a time.
R: Hmmhmm.
N: Then, I'll ask you how you expect to go about it and what sort of things you might expect to have to do.
R: Hmmhmm.
N: Then I'll ask you how long you think it's going to take.
R: Hmmhmm.
N: And then I'll ask you to do it.
R: Right.
N: And then after that, er, I'll ask you if you, if you had any difficulties where you did and, if you have any thoughts about how we could make them easier.

R: Mm.
N: Things like that. We'll have a chat afterwards about what we can do to make it better.
R: Right.
N: Ermm. (3.9) That's it from me. (3.0) What you've got in front of you is a DNS, it's a Winchester machine.
R: Hmmhmm.
N: It's got one Winchester and one floppy disk.
R: Hmmhmm.
N: It's got a VGA colour monitor.
R: VGA, colour monitor, that's a colour monitor.
N: Yeah.
R: That one.

Appendix 2

DNS USABILITY TRIALS – 8 FEBRUARY 1989

(R/N/P/SW = Ruth/Nina/Pete/Steve; 2:17:15 – 2:20:13)

R: Now (2.0) though it doesn't say in the instructions I'd be inclined to turn it off before I plugged in the, printer
N: Okay you do that
R: Alright?
N: Do whatever you like
R: Thank you, if I can find the switch (first) huhhh, that's just the monitor but, does it have a, switch I can't reach
((Ruth moves to back of machine))
(13.0)
R: This is?
(4.0)
R: (ahhh) right
((Fan noise switched off))
(9.0)
((Ruth returns to front of machine; looks at instruction books))
(16.0)
((Ruth takes the printer instructions book to rear of machine))
(21.0)
R: Hmm
(7.0)

((Pete looks at back of machine))
(7.0)
R: (this point) oh gosh (4.0) hmmm (7.0) I must be extremely thick I I can't see where this plug go (plugs in), at all. I'm going to ask for help Nina ha on this one hahahahahuhn
N: Are you. What are you looking for?
R: I'm trying to look for the point where this plugs into
((Nina comes to back of machine))
R: Because I would have thought this would have been a similar connection to this but I can't see one that's free.
(3.0)
N: I think we've discovered a *major difference* between the DNS and the K series machines!
R: It's not the right errmm connection
((Nina moves across to the corner of the room, to look at a K series machine))
(4.0)
((Steve peers at back of DNS machine))
(4.0)
N: We've discovered a *major* incompatibility ( )
R: Oh it's *not* just me being thick. Thank *god* for that hah hah I came in the back an' as *soon* as I got round here, with the machine I looked at this and looked at that and I thought 'No I'm being stupid, now this is silly' Well I *wasn't* hahahah
N: But in fact *we* were being silly asking you to do it

Materials of power

Technology is society made durable

Bruno Latour

Abstract

Is it possible to devise a set of concepts that could replace the technology/society divide? This set of new concepts – association and substitution – might help to rephrase some of the traditional questions of social order and especially that of the durability of domination of power. However, instead of using different tools to analyse power and weakness, it is argued that power and domination are simply different values of variables that should be studied in their whole range. By reconstructing networks it is argued that a full description of power and domination may be obtained.

For a long time social theory has been concerned with defining power relations (Barnes 1988), but it has always found it difficult to see how domination is achieved. In this paper I argue that in order to understand domination we have to turn away from an exclusive concern with social relations and weave them into a fabric that includes non-human actants, actants that offer the possibility of holding society together as a durable whole. To be sure, the distinction between material infrastructure and symbolic superstructure has been useful to remind social theory of the importance of non-humans, but it is a very inaccurate portrayal of their mobilisation and engagement inside the social links. This paper aims to explore another repertoire for studying this process of mobilisation. In the first part, I will use a very simple example to illustrate what I believe to be the right focus for detecting the entry point of techniques into the human collective. In the second part, I will analyse the beautiful case of the Kodak camera studied by R. Jenkins to show how social theory could benefit from history of technology. Finally, I will try to explain how stability and domination may be accounted for once non-humans are woven into the social fabric.

1 From context and content to association and substitution

Consider a tiny innovation commonly found in European hotels: attaching large cumbersome weights to room keys in order to remind customers that they should leave their key at the front desk every time they leave the hotel instead of taking it along on a tour of the city. An imperative statement inscribed on a sign – 'Please leave your room key at the front desk before you go out' – appears to be not enough to make customers behave according to the speaker's wishes. Our fickle customers seemingly have other concerns, and room keys disappear into thin air. But if the innovator, called to the rescue, *displaces* the inscription by introducing a large metal weight, the hotel manager no longer has to rely on his customers' sense of moral obligation. Customers suddenly become only too happy to rid themselves of this annoying object which makes their pockets bulge and weighs down their handbags: they go to the front desk on their own accord to get rid of it. Where the sign, the inscription, the imperative, discipline, or moral obligation all failed, the hotel manager, the innovator, and the metal weight succeeded. And yet, obtaining such discipline has a price: the hotel manager had to ally himself with an innovator, and the innovator had to ally herself with various metal weights and their manufacturing processes.

This minor innovation clearly illustrates the fundamental principle underlying all studies of science and technology: the *force* with which a speaker makes a statement is never enough, *in the beginning*, to predict the path that the statement will follow. This path depends on what successive listeners do with the statement. If the listener – in this case the hotel customer – forgets the order inscribed on the sign, or if he doesn't speak the language, the statement is reduced to a bit of paint on the piece of board. If the scrupulous customer obeys the order, he has complied with the imperative, thereby adding reality to it. The strength of the statement thus depends in part on what is written on the sign, and in part on what each listener does with the inscription. A thousand different customers will follow a thousand different paths after reading the order. In order to be able to predict the path, the hotel manager has two choices. He can either make all the customers equal by ensuring that they will know how to read the language and that they will know that going to a hotel in Europe means that one has a private, locked room but that the key must be left at the

desk upon exiting the hotel every day. Or he can *load* his statement in such a way that lots of different customers all behave in the same manner, regardless of their native language or their experience with hotels. The choice is between incorporation and excorporation.

The grammatical imperative acts as a first load – 'leave your keys'; the inscription on the sign is a second load; the polite word 'please', added to the imperative to win the good graces of the customer constitutes a third; the mass of the metal weight adds a fourth. The number of loads that one needs to attach to the statement depends on the customers' resistance, their carelessness, their savagery, and their mood. It also depends on how badly the hotel manager wants to control his customers. And finally, it depends on the cleverness of the customers. The *programs* of the speaker get more complicated as they respond to the *anti-programs* of the listeners. If a weird client could break the ring connecting the light key to the heavy weight, the innovator would then have to add a soldered ring to prevent such breakage. This is an anti-anti-program. If a paranoid hotel manager wanted to ensure zero key loss, he could place a guard at each door to search the customers – but then he would probably lose his customers instead. It is *only* once most of these anti-programs are countered that the path taken by the statement becomes *predictable*. The customers obey the order, with only a few exceptions, and the hotel manager accepts the loss of a few keys.

But the order that is obeyed is *no longer the same* as the initial order. It has been *translated*, not *transmitted*. In following it, we are not following a sentence through the context of its application, nor are we moving from language to the praxis. The program, 'leave your key at the front desk', which is now scrupulously executed by the majority of the customers is simply not the one we started with. Its displacement has transformed it. Customers no longer leave their room keys: instead, they get rid of an unwieldy object that deforms their pockets. If they conform to the manager's wishes, it is not because they read the sign, nor because they are particularly well-mannered. It is because they cannot do otherwise. They don't even think about it. The statement is no longer the same, the customers are no longer the same, the key is no longer the same – even the hotel is no longer quite exactly the same (Akrich 1987; Latour 1991; Law 1986a).

This little example illustrates the 'first principle' of any study of innovation in science and technology: the fate of a statement is in

the hands of others (Latour 1987b). Any vocabulary we might adopt to follow the engagement of non-humans into the social link should consider both the succession of hands that *trans*port a statement and the succession of *trans*formations undergone by that statement. To take these successive transformations into account, the very meaning of the word 'statement' must be clarified. By statement we mean anything that is thrown, sent, or delegated by an enunciator. The meaning of the statement can thus vary along the way, and it does so as a function of the load imposed by the enunciator. Sometimes it refers to a word, sometimes to a sentence, sometimes to an object, sometimes to an apparatus, and sometimes to an institution. In our example, the statement can refer to a sentence uttered by the hotel manager – but it also refers to a material apparatus which forces customers to leave their keys at the front desk. The word 'statement' therefore refers not to linguistics, but to the *gradient* that carries us from words to things and from things to words.

Even with such a simple example, we can already understand that when studying science and technology, we are not to follow a given statement through a *context*. We are to follow the simultaneous production of a 'text' and a 'context'. In other words, any division we make between society on the one hand and scientific or technical content on the other is necessarily arbitrary. The only non-arbitrary division is the succession of distinctions between 'naked' and 'loaded' statements. These, and *only these*, are the distinctions and successions which make up our socio-technical world. These are the ones we must learn to document and to record.

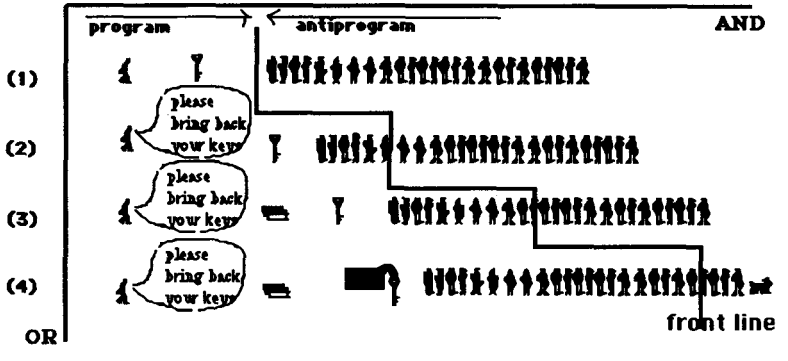
We wish to be able to follow both the *chain* of speakers and their statements and the *transformation* of speakers and their statements. We thus define two dimensions: association (akin to the linguist's syntagm) and substitution (or paradigm for the linguists). To simplify even further, we can think of these as the AND dimension, which is like latitude, and the OR dimension, which plays the role of longitude. Any engagement of non-humans can be traced both by its position on the AND-OR axes and by the recording of the AND and OR positions which have successively defined it. The vertical dimension corresponds to the exploration of substitutions, and the horizontal dimension corresponds to the number of actors which have attached themselves to the innovation (see Latour, Mauguin and Teil in press).

To trace a diagram on the example of the key, we will pick the

hotel manager's point of view as an origin. He is the speaker, or the enunciator – that is, the one who emits the statement. The track that the manager wishes his customers – the listeners – to follow we will call the *program of action*. We shall use numbers in parentheses to enumerate the successive versions of a program of action as seen from a single point of view. We will place all the programs to the left of the chosen point of origin, and all the anti-programs to the right. Let us also agree to enumerate the segments of the programs of action with numbers in parentheses. Finally, let us agree to draw the dividing line between programs and anti-programs in bold face; this line corresponds to the front of the tiny controversy we are following here.

Figure 1

The hotel manager successively adds keys, oral notices, written notices, and finally metal weights; each time he modifies the attitude of some part of the 'hotel customers' group



In version (4), the hotel manager and almost all of his customers are in agreement, while in version (1) the manager is the only one to wish for the return of his flighty keys. The syntagm or the association or the AND dimension have extended themselves in a lasting manner. But this extension to the right had a price: it became necessary to descend along the OR dimension by enriching the program of action with a series of subtle translations. The manager's wishes are supplemented first by a sentence in the imperative tense, then by a written sign, and finally by metal weights. The customers were nibbled away at little by little: they finally abandoned their anti-program and 'surrendered' to the program. But the finances, the energy, and the intelligence of the

hotel manager have also been nibbled away at! In the beginning, the wish was naked; in the end – an end which can only be provisional, as other anti-programs could always manifest themselves – it was clothed, or loaded. In the beginning it was unreal; in the end, it had gained some reality.

Such a diagram does not retrace the displacement of an immutable statement *within a context of use or application*. Nor does it retrace the displacement of a technical object – in this case a key weighed down by metal – within a context of use or application. Instead, it retraces a movement which is neither linguistic, nor social, nor technical, nor pragmatic. The diagram keeps track of successive changes undergone by customers, keys, hotels, and hotel managers. It does this by recording the ways in which a (syntagmatic) displacement in the associations is 'paid for' by a (paradigmatic) displacement in the substitutions. In such a diagram every move towards the right is to be paid by moving downward.

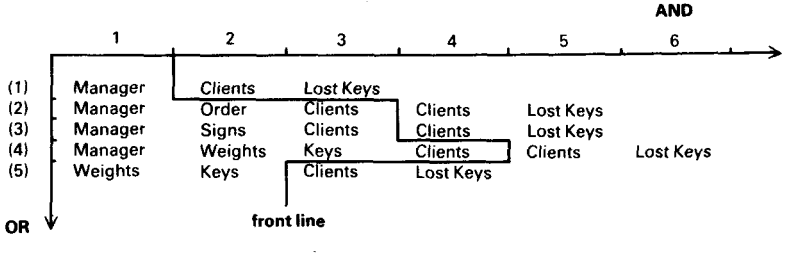
The degree of attachment of an actant to a program of action varies from version to version. The terms 'actant' and 'degree of attachment' are symmetrical – that is, they apply indifferently to both humans and non-humans. The key is strongly attached to the weight by a ring, just as the manager is very attached to his keys. It does not matter here that the first link is called 'physical' and the second 'emotional' or 'financial' (Law 1986b; Bijker and Law 1992; Bijker, Hughes and Pinch 1986). The problem is precisely for the hotel manager to find a way to attach his keys to the front desk when his customers go out, and he does this by attaching his customers to the front desk in a stronger and more lasting manner than that with which the keys are attached to his customers' pockets or handbags!

We notice in the diagram that the social group of the hotel customers finds itself transformed little by little. The accumulation of elements – the will of the manager, the hardness of his words, the multiplicity of his signs, the weight of his keys – ends up trying the patience of some customers, who finally give up and agree to conspire with the manager, faithfully returning their keys. The group of customers which has not been enrolled at the (provisional) end is composed (according to the manager) either of folks of unmanageably bad faith or of exceptionally distracted professors. This gradual transformation, however, does not apply to the 'hotel customers' social group alone; it also applies to the keys. Suddenly, indifferent and undifferentiated keys have become

'European hotel keys' – very specific objects which we must now distinguish and isolate just as carefully as we did with clients. Herein lies the whole point of following innovations. Innovations show us that we never work in a world filled with actors to which fixed contours may be granted. It is not merely that their degree of attachment to a statement varies; their competence, and even their definition, can be transformed. These transformations undergone by actors are of crucial importance to us when we follow innovations, because they reveal that the unified actor – in this case, the hotel-customer-who-forgets-the-key – is itself an association made up of elements which can be redistributed. It is opening and closing these black boxes that, until now, have made understanding the entry points of innovations such a delicate process.

Note that in the case presented here the success of the innovation – that is, its extension toward the right from the manager's perspective – is only made possible by constantly *maintaining* the entire succession of accumulated elements. It is only because the hotel manager continues to want his keys back, reminds customers aloud, puts up signs, and weighs down the keys that he can finally manage to discipline his customers. It is this accumulation that gives the impression that we have gained some reality. But another scenario could be imagined.

Figure 2



The manager might ask his customers to leave their keys, but, after putting up a few signs, he feels that he's done enough and has nothing more to say. As a result, there are just as many customers who do not follow either the oral or the written instructions. A technicist at heart, our good man chooses a technical fix and proceeds to delegate all the work to the object. He weighs down all his keys without bothering to put up signs or deliver oral instructions any more. He gets a few more customers to conspire with his wishes, but soon gets disgusted and abandons his

program. What is left in this case? A bunch of keys strongly attached to a bunch of metal weights by some beautiful metal rings, and customers who merrily carry the key-weight combination wherever they go. As for the hotel manager, no one knows what he wants any more. In this scenario the final version (5) would associate fewer elements from the point of view of the original enunciator and is thus, by our definition, less real. But for us, who wish to observe the mobilisation of non-human into a human assembly, the only interesting reality is the *shape* of the front line. Whereas the asymmetry between the feasible and the unfeasible, the real and the imagined, or the realistic and the idealistic dominates most studies of innovation, our account only recognizes *variations of realization and de-realization*. The front line traced by the exploration of what holds and what does not hold together records the compatibilities and the incompatibilities of humans and non-humans – that is, the socio-logics of the worlds in which we live.

These two possible scenarios in our example show how difficult it is to avoid the twin pitfalls of sociologism and technologism. We are never faced with objects or social relations, we are faced with chains which are associations of human (H) and non-humans (NH). No one has ever seen a social relation by itself – or else it is that of the hotel manager unable to discipline his customers – nor a technical relation – or else it is that of the keys and the weights forgotten by everyone.

Instead we are always faced by chains which look like this

H-NH-H-NH-NH-NH-H-H-H-H-NH (where H stands for a human-like actant and NH for a non-human).

Of course, an H-H-H assembly looks like social relations while a NH-NH-NH portion looks like a mechanism or a machine, but the point is that they are always integrated into longer chains. It is the chain – the syntagm – we study or its transformation – the paradigm – but it is never some of its aggregates or lumps. So instead of asking 'is this social', 'is this technical or scientific', or asking 'are these techniques influenced by society' or is this 'social relation influenced by techniques' we simply ask: has a human replaced a non-human? has a non-human replaced a human? has the competence of this actor been modified? has this actor – human or non-human – been replaced by another one? has this chain of association been extended or modified? Power is not a property of any one of those elements but of a chain.

2 Weaving together a story of technology

The main difficulty of integrating technology into social theory is the lack of a narrative resource. We know how to describe human relations, we know how to describe mechanisms, we often try to alternate between context and content to talk about the influence of technology on society or vice-versa, but we are not yet expert at weaving together the two resources into an integrated whole. This is unfortunate because whenever we discover a stable social relation, it is the introduction of some non-humans that accounts for this relative durability. The most productive way to create new narratives has been to follow the development of an innovation (Bijker *et al.* 1986; Bijker and Law 1992; Hughes 1983). Those recent histories allow one to go from powerless engineers to domination that is so complete that it has become invisible. It is now the landscape in which human action and will flow effortlessly.

Consider Jenkins's story of the simultaneous invention of the Kodak camera and of the mass market for amateur photography (Jenkins 1975, 1979). Let us abridge this story by identifying each program and anti-program and by successively recording all the new actors, be they human or non-human, single or collective.

Table 1

Abridged script of a socio-technical path (according to Jenkins)[1]

(1) professional-amateur (A)/ daguerrotype (B)

(2) professional-amateur (A)/ wet collodion (C) **1850**/ paper manufacturing (D)-//- doing everything oneself right away

(3) professional-amateur (A)/ paper manufacturing (D)/ *dry* collodion plates made ahead of time (E) **1860–1870** -//-

(4) professional-amateur / paper manufacturing / more sensitive dry **gelatin** plates **1870–1880**/ companies that manufacture plates ahead of time -//-

(5) professional-amateur / paper manufacturing / dry **gelatin** plates/ companies that manufacture plates ahead of time/ continuous plate coating machine/ Eastman -//-

(6) **(5)**/ capital from Strong/ EASTMAN DRY PLATE COMPANY **1881–1883** -//- low entry price/ easy competition

(7) **(6)** consortium of plate manufacturers -//- still limited market/ fragile plates

(8) **flexible Walker film**/Walker's Pocket Camera **1884** -//-

(9) roll film instead of plate film/ camera using the films -//- nothing other than heavy cameras using plate film exists on the market

(10) camera using the films/ Warnerke's 1870 prototype in England non-patented roll/ roll holder/ two paper rolls coated with collodion -//- too expensive/ difficult unloading/ uncertain markers/ distortion leading to fuzzy pictures/ not too reliable/ still for professional

(11) Eastman/ Walker/ high status company/ commercial network/ roll holder/ flexible film in rolls/ production line manufacturing machine -//-

(12) **(11) 1884** gelatin layers plus collodion -//- fragile

(13) **(12)** paper/ collodion -//- fragile

(14) **(13)** paper/ gelatin -//- fragile

(15) **(14)** paper/ soluble gelatin/ less soluble photosensitive gelatin -//- distortion

(16) **(15)** / gelatin on the back to avoid distortion/ thick gelatin layer -//-

(17) **(16)**/ roll holding frame/ spring against distortion/ removable parts against loading and unloading/ measurement drum/ trigger to advance film/ puncher for exact marking -//-

(18) **(17)** / **early 1884** continuous paper machine for serial printing -//-

(19) **(18)** / patents -//- **1885** encroaching Houston patents inventing punch holes in roll film for exact marking, avoiding superimposed pictures

(20) **(19)** / Houston **spring 1889** sells the patent -//- very expensive patent

(21) **(20)** new commercial company EASTMAN DRY PLATE AND FILM COMPANY/ Strong/ Walkers/ eight stockholders //subcontractor manufactures roll holder -//- film cracks

(22) **(21)** / **end 1885** film available in long strips -//-

(23) **(22)** / seduces photography leaders/ worldwide rewards **June 1885** London -//-

(24) **(23)**/ Warnerke says 'it's better than mine and different because of mass production' -//- film too delicate to develop/ doesn't appeal to professionals of lesser quality than plates

(25) Eastman printing paper very good/ professional market interested/ Eastman company does fixing and development in series/ 1887 6000 developments a day -//- market still limited to development

(26) film not good for professional **good for amateurs** -//- abandon of amateur professional **(opening of black boxes (2) to (6))**

(27) good for amateur/ mass market -//- no camera **summer 1887**

(28) mass market/ flexible film **(16)**/ existing cameras/ development fixing by the Eastman Company -//- amateurs not interested because existing camera hard to use

(29) mass market/ flexible film **(16)**/ existing cameras/ development fixing by the Eastman Company/ user doesn't have to do anything -//- the Eastman company does all the work

(30) mass market/ **Eastman camera**/ flexible film/ **1887 Kodak name**/ 25 dollars/ 100 exposures/ Eastman commercial network/ manual of use/ advertisement -//-

(31) **(30)** triumphant reception -//- film still fragile

(32) **(31)** then replacement of support for nitrocellulose paper/ displacement of rolls in front of instead of behind focal plane -//-

(33) **(32)** whole world/ rewards/ mass market verified -//- celluloid problems sales go down **1892 1893**

(34) **(33)**/new support for film/market takes off -//- potential competitors and patents

(35) **(34)**/ buys back all the patents -//-

(36) **(35)/1899** large industry/ mass production/ mass market increased to amateurs from 7 to 77 years old/ hundreds of thousands of cameras sold-//-

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This table summarizes a success story, that of the simultaneous building of a new object (the Kodak camera) and of a new market (the mass-market). What is remarkable in the story is that you are never faced with two repertoires – infrastructure and superstructure, techniques and economics, function and style – but with shifting assemblies of associations and substitutions. The film is substituted to the plates, the dry collodion is substituted to the wet collodion, capitalists replace other capitalists, and above all, average consumers replace professional-amateurs. Is the final consumer forced to buy a Kodak camera? In a sense, yes, since the whole landscape is now built in such a way that there is no course of action left but to rush to the Eastman company store. However, this domination is visible only at the end of the story. At many other steps in the story the innovation was highly flexible, negotiable, at the mercy of a contingent event. It is this variation that makes technology such an enigma for social theory. Let us

now examine several of those enigmas by using the simplified story of the Kodak camera.

a) Trajectory or translation?

The first of these enigmas is the notion of *trajectory*. For example, the curator of a museum of technology trying to put together an exhibit on the history of photography might be tempted to link succeeding versions of early cameras in a display case. These, after all, are hard, physical objects which can be easily preserved and shown. The curator does not deny the existence of the 'rest' – of all the photographers, subjects, markets, and industries that surrounded the cameras. Instead, all this gets transformed into a context *in which* the technical object moved, grew, changed, or became more complex. Yet, if we compare Warnerke's invention with Eastman's first camera, we notice that they are exactly as dissimilar as version (10) is from version (24) of the table above – an episode in which Warnerke most courteously recognizes Eastman's originality. The degree of resemblance has to be taken as an index on an association chain.

From the perspective of the trajectory of a glass-and-wood object moving through society, these two innovations should no more be linked in a museum display case than a sewing machine and an operating table. By cutting across the translations, the notion of trajectory invents surrealist '*cadavres exquis*'. And yet, from the perspective of the flow of associations and substitutions, there does indeed exist some link, established by Warnerke and Eastman themselves. But this link is not supported by wood, reels, or glass. The two inventions do not have a single non-human in common: they only appear to do so in retrospect. Eastman's exploration work alone establishes a link between the roll holder designed for professional amateurs in England and the automatic camera mass-produced in America. Either we give this work a place in our analyses, in which case the link is not fortuitous, or we don't, in which case the link between the two is nothing but an artefact of the technical history of technology.

b) Forms or contents?

Rather than confusing the secondary mechanism of attribution with the primary mechanism of mobilization, we should stick to

the latter. An innovation is a syntagmatic line (AND) containing just as many humans and non-humans as were recruited to counter the anti-programs. If even a single segment differs from one version to the next, the innovation is simply *no longer the same*. If all the segments but one are distinct, there is absolutely no reason to group two versions in the same showcase. We still have the diffusionist's (Latour 1987b) bad habit of considering that one particular segment of a program of action is the essence of an innovation, and that the others are merely context, packaging, history, or development. But the only essence of a project or of a knowledge's claims is its total *existence*.

This existentialism (extended to things!) provides a precise content to the distinction between questions of rhetoric (or packaging) and substantive questions. Network analysis has been widely criticized for transforming scientists into washing machine salesmen, people constantly worried about rhetoric and enrolments and very little concerned about the content of their discoveries. But this objection is doubly unfair, both for washing machine salesmen, who surely exercise much more subtlety than they are usually given credit for, and for innovators. Is the invention of the word 'Kodak' important or not? Is merely deciding to build a market enough? Or is such a decision superfluous? Is the whole thing simply a marketing problem? All these questions should acquire a precise meaning: does the actor 'the name Kodak' lead to a modification in the durability of the syntagm, and if so how much of a modification? In Jenkins's narrative, the actor 'name Kodak' in version (30) is an actor among twenty-three other actors, and only allows the recruitment of a single new actor in version (31). In this precise case, we can measure the exact weight of rhetorical packaging. The contingency or necessity itself varies according to the size of the syntagm and the amount of substitution it later endures.

Consider, however, the case of the Turkish astronomer in Saint-Exupéry's *The Little Prince*. When he demonstrates the existence of asteroid B 612 dressed in his traditional national costume, his colleagues treat him with scorn and laughter. The next day, he makes 'the same' demonstration dressed in a three-piece suit and wins the esteem of the colleagues. The only difference is the astronomer's clothing. Here indeed we have a case in which the weight of mere rhetoric is essential. Only a diffusionist, an essentialist, or an epistemologist would find it ridiculous that the astronomer's first demonstration was missing nothing but a tie.

Those who follow innovations know perfectly well that a tie may make all the difference, and that there is no reason to *equate* the syntagm 'demonstration + Turkish national costume + collegial laughter' with the syntagm 'demonstration + three-piece suit + collegial esteem'. But we do not necessarily have to conclude that the weight of a tie and a three-piece suit is in principle and for ever essential to mathematics! The analyst should never predetermine the weight of what counts and what does not, of what is rhetoric and what is essential, of what depends on Cleopatra's nose and what resists all contingencies. The weight of these factors must be *calculated* as a function of the movement of syntagms and they will be different in each story.

c) Social context or technical content?

Symmetrical to the illusion of a trajectory crossing a context is that of a context crossed by innovations. We need to dismiss this other sociological ghost as well if we wish to understand how the weaving of humans and non-humans is done.

Can one say that the amateur professionals of the first days of photography closed their minds to technological progress as of 1886, and that the larger public opened its mind to progress as of 1892? Can one explain the diffusion of photography by examining the nature of the social groups interested in it? In other words has the notion of interest to be stabilised in order to account for the path of the knowledge claims? No, because the social groups themselves were deeply transformed by the innovations. The professional amateurs interested in Eastman's dry-plate – versions (5) and (6) – were extremely disappointed in roll film – version (24) – whose quality was vastly inferior to that of the plates; they were interested in printing and developing pictures on Eastman's photographic paper (25), and totally non interested in the Kodak camera. They actively sorted the proposed innovations, but they also were altered, modifying their laboratories and delegating the task of plate, then paper, preparation to individual companies. What we observe is *a group of variable geometry entering into a relationship with an object of variable geometry*. Both get transformed. We observe a process of translation – not one of reception, rejection, resistance, or acceptance.

The same applies to the amateurs. The amateur in version (36) who only has to click the Kodak camera, thereby imitating millions

of other amateurs, and who does not need any laboratory since he can send the camera with the films to be developed at Eastman's factories, is no longer the same as the one in version (24), who bought intimidating cameras whose film got stuck and produced fuzzy pictures. The amateur market was explored, extracted, and constructed from heterogeneous social groups which *did not* exist as such before Eastman. The new amateurs and Eastman's camera *co-produced* each other. We see neither resistance to, nor opening of, nor acceptance of, nor refusal of technical progress. Instead we see millions of people, held by an innovation that they themselves hold.

And what about Eastman? Is he a fixed actor? Not at all. The contours of what Eastman can and wants to do, as well as the size and the design of his company also vary in this story. Contrary to the claims of those who want to hold either the state of technology or that of society constant, it is possible to consider a path of an innovation in which *all the actors* co-evolve. The unity of an innovation is not given by something which would remain constant over time, but by the moving translation of what we call, with Serres, a *quasi-object* (Serres 1987).

d) Realistic or unrealistic?

By dissolving the difference between that which mutates and the surroundings in which an innovation mutates, we should remove yet another problem: that of the asymmetry between the realizable and the unrealizable.

Reading Eastman's socio-technical narrative, we can easily see that version (36) is not the realization – or objectivation, or reification, or incarnation – of version (1), since none of the same actors can be found at the (temporary) end of the controversy. And yet we are dealing with the progressive construction of reality. But the continuity of this story is not that of a slightly crazy idea that finally becomes reality; it is that of a translation which completely transforms that which gets transported. The real is no different from the possible, the unrealistic, the realizable, the desirable, the utopian, the absurd, the reasonable, or the costly. All these adjectives are merely ways of describing successive points along the narrative. Version (24) only seems unfeasible when compared to the violent event of version (26); version (10) is not an incarnation of version (9), as the two only have a single

element in common. The narrative thus should employ the *same tools* to treat each stage of our story without ever having to judge how 'intrinsically' realistic or unrealistic an association is. The only reality that it records is socio-logical.

A major result of this manner of recording socio-logics is that 'reality' is not a final, definitive state demanding no further effort. A chain of associations is *more real* than another one if it is *longer* – from the perspective of the enunciator designated as a starting point in the story. Maintaining reality is thus paid for by a continual extension in the syntagm (AND). Thanks to this narrative, the 'inertial force' of innovations – that famous state in which they would be irreversible and would zoom through society under their own steam – is quite simply dissolved. So is the symmetrical 'inertial force' of groups incapable of 'accepting' an innovation. Nothing becomes real to the point of not needing a network in which to upkeep its existence. No gene pool is well adapted enough to the point that it needs not reproduce. The only possible thing to do is to diminish the margin of negotiation or to transform the most faithful allies in black boxes. The only absolutely impossible thing is to diminish the number of associated actors while pretending at the same time that the existence of the innovation continues to be just as 'real'. Domination is never a capital that can be stored in a bank. It has to be deployed, black-box, repaired, maintained.

e) Local or global?

The narrative should also account for another little mystery: the progressive passage from the microscopic to the macroscopic. Network analysis and field work have been criticized for giving interesting demonstrations of local contingencies without being able to take into account the 'social structures' which influence the course of local history. Yet, as Hughes has shown in a remarkable study of electrical networks (Hughes 1979, 1983) the macro-structure of society is made of the same stuff as the micro-structure – especially in the case of innovations which originate in a garage and end up in a world that includes all garages – or, conversely, in the case of technological systems which begin as a whole world and end up on a dump. The scale change from micro to macro and from *macro to micro* is exactly what we should be able to document.

If a version does indeed represent a progressive change of scale from micro to macro with the inclusion of greater and greater numbers of black boxes (each of which counts 'as one'), then we can also document, using the same tool, the progressive re-opening, dispersion, and disbanding of actors passing from the macro level to the micro level. The socio-technical world does not have a fixed, unchanging scale, and it is not the observer's job to remedy this state of affairs. The same innovation can lead us from a laboratory to a world and from a world to a laboratory. Respecting such changes of scale, induced by the actors themselves, is just as important as respecting the displacement of translations. Given the tools of network analysis that we have at our disposal, trying to endow actors with a fixed dimension as well as a fixed form is not only dangerous, but simply unnecessary.

f) Slow or fast?

It is worth noting one last consequence of substituting socio-logics to asymmetric notions of the real and the possible. The passage of time becomes the consequence of alliances and no longer the fixed, regular framework within which the observer must tell a tale. The observer has no more need for a regulated time frame than for actors with fixed contours or predetermined scales. Like the relativist in physics, the relativist (or relationist) science or technological studies is content with what Einstein so beautifully called 'mollusc of reference' (Einstein 1920). Just as we let actors create their respective relationships, transformations, and sizes, we also let them mark their measure of time; we even let them decide what comes before what.

The OR dimension records the order in which different versions succeed one another – as seen from the perspective of the observer chosen as a starting point – but it does not regularly measure time. Referring back to the Eastman example, thirty years elapse between versions (1) and (15), but only a few months go by between versions (25) and (30). Should we then conclude that the innovation 'drags its feet for thirty years' and 'accelerates brusquely' in 1887 as historians so often say? We could indeed reach this conclusion, but words such as 'fast' or 'slow', 'mature' or 'premature', 'feasible', 'utopian', 'real', merely float on the surface of translation movements without explaining anything. The number and speed of events depend entirely on movements of

alliance or rupture performed by the actors. If you can reconstitute these movements, you obtain the dimension of temporality as well; if you cannot reconstitute these movements, the regular passage of time won't tell you anything. What the socio-technical graph reconstitutes is the historicity of innovations ever dependent on the socio-logics of actors. Like everything else, time must be constructed. It is not given to you. The innovator never rests on the seventh day.

3 Repairing relativism

Admitting that we are now capable of displaying the fine variations of a socio-technical exploration, how does this ability help us *explain* the contingent shape adopted by a particular trajectory? The three Graces of Truth, Efficiency, and Profitability, so handy for providing causes in science, technology, and economics, are obviously unusable, as they are the result and not the cause of these displays. Eastman's cameras in versions (8) to (29) are neither profitable nor efficient. They will take on these qualities, but only somewhere around version (36). It is thus impossible to use the end of the story to explain its beginning or its development. The study of innovations is no more teleological than Darwinian evolution. But there is no question of substituting sociological interests for the three Graces as the motor of history. Stable Interests, like good Efficiency or sure Profitability, need stable networks and instruments to be able to make predictions. But the amateurs do not know that they need photography before version (36). Stockholders wait twenty years to decide whether their interests are better served by plates, films, or Kodak cameras. And as for Eastman, he designs his interests little by little as his research develops. Both economics and stable sociology arrive on the scene *after* the decisive moments in the battle. They arrive after the points where large AND variations are paid for by large OR displacements, and they deal with states in which large AND displacements are only paid for by tiny OR displacements.[2]

Since an explanation of an innovation's path cannot be retrospective, it can only spring from the socio-logics of programs and anti-programs. Can anti-program actors be either recruited, ignored, or rebuffed? Can program actors maintain their association if such and such an actor is recruited, ignored, or rebuffed? At all times, the front line of a controversy generates such questions. It is

the answers to these *particular* questions that make or break an innovation. And all these answers depend on how actors resist the proposed tests: if I add actor D to a syntagm made of ABC, what will A do? What will B and C do? To understand the path taken by an innovation, we must evaluate the resistance put up by the successive actors that it mobilizes or rejects. Explanation does not follow from description; it is description *taken that much further.* We do not look for a stabilized and simplified description before we begin to propose an explanation. On the contrary, we use what they do to an innovation or a statement to define the actors, and it is from them and them alone that we extract any 'cause' we might need. Paradoxically our explanation are 'internalist' in the sense that they all come from the inherent topography of specific networks.

a) Defining actors by the list of their trials

We define an actor or an actant only by its actions in conformity with the etymology. If an innovation is defined by a diagram in which its essence is co-extensive to its existence – that is, the ever-provisional aggregate of its versions and their transformations – then these versions and transformations are in turn completely defined by the actants that constitute them. But where do we get these actants from? Where do the hotel customer, the manager, the key, and the sign come from? What would be the use of displaying innovations without reductionism if we use a reductionist definition of actants? Luckily for us an actant is defined exactly like an innovation. All we have to do is shift our perspective: instead of using an innovation that passes from actor to actor as a starting point, we must use one of these actors in whose 'hands' successive versions of the innovation pass. Here again, the linguistic metaphor can help us. A linguist can study either a syntagm – a group of associated elements in a meaningful sentence – or the element itself in the framework of all the meaningful sentences in which it appears, that is a paradigm. This would be like moving from:

The fisherman
The fisherman / fishes /
The fisherman / fishes / a shark/
The fisherman / fishes / a shark / with/ a gun
The painter /fishes / a trout / with / a knife

to

The painter/ paints/ pictures
The painter/ paints/ houses
The painter/ is /a/ substantive
The painter/ is/ / hyper-realistic

What changes is the point we choose to hold fixed. In the first case, our object is the length of the syntagm as well as the group of paradigms that can be substituted in each articulation. In the second case, our object is a specific articulation, and we wish to reconstitute the group of syntagms in which it occurs. Defining the essence of innovations by the existence of their successive and simultaneous actants, and then turning around to define the actants by the successive innovations in which they appear, is no more circular or contradictory here than in linguistics.

How do we define an actant? An actant is a list of answers to trials – a list which, once stabilized, is hooked to a name of a thing and to a substance. This substance acts as a subject to all the predicates – in other words, it is made the origin of actions (Callon 1991). How do we define our hotel manager of the key story? He certainly 'is' the obstinate speaker who reminds customers to leave their keys, but he is also more than that. He 'is' also the one who makes up the bills, orders clean sheets, places ads in the phone book, summons painters, etc. The key also can be defined not merely by its appearance in our innovation story, but by the list of everything it must submit to in all the innovation stories in which it appears. Its sole purpose in life is not returning to the front desk; it also throws bolts, get stuck when a drunken customer tries to force a lock, gets imitated by a master key, etc. And as for the metal weight, it does not merely intervene as a modest attachment to a hotel key. It undergoes many other tests, which define it much more completely: it melts at 1800° in a furnace, it is made up of iron or carbon, it contains up to 4% silicon, it turns white or grey when it breaks, etc.

The longer the list, the more active the actor is. The more variations that exist among the actors to which it is linked, the more polymorphous our actor is. The more it appears as being composed of different elements from version to version, the less stable its essence. Conversely, the shorter the list the less important the actor. The more diversity it encounters among the different actors it meets, or the more difficult it is to open its black-

box, the more coherent and firm it is. The list of tests undergone by a given actor defines its historicity, just as a socio-technical graph defines the historicity of an innovation or knowledge claim.

Just as an innovation can become increasingly predictable by black-boxing longer and longer chains of associations, an actor can become so coherent as to be almost predictable. If A is always associated with B or dissociated from D in the succession of stories, we can safely assume that when A relates to B in a new narrative, it will link itself with B and unlink itself from D. We can thus begin to deduce the *performance* of actors from their *competence*. We are then, but only then, allowed to be normative again, but these norms are not forced onto the data, they are extracted from the actor's own efforts at rendering each other's behaviour more predictable. Power and domination are the words given to those stabilizations and not an account of their coming into being. They are only one possible state of the associations. An essence emerges from the actor's very existence – an essence which could dissolve later. Its history becomes a nature to use Sartre's expression, but perhaps we should add to later become history again. The actor has gone from Name of Action to Name of Object (Latour 1987a). The lists constructed from the joint story of innovations and actors highlight the continual variation in an actor's isotopy, i.e., in its stability over time. Its behaviour becomes either more and more or less and less predictable. The list allows us to go from extremely shaky certainty to necessity, or from necessity to uncertainty. The force of habit, or of habitus, will either exert itself *or not*; it will act or not as a function of the historical records of the actor.

b) Following the relativist variations of translation

In spite of this circular definition of actors and innovation we are still far from providing explanations: we can only predict how long an association will last if an innovation grabs an actor or if an actor grabs an innovation. To be more precise, we can only predict such reactions for those cases that interest us the least: those in which the innovation is already a black box, in which the actors have such a stable history that it has almost become second nature, in which the traditional notion of power and domination may be predictably used. How can we manage to anticipate reactions in other cases

when domination is not yet exerted? To do so, we must tame a third source of variation.

Since we are capable of mutually defining actants and innovations without any further essentialism we can therefore map the translation operation. This crucial operation engenders the establishment – albeit local and provisional – of social links. Thanks to translation, we do not have to begin our analysis by using actants with fixed borders and assigned interests. Instead, we can follow the way in which actant B attributes a fixed border to actant A, the way in which B assigns interests or goals to A, the definition of those borders and goals shared by A and B, and finally the distribution of responsibility between A and B for their joint action. In a universe of innovations solely defined by the associations and substitutions of actants, and of actants solely defined by the multiplicity of inventions in which they conspire, the translation operation becomes the essential principle of composition, of linkage, of recruitment, or of enrolment. But since there no longer exists any external point of view to which we could ascribe the degree of reality or of success of an innovation, we can only obtain an evaluation by triangulating the many points of view of the actors. It is thus crucial to be able to shift easily from one observer to another.

Consider a particularly elegant translation operation by Pasteur:

> To the Minister of Public Education
> Paris, 1 August, 1864
>
> Minister,
>
> Wine constitutes one of the greatest agricultural riches of France. The value of this product of our soil is increased by the commercial treaty with England. Thus in all wine-growing countries, there is interest in improving methods with a view to increasing both the number and quality of those wines that can be profitably exported.
>
> Unfortunately, our knowledge of this precious beverage leaves much to be desired. Studies of its composition are so incomplete that only in the past two years have two of its main components – glycerine and succinic acid – been identified. Despite the progress of modern chemistry, there is no more knowledgeable and precise treatise on wines than that of Chaptal, which came out more than sixty years ago. This is sufficient to indicate how much remains to be done.

For the past five years, I have been working on the problem of fermentation. I have taken particular interest in the fermentation of alcohol at the heart of the wine-making process. The very progress of my research has led me to want to continue it *in situ* and in countries known for the production of those wines that are most valued in France. I wish to study the fermentation processes there, and in particular to examine the microscopic vegetable matter that is the sole cause of this great and mysterious phenomenon.

I intend to carry out this work during my next leave. There will be about six weeks of travelling and of study, with one assistant and a few necessary items of equipment and chemical products. I estimate the outlay to be 2500 francs.

The aim of this letter is to put this project before your Excellency, and to ask for a grant to cover the cost of its execution. This will not be the end of my interest in the matter. I will follow it up with work in future years, at the same time of the year.

Further, I am the first to admit that there may be no immediate practical consequences of my studies. The application of the results of science to industry is always slow. My present goals are very modest. I should like to arrive at a better knowledge of the crytogamic plant that is the sole cause of fermentation in grape juice.

Successive layers of actants – the Minister, chemistry, my research, my trip to the Arbois – get goals and borders attributed to them. Each of these layers is characterized by incompatible vocabulary: 2500F, the trade treaty with England, succinic acid, the cryptogamic plant. (Hence the word translation.) An anti-program gets attributed to each of these programs of action: it would be nice to sell wine to England, but these wines are diseased; it would be nice to know the origins of these diseases, but wine chemistry is sixty years old; I would like to pursue my research, but I lack money and assistants. On the one hand, the translation operation consists of defining successive layers of vocabulary, of attributing goals, and of defining impossibilities; on the other hand, it consists of displacing – hence the other meaning of translation – one program of action into another program of action. The overall movement of the translation is defined by a *detour* and by a *return*. In the end, by giving Pasteur 2500F, the Minister is supposed to restore the balance of payments and thereby attains his goals.

But the translation operation is always risky. Indeed, nothing guarantees that the detour will, in the end, be paid, rewarded by a return. In fact, Pasteur, always clever, gives a good indication of this in his last paragraph. The only goal that must be attained, he said, is that of pure knowledge of the cryptogamic plant: applying this knowledge – i.e., the return – is always problematic. One can imagine many other possible scenarios: the Minister might be uninterested in the wine trade, wine diseases might be due solely to chemical phenomena, the 2500F might never materialize, or Pasteur could change his research project. Those things composed and linked by the translation operation might disperse themselves like a flight of birds. This is precisely the possibility we must predict if we want to explain and produce some evaluations. And how else could we do this, since we no longer have an external referent, except by submitting Pasteur's version of the goals and desires of all the human and non-human actors to a *test* by *comparing* them with the goals and desires they give themselves or attribute to Pasteur? Indeed, nothing guarantees that the operation proposed by Pasteur corresponds to the version held by the actants named Minister, chemistry, cryptogamic plant, England, or ferment. In order to measure the potential success or failure of the translation operations – relative, of course, to an enunciator and to an observer – we must verify whether or not they occupy the position expected by Pasteur. The durability of Pasteur's position is not to be explained by his power, but only by the convergence between what he expects others to do and what others expect him to do. It is this negotiation process that is always forgotten by those who use already acquired domination to explain future one.

Suppose that we notice through further interviews and documents that as far as the Minister is concerned, the problem of balancing payments has nothing to do with wine and its diseases. His problem lies with silk, whose trade is hampered by Japan. As for the chemists, they certainly do not occupy the position predicted by Pasteur. Their tragedy has nothing to do with the fact that their discipline is out of date; on the contrary, they are concerned about the dramatic return to vitalism, which is slowing down progress in chemistry. In fact, Pasteur and his fermentations figure prominently in their anti-programs! And finally, the ferments: they're beginning to die from lack of air, thereby annihilating Pasteur's efforts to cultivate them. By comparing what Pasteur says the others want and what the others say they want, we can easily imagine that Pasteur might have a few problems in getting his funds, because

those mobilized in his version *do not occupy* the position he assigned them, at least, not yet. Such a comparison would show the actants' state of alignment or dispersion and would help predicting the complexity of future negotiations.

This example shows us that it is not merely statements which vary as a function of innovations. Both also vary *as a function of the perspective* of the observer or of the informant.

Until now, the starting points of all the narratives have remained stable. We told the story of the hotel keys from the manager's perspective, and we told the Kodak story from the perspective of Eastman and Jenkins. Yet a program's capability to counter an anti-program obviously depends on how well an actor's conception of others corresponds to their conceptions of themselves or of the said actor. If this convergence is weak, the actor will populate his world with other beings; but these beings will behave in an unpredictable fashion, attaching or detaching themselves to the program from version to version. If, on the other hand, this convergence is strong, the actor can begin to make predictions – or, in any case, to guarantee the consistent behaviour of the beings constituting his world.

We thus have to do more than follow the sequence of events surrounding an innovation: we should *compare the different versions* given by *successive* informants of the 'same' syntagm. We do not have an outside referee to test the credibility of a claim. The degree of alignment or dispersion of the accounts will be enough to evaluate the reality of a claim. Consider a sentence often cited by language philosophers: 'the present king of France is bald'. This sentence has launched endless discussion in the philosophy of language, because it is both grammatically correct and completely devoid of meaning, as it does not 'correspond' to any real state of affairs. It is said that this sentence has a signified but no referent. Can we evaluate the credibility of this sentence without having to take refuge in the notion of referent? If we are able to shift the observer's point of view and to keep track of it, it is possible.

Historians know Charles the Bald, but not the present king of France. Hairdressers know a few bald people, but no kings, not to mention kings of France; they do, however, hold scalps, creams, and hair lotions close to their hearts. Much is presently happening in Berlin and in Cambodia, but none of it has anything to do with the king of France. There are indeed people who run France, but they call themselves Presidents, and not kings. The only people

who take this sentence into consideration are linguists and philosophers, who use it as a cliché! Based on this script, we could calculate the degree of convergence or of divergence between the actors mobilized by the sentence *and what the actors say about themselves when questioned*. In the present case, none of the actors who have been mobilized can take up the statement without adding other, completely disparate statements. There are thus very few allies and many new actors, except in the last version. For the only version that adopts this sentence unproblematically is that of philosophers, who stabilize it by turning it into a classic puzzle in the philosophy of language.

This classic example allows us to loop network analysis back on itself. There is never any need to leave our networks, even if we are talking about defining the truth, the exactitude, the coherence, the absurdity, or the reality of a statement. The judgement of reality is immanent in, and not transcendant to, the path of a statement. To put this the other way around, forbidding oneself to exit a network does not entail forbidding oneself to judge. In this example, we can correctly judge the degree of truth of the statement 'the present king of France is bald' without ever appealing to the notion of referent; in fact, this notion is the only mythical element in the whole bald king story. Indeed, all statements have a reality, and this reality can be evaluated precisely by comparing, each time, what an actor says about another actor with what this other actor says about itself. This comparison delineates a network which is both the existence and the essence of the statement. Unicorns, bald kings of France, black holes, flying saucers, appearances of the Virgin, chromosomes, atoms, Roger Rabbit, and utopian technological projects all possess, without excess or residue, the degree of realism delineated by their networks. This point is not relativist: all statements are not equal. It is relationist: showing the relationships between the points of view held by mobilized and by mobilizing actors gives judgements as fine a degree of precision as one could wish for. The philosophy of language, science, or technology do not know how to reconstruct or calculate these judgements with any finesse (Pavel 1986); they are content with coarse, hasty judgements on the manifest absurdity or the inevitable reality of such and such a statement or project.

Conclusion

If we abandon the divide between material infrastructure on the one hand and social superstructure on the other, a much larger dose of relativism is possible. Unlike scholars who treat power and domination with special tools, we do not have to start from stable actors, from stable statements, from a stable repertoire of beliefs and interests, nor even from a stable observer. And still, we regain the durability of social assemblage, but it is shared with the non-humans thus mobilised. When actors and points of view are aligned, then we enter a stable definition of society that looks like domination. When actors are unstable and the observers' points of view shift endlessly we are entering a highly unstable and negotiated situation in which domination is not yet exerted. The analyst's tools, however, do not have to be modified and the gradient that discriminates between more and less stable assemblages does not correspond in the least to the divide between technology and society. It is as if we might call technology the moment when social assemblages gain stability by aligning actors and observers. Society and technology are not two ontologically distinct entities but more like phases of the same essential action.

By replacing those two arbitrary divisions with syntagm and paradigm, we may draw a few more methodological conclusions. The *description* of socio-technical networks is often opposed to their *explanation*, which is supposed to come afterwards. Critics of the sociology of science and technology often suggest that even the most meticulous description of a case-study would not suffice to give an explanation of its development. This kind of criticism borrows from epistemology the difference between the empirical and the theoretical, between 'how' and 'why', between stamp-collecting – a contemptible occupation – and the search for causality – the only activity worthy of attention. Yet nothing proves that this kind of distinction is necessary. If we display a socio-technical network – defining trajectories by actants' association and substitution, defining actants by all the trajectories in which they enter, by following translations and, finally, by varying the observer's point of view – we have no need to look for any additional causes. The explanation emerges once the description is saturated. We can certainly continue to follow actants, innovations, and translation operations through *other networks*, but we will never find ourselves forced to abandon the task of description to

take up that of explanation. The impression that one can sometimes offer in the social sciences an explanation similar to those of the exact sciences is due precisely to the stabilization of networks, a stabilization that the notion of explanation simply does not 'explain'! Explanation, as the name indicates, is to deploy, to explicate. There is no need to go searching for mysterious or global causes outside networks. If something is missing it is because the description is not complete. Period. Conversely, if one is capable of explaining effects of causes, it is because a stabilized network is already in place.

Our second conclusion relates to relativism and the heterogeneity of networks. Criticisms of studies of controversy insist on the local, soft, and inconsistent nature of the results. They have the impression that network analysis recreates 'that night when all the cows are grey' ridiculed by Hegel. Yet networks analysis tends to lead us in exactly the opposite direction. To eliminate the great divides between science/society, technology/science, macro/micro, economics/research, humans/non-humans, and rational/irrational is not to immerse ourselves in relativism and indifferentiation. Networks are not amorphous. They are highly differentiated, but their differences are fine, circumstantial, and small; thus requiring new tools and concepts. Instead of 'sinking into relativism' it is relatively easy to float upon it.

Finally, we are left with the accusation of immorality, apoliticism, or moral relativism. But this accusation makes no more sense than the first two. Refusing to explain the closure of a controversy by its consequences does not mean that we are indifferent to the possibility of judgement, but only that we refuse to accept judgements that transcend the situation. For network analysis does not prevent judgement any more than it prevents differentiation. Efficiency, truth, profitability, and interest are simply properties of networks, not of statements. Domination is an effect not a cause. In order to make a diagnosis or a decision about the absurdity, the danger, the amorality, or the unrealism of an innovation, one must first describe the network. If the capability of making judgements gives up its vain appeals to transcendance, it loses none of its acuity.

Notes

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1 I take the story as essentially correct since I simply want to show how such a narrative may help social theory in integrating technology to its canonical questions. When a version reuses a former one simply adding to it the number of the black-boxed version is included in bold. The symbol -//- points out the dividing line between programs and anti-programs (from the point of view of Eastman). For all the coding problems see Latour, Mauguin and Teil (in press).
2 This division of labour is not a weakness of economics or sociology. It is simply linked to the problem of controlling large amounts of things: an object's ability to recruit large numbers of either masses or markets in a predictable manner depends on the stability of both the object and its network.

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Techno-economic networks and irreversibility

Michel Callon

Abstract

This paper explores the heterogeneous processes of social and technical change, and in particular the dynamics of techno-economic networks. It starts by considering the way in which actors and intermediaries are constituted and define one another within such networks in the course of translation. It then explores, first the way in which parts of such heterogeneous networks converge to create unified spaces linking incommensurable elements, and second how some of these links achieve longevity and tend to shape future processes of translation.

Introduction

Science and technology lie at the heart of social asymmetry. Thus technology both creates systems which close off other options[1] and generates novel, unpredictable and indeed previously unthinkable, options.[2] The game of technology is never finished, and its ramifications are endless. But how should we think of technological change? How should we think of the relationship between science, technology, and asymmetry? And how, in particular, should we make sense of the processes that build up and break down asymmetries?

During the last ten years sociologists and economists have shown that the standard models of technological development are flawed. Technology rarely grows in a predictable and unilinear manner within a relatively stable social and industrial context (Foray 1989). Models which assume this cannot explain its radical, and sometimes revolutionary, character. Instead, the new sociology and economics of technology suggest that science and technology are a product of interaction between a large number of diverse actors.[3] But how should we describe and analyse these interactions?

As yet there is no satisfactory answer to this question. Here, however, I want to explore it by introducing the concept of the *techno-economic network* (TEN). This is a term which I will use to describe a coordinated set of heterogeneous actors which interact more or less successfully to develop, produce, distribute and diffuse methods for generating goods and services. It is sometimes possible to predict the way in which a TEN will evolve. The unilinear model of technological change is not always wrong. But more often the actors have significant degrees of freedom. They develop complicated strategies and many possible innovations with unexpected social and technical implications. The question, then, is how and why this happens. How should we make sense of the radical potential of technology, of its relationship to social and economic asymmetry?

In Part 1 I describe a set of analytical tools for exploring the mechanisms by which heterogeneous activities are brought into relationship with one another, and introduce the concepts of *intermediaries*, *actors* and *translation*. In Part 2 I show how networks are established and evolve, and talk of *convergence* (which deals with the construction of a unified space for incommensurable elements) and *irreversibilisation* (which has to do with the longevity of these connections and the extent to which they are predetermined). I also touch on network dynamics and consider the way in which both agency and the possibility of quantification depend on the character of the network. Finally, in the Conclusion I argue that the relationship between the macro- and the micro-social and many of the great social and technical asymmetries reflect network *punctualisation*.[4]

1. Actors and intermediaries

Life is complicated. But I will start with a heuristic simplification and assume that TENs are organised around three distinct poles: *First* there is a *scientific pole* which produces certified knowledge. This is where scientific research is practised: for instance, in independent research centres, universities and relatively basic industrial laboratories.

Second there is a *technical pole* which conceives of, develops and/or transforms artefacts. Its products include models, pilot projects, prototypes, tests and trials, patents, norms, and technical rules,

and it is found in industrial technical laboratories, research associations, and pilot plants.
Third there is a *market pole* which refers to users or consumers who more or less explicitly generate, express or seek to satisfy demands or needs.[5]

In one sense these poles are worlds apart. What does a research scientist working on the fine structure of ceramics have in common with a consumer looking for a powerful but comfortable, economical and reliable car? *In principle* they are as different as chalk and cheese. *In practice*, however, they are linked. The scientist who worries what her colleagues think about her work, the engineer trying to convert a prototype into a pilot product without giving away proprietary information, and the consumer – in one way or another these are all connected. But how are they connected? How does science or technology interact with the social? How do they shape one another? To understand this we have to draw both on economics and on sociology.

Economics tells us that it is *things* that draw actors into relationship with one another. For instance, it tells us that a consumer and a producer enter into relationship via a product. Or that an employer and an employee are linked because the skills of the latter are mobilised and paid for by the former. Economists thus speak of *intermediaries*. And this is an important insight that may be generalised. I will say, then, that an *intermediary is anything passing between actors which defines the relationship between them*.[6] Examples of intermediaries include scientific articles, computer software, disciplined human bodies, technical artefacts, instruments, contracts and money.

Unlike economics, sociology does not start with a stylized image of the actor. Instead it assumes that actors are only intelligible when they are inserted into a common space which they have built themselves. For instance, Crozier and Friedberg (1977) speak of actors and systems, Bourdieu (1980) of agents and fields, and Parsons (1977) of roles and functional prerequisites. In their different ways sociologists thus assume that every actor contains *a hidden but already social being*: that agency cannot be dissociated from the relationships between actors.

Economists teach us that interaction involves the circulation of intermediaries. Sociologists teach us that actors can only be defined in terms of their relationships. But these are two parts of the same puzzle, and if we fit them together we find the solution.

This is that *actors define one another in interaction – in the intermediaries that they put into circulation.*[7]

1.1 Intermediaries

Again I will simplify, and talk of four main types of intermediary:
First there are texts, or more generally *literary inscriptions* (Latour 1986). These include reports, books, articles, patents and notes. These are materials, for they are inscribed and circulate on paper, floppy discs and magnetic tapes – relatively immutable media that resist transport.[8]
Second there are *technical artefacts*. These, which include scientific instruments, machines, robots and consumer goods, are (relatively) stable and structured groups of non-human entities which together perform certain tasks.
Third and obviously, there are *human beings*, and the skills, the knowledge and the know-how that they incorporate.
And *fourth* there is money in all its different forms.

I want now to argue that such intermediaries *describe* their networks in the literary sense of the term. And they *compose* them by giving them form. Intermediaries thus both order and form the medium of the networks they describe.

Texts as networks

Texts are vital to many areas of social life, but nowhere more so than in science (Callon *et al.* 1986; Latour 1989). Thus a scientific text may be seen as an object which makes connections with other texts and literary inscriptions. The choice of journal, of language and of title – these are the methods by which an article seeks to define and build an interested audience. The list of authors tells of collaboration and of the relative importance of each contribution. Here, then, is the start of a network. But that network extends into the references and citations. These rework the cited texts, insert them into new relationships, and identify and link new actors together. Words, ideas, concepts and the phrases that organise them thus describe a whole population of human and non-human entities. Some may be well established and others novel. But taken together they define, explore, stabilise, and test their identities against one another. A text may speak of electrons,

enzymes, government agencies, oxides, methods, experimental arrangements, multinational companies and sectors of industry. But like the actors in some American novels who would otherwise never come together, their destinies are intertwined in the 'socio-technical dramas' described in scientific papers.[9]

The words in a text refer to other texts, and rework and extend the networks to be found in these. So whereas, traditionally, we have assumed that texts are closed – we have distinguished between their context and their content – now we are saying that texts have neither an inside nor an outside. Rather they are objects that define the skills, actions and relations of heterogeneous entities. Thus, like other texts, *the scientific article is a network whose description it creates.*[10]

Technical objects as networks

What is the strange alchemy that allows us to transmute groups of non-humans into networks that define and link heterogeneous actors? How can we treat machine tools, internal combustion engines, video recorders, nuclear plants or automatic ticket machines in this way? Recent work in the sociology of technology, in particular by Madeleine Akrich and Bruno Latour, suggests that a technical object may be treated as *a program of action co-ordinating a network of roles*. These roles are played by non-humans (the machine itself and such other objects as accessories and power supplies) and 'peripheral' humans (such as salespersons, consumers, repair people).

In practice it is not too difficult to describe the programs embodied in technical objects, or the ways in which their socio-technical components act, communicate, issue orders, interrupt one another and follow protocols. The reason is that descriptions or 'textualisations' are common. Technical objects are not as dumb as we think!

Thus in its design stage, the character of an object is endlessly debated:[11] what will it look like? what will it do? what will it be used for? what skills will its users need? what maintenance will it require? Such talk is heterogeneous. Indeed engineers transform themselves into sociologists, moralists or political scientists at precisely those moments when they are most caught up in technical questions. Should a car be treated simply as a basic and economical means of transport? Or should it satisfy repressed

desires for conspicuous consumption (Callon 1987)? Should users be allowed to intervene when a solar lighting kit breaks down? Or should it be hermetically sealed to stop damage by amateurs (Akrich *et al.* 1987)? Answers to these questions – questions about design – are *both* technical *and* social. They imply decisions about the definition and distribution of roles between the object and its environment. The definition of an object is also the definition of its socio-technical context: *together* they add up to a possible network configuration. There is no 'inside' or 'outside'.

Such 'textualisation' is also found in apprenticeship. Here the instructor describes the operation of an object: the network 'inscribed' in it is set out and inspected. What are the links between technical objects? And what are the roles that humans play? Perhaps they watch a sluicegate and press a lever? Or observe the screen and click the mouse? In this way the machine is interpreted, deconstructed, and inserted back into its context – though possibly not in the way intended by the designer. The written traces of such efforts to put objects into words are to be found everywhere, as are the controversies to which they lead.[12] Codes, checklists, maintenance manuals and user handbooks, all of these escort objects on their travels (Akrich 1989b), and sometimes texts are inscribed in the machines themselves. Such texts impute skills to humans – the ability to detect different coloured signals, or to read labels which say 'on/off', 'record', or 'play'. Here machines are ordering human beings around by playing with their bodies, their feelings or their moral reflexes (Latour 1988).[13]

To sum up, artefacts are not the enigmatic and remote objects to which they are often reduced. When they come into contact with their users, they are carried on a wave of texts which bear testimony to the scars of the textualizations that accompanied their design and displacement (Akrich 1989a). Technical objects thus more or less explicitly define and distribute roles to humans and non-humans. Like texts they link entities together into networks in ways that may be decoded.

Skills as networks

Embodied skills may also be treated as networks of entities. Sometimes, to be sure, humans may be seen as networks of 'purely social' flesh and blood: perhaps this is the picture of humanity

carried by head-hunters. More often, however, they are thought to embody technical skills. Thus a 'pure' technician such as a computer programmer or a disciplined production worker induces groups of non-humans to play their roles. Other skills operate within a 'pure' universe of codified texts (bureaucrats or accountants) or financial instruments. The division between context and content disappears again. No description of skills is possible unless the networks of humans, texts and machines within which they are expressed and put to work are reconstituted (Cambrosio and Limgoes 1990; Mustar 1989). To describe a skill is thus, at the same time, to describe its context.

Money as a network

Traditionally, money is interpreted as a reserve of value and instrument of exchange. As an instrument of exchange, it demands something in return[14] and a minimal but essential return in the form of information. Accordingly, it constitutes the buyer and seller and measures the strength of their mutual commitment – a relationship explored and analysed in economics. But the relationship between money and return is even clearer for reserve value, or public or private funding (Aglietta and Orlean 1982). For instance, when venture capital funds research, this is based on a program of action, which acts as counterweight to the loan. In this money is textualised, translated into orders, indicators and recommendations. These define and link a range of heterogeneous human and non-human actors: cooperate with X at ICI and Y from Laboratory Z to obtain a critical temperature of 150°K and you will get a loan of $A. Here again the intermediary is a network of roles.

From pure to hybrid intermediaries

These are limiting cases. In practice, the world is filled with *hybrid intermediaries*. Nowhere is this more true than for the texts which chaperone other classes of intermediary. Here we find that we are entering a civilization of inscriptions which covers all forms of intermediary. And the ubiquity of texts means that the equivalence between networks and intermediaries is strengthened. It is made more legitimate, more explicit, and more subject to challenge. The

more one reads the more one links,[15] and the more important it is to negotiate and compromise.

But human/non-human hybrids are no less invasive. Indeed, as several of the other contributors to this volume suggest, it is increasingly difficult to distinguish between humans and non-humans. For instance, there are systems of distributed intelligence which mix up computers that demand programmers and programmers who mobilise computers with an abandon that would make Rene Girard tremble. Who is negotiating with whom? What implies what? Which is the actor, and which the follower? These are open questions.

Impurity, then, is the rule. Nowhere is this more visible than in the service sector.[16] The product sold by Club Med, Cap Sogeti or CISI is a mixture of humans and non-humans, texts, and financial products that have been put together in a precisely co-ordinated sequence. Consider what it takes for Mr Smith to be able (and willing) to spend his holiday on the banks of Lake Ranguiroa, watching the barracudas mingle with the tanned bodies of his fellow-humans. Computers, alloys, jet engines, research departments, market studies, advertisements, welcoming hostesses, natives who have suppressed their desire for independence and learned to smile as they carry luggage, bank loans and currency exchanges – all of these and many more have been aligned. Truly the intermediary linking Mr Smith to the (initially improbable) dreams and interests of the package tour operator is monstrous and complicated. But in principle it works like any other intermediary. If Mr Martin uses a fork to mash potatoes this is just another (albeit simpler) intermediary. Like its more complex cousin it assigns him a role – the role of human being with a number of options and rights. So what lies at the *end* of the chain is equally easy to describe in both cases. The complexity of the intermediary itself is irrelevant.[17]

Decoding intermediaries

I have tried to show that intermediaries more or less explicitly and consensually describe their networks. That is, they describe a collection of human and non-human, individual and collective entities. These are defined by their roles, their identities, and their program – which all depend on the relationships into which they enter. My argument has two consequences. The first has to do with

the crucial role played by intermediaries in giving shape, existence and consistency to social links. I want to say that *actors define one another by means of the intermediaries which they put into circulation*. The second is methodological. It is that *the social can be read in the inscriptions that mark the intermediaries*.

At the time of the Renaissance the great Book of Nature was read and re-read. Now we must extend the literary metaphor. Our concern should be to read the many intermediaries that pass through our hands: to learn to read artefacts, texts, disciplined bodies, and cold money. Sociology is simply an extension of the science of inscriptions. Now it should broaden its scope to include not only actors but the intermediaries through which they speak.

1.2 Actors

In the way I initially want to define the term, an 'actor' is any entity able to associate texts, humans, non-humans and money. Accordingly, it is any entity that more or less successfully defines and builds a world filled by other entities with histories, identities, and interrelationships of their own. This initial definition suggests that intermediaries are synonymous with actors. For instance, a scientific text seeks to create a reader with the skills needed to mobilise, consolidate, or transform the network described in the paper. Thus it acts: it is an actor.[18] And the same is also true for other intermediaries. Like intermediaries, actors may be hybrid. They may but need not be collectivities. They may take the form of companies, associations between humans, and associations between non-humans.[19] In this ontology actors have both variable content and variable geometry.

Of course, actors are not always successful. An article may not find the right readers, or it may be deconstructed. A machine may rust away. An incorporated skill may find no employer. An application for a grant may be turned down. And so on. The injunctions to act are inscribed in intermediaries.[20] If nothing is said or inscribed (and I have argued that inert matter is talkative) then nothing acts. Action works via the circulation of intermediaries. These tirelessly carry messages which describe (in both senses of the word) the networks in which they are inscribed. Why then, do we need the notion of actor? Why should we not simply make do with that of intermediary?

The answer has to do with authorship. All interactions involve a

method for imputing intermediaries to authors. Indeed, authorship is often inscribed in the intermediaries themselves. Scientific articles are signed and technical objects are trademarked. Incorporated skills are attributed to the body or to the subject. Thus I want to say that *an actor is an intermediary that puts other intermediaries into circulation*[21] – that an actor is an author. And, to be sure, that the imputation of authorship, like all the other claims or suggestions made by intermediaries, is controversial, open to doubt or question.

Defined in this way, an actor is an entity that takes the last generation of intermediaries and transforms (combines, mixes, concatenates, degrades, computes, anticipates) these to create the next generation. Scientists transform texts, experimental apparatus and grants into new texts. Companies combine machines and embodied skills into goods and consumers. In general then, actors are those who conceive, elaborate, circulate, emit, or pension off intermediaries,[22] and the division between actors and intermediaries is a purely practical matter.[23] Is a group an actor or an intermediary? Is an actor a force for conservation or for transformation? The answer has nothing to do with metaphysics, ontology, or the rights of 'man'. Rather it is empirical.[24]

Consider, for instance, the case of a nuclear power station. This is a hybrid, a monstrous group which regulates interaction between graphite rods, turbines, atoms, operators, control boards, flashing lights, concrete slabs and engineers. Should we refuse this group the right to be an actor? 'It' transforms everything that is fed to it. Files, bills, fuel, water, skills and budget lines are converted into electrons transported to consumers, taxes paid to local councils, and waste products – which in turn lead to the formation of groups of angry environmentalists. It is certainly a network. But is it an actor, given that it is just a black box that converts known inputs into programmed outputs?

The question is empirical. Is the plant the *author* of the intermediaries that it puts into circulation? And the answer is yes but only sometimes. Thus the plant is often seen as a simple link in a chain which extends from the user to the generating company, and perhaps beyond to the terrible nucleocrats who conceived and planned it. In this case the actors are taken to pass *through* the plant without stopping. And the humans who actually work there, like the turbines, isotopes, waste pumps and cooling circuits with which they interact, disappear into its deepest recesses. On the other hand, for certain purposes the plant is carefully distinguished

from everything beyond it and becomes an author. For instance, some doubt its reliability and safety, or the ability of the operators to maintain the necessarily level of concentration.

Here, then, is the ambiguity. Some treat the group as an intermediary aligned by other actors who lie behind it and put it into circulation. Others treat it as a dignified actor that may introduce unexpected and unprogrammed sequences and associations. This ambiguity is the stuff of controversy though its intensity depends, of course, on circumstances. When the clouds from Chernobyl spread over Europe to contaminate Lapp reindeer and Welsh sheep, the plant became an actor rather than an intermediary. Forms of talk treating technology as an uncontrolled and autonomous force – as an actor in its own right (Ellul 1964: Winner 1977, 1986) – gained ground over those treating it as an instrument or tool. Thus quite minimal changes may transform intermediaries into actors, or actors back into intermediaries. It is a question of where the buck stops. Either you focus on the group itself, and go on further, in which case you have an actor. Or you pass through it into the networks that lie beyond, and you have a simple intermediary.[25]

2. Networks

All groups, actors and intermediaries describe a network: they identify and define other groups, actors, and intermediaries, together with the relationships that bring these together. When such descriptions include an imputation of authorship, then actors emerge in the stopping places, asymmetries, or folds (Deleuze 1989). But the network of intermediaries accepted by an actor after negotiation and transformation is in turn transformed *by* that actor. It is converted into a scenario, carrying the signature of its author, looking for actors ready to play its roles. For this reason I speak of *actor-networks*: for an actor is also a network.

But how do different actor-networks, which have no *a priori* reason to be compatible with one another, ever manage to reach agreement? What happens if one does not accept another's definition? Or if two actor-networks disagree about the nature of a third? How is it that sometimes agreements are reached? And those agreements may turn out to be durable? The answer to these questions has to do with *convergence* and *irreversibilization*. But

before discussing these I will first consider the elementary relationship between actors in the process of translation.[26]

2.1 Translation

'A translates B'. To say this is to say that A defines B. It does not matter whether B is human or non-human, a collectivity or an individual. Neither does it say anything about B's status as an actor. B might be endowed with interests, projects, desires, strategies, reflexes, or afterthoughts. The decision is A's – though this does not mean that A has total freedom. For how A acts depends on past translations. These may influence what follows to the point of determining them. The methodological point is that the *observer* should not exercise censorship. S/he should collect *all* the translations. None should be rejected *a priori*. There should be no division between those that are reasonable and those that are taken to be fantastic or unrealistic. All the entities and all the relationships between these entities should be described – for together they make up the translator.

The notion of translation thus implies definition. But, definitions are inscribed in intermediaries (we are not toying, here, with idealism or psychologism), which come in many forms. Accordingly, it makes little sense to speak of translation 'in general'. We have to define the medium, the material into which it is inscribed: round-table discussions, public declarations, texts, technical objects, embodied skills, currencies – the possibilities are endless. Nevertheless the elementary operation of translation is triangular: it involves a translator, something that is translated, and a medium in which that translation is inscribed.[27]

Translations may change as time passes. Sometimes they are a product of compromise and mutual adjustment negotiated through a series of iterations (Akrich, Callon and Latour 1987). And when they are embodied in texts, machines, bodily skills and the rest, the latter become their support, their more or less faithful executive. At one extreme the latter may be an isolated and homogeneous intermediary. And at the other it may be a hybrid cascade of intermediaries with articulated roles, links and feedback loops between the actors. In either case, a concern with translation focuses on the process of mutual definition and inscription. And, to be sure, it extends the traditional definition of action.

2.2 The network

The nature of the relationship between actors and their networks is never finally resolved. Thus when two translations link together they generate a third which may bring together groups that would otherwise have been separate. But the observer does not need to adopt the position of one of the actor-networks, for networks are formed out of the aggregation and composition of *all* the relevant but more or less compatible actor-networks. And behind the heterogeneity we will find textualisations that are *sometimes* in agreement. Sometimes it is possible to make links – and it is in this process that we must seek commensurability rather than in the cognitive capacities of actors.

2.2.1 Convergence

Having spoken of translation I can now explore the dynamics of networks – the complex processes in which actors and their talkative (sometimes indiscreet) intermediaries weave themselves together. To do this I will talk of *convergence* and *irreversibility*. Convergence measures the extent to which the process of translation and its circulation of intermediaries leads to agreement. At the same time, it is a method for exploring the boundaries of a TEN. Convergence has two dimensions: alignment and co-ordination.

Alignment

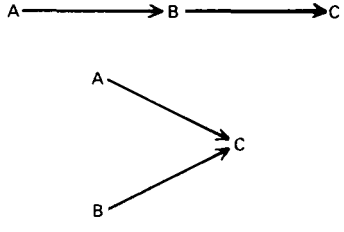
In the elementary operation of translation two objects are defined by an intermediary. But the extent to which that definition is embraced and performed varies. Sometimes there is controversy, conflict, and the translation is rejected as betrayal: *traduttore-traditore*. We find workers who do not want to play the role defined for them by the machine; consumers who doubt the quality and value of a product; scientists who denounce the arguments of their fellow-authors; borrowers who reject the conditions attached to a loan; or electrons that refuse to pass from one electrode to another. And we find actors who deny or reinterpret the character of their authorship: 'I only spoke about the memory of water in order to excite your curiosity. I was not really *serious*.'

Disagreements vary in scope. They may focus on an actor, or on

an intermediary. They may lead to open controversy, or simply to abstention. And they may or may not be overcome. But a translation that is generally accepted tends to shed its history. It becomes self-evident, a matter on which everyone can agree. There is empathy, the perfect piece of information which circulates without difficulty with the unshakeable felicity described by Austin. And between these two extremes lie all those situations so well described in game theory in which each player puts itself in the place of the other and they work through a series of iterations to a possibly stable conclusion. A successful process of translation thus *generates* a shared space, equivalence and commensurability. It *aligns*. But an unsuccessful translation means that the players are no longer able to communicate. Through a process of *disalignment* they reconfigure themselves in separate spaces with no common measure. Translations thus both flow through *and* are held in place by intermediaries.[28]

When there is 'perfect translation', A and B speak in exactly the same way about themselves, about one another, and about the intermediary that links them together. There is total equivalence with no ambiguity. But the further one moves from such agreement, the greater the differences and incoherences. Isotropy gives way to a space full of discontinuities: we move from harmony to polyphony, and finally to cacophony.

A network starts to form as soon as three actors are joined together by intermediaries. There are two basic possible configurations:



The first is one of complementarity in which the relationships are transitive. If A translates B which translates C, then A also translates C. The second is one of substitutability in which C is similarly translated by A and B. The level of alignment depends on the success of the translations – and in the case of substitutability on the extent to which they resemble one another.

The same two configurations join together to form longer chains of translations, for however complex they may be, networks are built out of these two basic building blocks.[29] So however complex and extended a network may be, we may determine how well aligned it is, albeit perhaps only qualitatively. A *strongly aligned* network is one in which the translations are successful and (in the case of substitutability) relatively similar. Conversely, a *weakly aligned* network is one in which these conditions are not fulfilled.[30]

Co-ordination

The imputation of the authorship is an important part of the process of translation. But such imputations are shaped by more or less explicit and stable rules or conventions that have been produced in past interaction. What do these look like?

First, there are rules about the *identity* of actors. Is A *really* an actor? Here the issue has to do with the intermediaries that may be imputed to A. The rules that determine these questions range from written laws to customs. For instance, there are legal rules about attributing products to companies; there is legislation which can deny inventors the right to ownership of their invention;[31] and there are unwritten conventions which prevent someone funding a research program co-signing the articles that emerge from it.

Second, and rather similarly, there are rules and conventions about *imputing intermediaries* to particular actors. Some of these are complex, controversial, and enforced only with difficulty. For instance, there are companies operating as civil persons, using commercial trademarks, which have neither the right to own property, nor the contractual ability to demand that the retailer pass on payments from the client. Here the ambiguities are huge (Eymard-Duvernay 1989). Again, a scientist may sign an article, but unless the signatures are in the right order, the date on which the paper was received by the journal is recorded, and there is some obligation to cite it, authorship of the translation inscribed in the paper may not be imputed to her at all.

Third, there are conventions about who may *speak* on behalf of whom. This is particularly obvious in politics, with its legitimated procedures for designating representatives – and also in industry where there are contractual and collective agreements which spell out responsibilities and working conditions. But such rules may also be found in the organisation of the market, where it takes the

form of price controls, methods for regulating the prices charged by state monopolies, and informal networks which pass on information about reputations (Karpik 1989). Again, they are to be found in science: the ability of a scientist to 'translate' a higher order primate or a human being depends on a series of regulations – codes of ethics about permissible experiments.

All such conventions tend to rarefy the universe of possible actors by organising imputation and limiting the number of translations that can be easily stabilised.[32] I will call these codifying regulations forms of *co-ordination* or *translation regimes*.[33] Some are intended to apply generally. Such conventions embody general definitions – for instance about what is to count as a citizen, an official diploma, a guaranteed loan, a standard technical object, or the conditions under which a loan may be made. On the other hand, some are limited in scope. These draw on more general conventions, but work to divide the universe of actors and intermediaries up into subsets with conventions that are locally, but only locally, valid.[34]

Though the distinction is abstract, it makes good empirical sense. Thus there are many regulations which have only limited scope. These include: the constitution of cartels; collective agreements in specific industrial sectors; rules of professional certification; technical norms local to a few producers and users; the development of an *appelation controlée* for wines; the founding of consumer groups; the organisation of professional associations or scientific societies; the mounting of training courses for a few companies; and the creation of research associations. Such forms of local co-ordination often rest on more general regulations – for instance anti-trust laws. But the distinction between local and general conventions is only relative. General conventions may become local again if they are successfully denounced and challenged (Reynaud 1989). Conversely, local forms of co-ordination may be spread. Thus conventions from one sector may spread over the whole economy, private norms may become public, or conditions for guaranteeing credit may be generally adopted. Accordingly, I will speak of *weak co-ordination* when I wish to characterise a network which has no specifically local rules. And, conversely, I will speak of *strong co-ordination* to refer to a network shaped by both local *and* general rules. By comparison with the former, in the latter the universe of possible translations is relatively restricted, and network behaviour is relatively predictable.

Convergence

I will use the notion of convergence to refer to a combination of alignment and co-ordination. Thus the higher the degree of alignment and co-ordination of a network, the more its actors work together, and the less their very status as actors is in doubt. This does not mean that everyone does the same thing, for networks usually include a range of complementary actors – for instance scientists, technologists, entrepreneurs, salespersons and customers. Rather it points to the way in which the activities of actors fit together despite their heterogeneity. It also points to the way in which each actor in a convergent network is able to identify and mobilise the skills within that network without having to get involved in costly adaptation, translation or decoding. Thus in a convergent network, faced with an angry client, the salesperson immediately knows which engineer to call and how to describe the problem so that the engineer can work on it. Again the salesperson knows how to approach a basic scientist with an appropriately reformulated version of the problem. And the return journey is equally easy: usable recommendations and suggestions flow from the laboratory back to the salesperson.[35]

A totally convergent network would thus be a kind of Tower of Babel. Everyone would speak their own language, but everyone else would understand them. Each would have specific skills, but everyone else would know how to use them. It would be particularly efficient, for it would draw on both the force of the collective and the synthetic capacity of the individual. Each actor would be able to speak for all, and to mobilise all the skills and alliances in the network. And the network as a whole would be capable of concentrating its efforts at a single point. But such a network is a limiting case. Strongly convergent networks only develop after long periods of investment, intense effort, and coordination.[36] There are many others which are only weakly convergent – networks in which actors find both that their status is constantly in question, and that it is difficult (albeit not impossible) to mobilise other parts of the network.

2.2.2 Boundaries

The boundary of a network can be related to its level of convergence. Thus I want to suggest that an element may be

treated as lying outside a network if it weakens the alignment and coordination – that is the convergence – of the latter when moved into the network.[37] This, however, raises a further question: that of measurement. How can one calculate a degree of convergence? How can one give it a numerical value? How can one trace the boundary between inside and outside in practice?

These questions depend on the methods for identifying and describing translations or intermediaries. Since any intermediary can be put into words or texts, in effect they have to do with how to analyse the more or less redundant body of texts which define actors, their identities, and their relationships. In practice the appropriate method of measurement is extremely straightforward (though it is also computationally demanding). It is a simple matter of counting the number of times in which a specific translation is inscribed in the relevant body of texts or textualisations.[38]

Another important element in the establishment of boundaries concerns the compatibility of translation regimes. This is just one of the dimensions of convergence. For instance there are rules and regulations which distinguish the scientific pole and render it partially autonomous from – but at the same time link it in specific ways to – the technical. These include: delay in the publication of results which derive from research funded by industry; the principle of the non-appropriability of published results; and regulations about the patentability of certain organisms produced by genetic engineering.

Finally, it is possible to distinguish between *long* and *short* networks. Long networks include all the poles and intermediaries described above: they extend from basic academic research into 'science-based' industrial sectors. Short networks do not reach so far. Though they may draw on industrial research from time to time, such links are neither stable nor systematic. Short networks are thus organised around the technical and the market poles. The distinction thus concerns the length of the detour that has to be organised in order to create or to develop a market – though both, of course, have to do with the co-ordination of activity.[39]

2.2.3 Irreversibilisation

I will say that the degree of irreversibility of a translation depends on two things:

(a) the extent to which it is subsequently impossible to go back to a point where that translation was only one amongst others; and
(b) the extent to which it shapes and determines subsequent translations.

Defined in this way the irreversibility of a translation is a relational matter – one which can only be measured when it is put to the test. It is also a matter that is never finally resolved: all translations, however apparently secure, are in principle reversible.

How can a translation resist persistent and obstinate assaults by competing translations? How can it see such challenges off? The answer depends on its *durability* and its *robustness*. Again, these are relational properties. As a number of other contributors to this volume show, it is easy to imagine that there is a gradient of material resistance stretching from inscriptions embedded in idle canteen talk, through laws and legal codes, to those that are etched into the concrete of a nuclear plant. Again, it is also easy to imagine that robustness might depend on the extent to which the identities of the actors inscribed in the translation are themselves resistant to erosion. But this is simply to displace the problem. Thus, as we have seen, actors are hybrid groups, constantly threatened by dissension and internal crises. So we must be careful, for no strategy is assured of victory. Overall, however, it could be said that irreversibility increases to the extent that each element, intermediary and translator is inscribed in a *bundle* of interrelationships. In such tightly coupled networks, any attempt to modify one element by redefining it leads to a general process of retranslation. Accordingly, I venture the following proposition: the more numerous and heterogeneous the interrelationships the greater the degree of network co-ordination and the greater the probability of successful resistance to alternative translations.

The durability and robustness of a translation tells us nothing about the extent to which it is likely to shape future translations. To what extent does a robust scientific text which withstands attack and translates a monoclonal antibody lead inevitably to specific research developments and necessary industrial strategies? To what extent do a microcomputer and its software, with their hierarchy of problems and roles for users, actually render the behaviour of the latter predictable? We might say that a translation is irreversible if it is likely to lead to a search for substitutes, or for translations that are intended to prolong its life

or extend its scope. Apprenticeship is a case in point. In this the elements involved in a translation become dependent on one another in a process of mutual adaptation. A skilled machinist cannot work without his machine. The development of a technology depends on engineers with a specialist training. The practice of this trade puts specific objects into circulation. And so on. In this way decisions become more and more dependent on past translations.

The creation of systemic effects and the apprenticeship process are expressions of a more fundamental mechanism: that of the *normalisation* which accompanies and measures the irreversibilisation of translation. As David (1987) notes, this process is found in all kinds of hybrid groups. Normalisation makes a series of links predictable, limits fluctuations, aligns actors and intermediaries, and cuts down the number of translations and the amount of information put into circulation. It operates by standardising interfaces – that is, by standardising and constraining actors and intermediaries. Thus it may range from reference standards to fully compatible interfaces, by way of the definition of maximum and minimum thresholds. And if a relationship between actors is normalised, it may contribute powerfully to the production of systemic effects. This is because its elements are only able to rearrange themselves by making use of well-defined elements which adopt compatible standards. The stricter the compatibility rules (plugs) the more alternative translations are disqualified and the more predictable choices become. A network whose interfaces have all been standardised transforms its actors into docile agents and its intermediaries into stimuli which automatically evoke certain kinds of responses. The rules of co-ordination then become constraining norms which create and control deviance: the past engages the future. In a word, irreversibilisation, taken as the predetermination of translation and as the impossibility of a return to competing translations, is synonymous with normalisation.

With normalisation or standardisation comes the possibility of quantification. Minimally, norms for interfaces require at least one pertinent variable which may take one of two possible values – for instance, good or bad, or pass or fail. But they can extend to fine tuning between multiple continuous variables by way of upper and lower threshold limits.[40] The more precise and quantified these standards, the more a successful translation becomes irreversible. A network which irreversibilises itself is a network that has become heavy with norms. And it is a network that has slipped into a codified metrology and information system.

It is not hard to mathematise the description of such a network, since each element is quantitatively linked, by its specifications, to other elements. For example, it is possible to link the performance of a technical object (the speed, memory and power of a microprocessor), the type of user, and the price that they are willing to pay.[41] With the irreversibilisation of translation and its normalisation we enter a world familiar to economists (Akrich 1989c). In effect it becomes possible to say that it would be expensive to challenge certain translations. This means that in order to establish other links and new translations you would first need to undo all those already in existence by mobilising and enrolling new alliances. Accordingly, I want to say that economics does not begin with the *allocation* of scarce resources, but rather with their *localisation* or 'location' (renting).[42]

2.2.4 Network dynamics and punctualisation

Networks can rarely be cut up into simple and easily quantifiable descriptive frameworks. 'Putting things into numbers', which is the extreme case of 'putting things into words' is only one possible form of description. Whether or not this is possible clearly depends on the state of the network. It makes no sense to try to quantify or to reduce behaviour to variables and functions under all circumstances. On the other hand, it is silly to reject all quantification. The choice of method obeys no epistemological imperative, since it is entirely dictated by the state of the network. If the network standardises itself then one is bound to count and calculate. If it is divergent and reversible, then excessive simplification (and quantification) will betray the state of the network, and it is better just to tell a story! Each actor is relatively unpredictable, because any translation is constantly being undone. Here, then, the only faithful – indeed intelligible – method is that of literary description. Such description multiplies points of view to form a polyphonic narrative distributed over as many voices as there are actors, and recovers all the relevant details.

When a network is strongly convergent and irreversibilised, it can be assimilated to a black box whose behaviour is known and predicted independently of its context. It may then link itself to one or more 'external' actor-networks with which it exchanges intermediaries. Under such circumstances it is *punctualised* in these other networks (Callon 1987). Complete industrial sectors,

scientific disciplines, markets or technologies may be punctualised. Thus for certain purposes the microcomputer industry may be treated as a black box which produces a particular product with well-defined characteristics from specified inputs. It may be analysed by looking at the intermediaries which circulate between it and its neighbours.

The process of punctualisation thus converts an entire network into a single point or node in another network. But this may be repeated indefinitely. Punctualised nodes may be juxtaposed with other punctualised nodes in successive translations that are no different in principle from those discussed above. They may play the role of actors or intermediaries. The principle, then, is general: networks of punctualised networks may themselves be folded up into points. And, as such points are clustered together, so one moves from the micro-social to the macro-social. But convergence and irreversibility may also decrease. Indeed, they may decline catastrophically. Sometimes markets collapse, industrial sectors are dislocated, and scientific specialties tear themselves apart. The macro-social is no different in kind from the micro-social, and we may chart the rise and fall of asymmetry by exploring the fate of these punctualisations.

Conclusion

TENs are not like networks as normally defined. They bear only a distant resemblance to the technical networks (such as telecommunication systems, railways or sewers) studied by economists. These can, in essence, be reduced to long associations of non-humans that, here and there, join a few humans together. Nor are they reducible to the networks of actors described by sociologists, which privilege interactions between humans in the absence of any material support. Techno-economic networks are composite. They mix humans and non-humans, inscriptions of all sorts, and money in all its forms. Their dynamics can only be understood if we study the translation operations which inscribe the mutual definition of the actors in the intermediaries put into circulation and 'read' the relevant inscriptions. Further, the translation operation is itself regulated by more or less local and revisable conventions.

One of the advantages of reasoning in terms of TENs is that it shows that actors' own theories are not universal. The behaviour of actors, and more generally their definition, changes with the

state of the network, which is itself the product of previous actions. The actors and their profiles of action may be characterised for each possible configuration of a network. The less convergent a network, the less it is irreversibilised and the more the actors composing it can be understood in terms of concepts such as strategy, the negotiation and variation of aims, revisable projects, and changing coalitions. Under such circumstances analysis has to start with the actors and chart their fluctuating interactions. The trail is still hot. Information is scarce, contradictory, asymmetrical, and difficult to interpret and use. Uncertainty rules the day.

At the other extreme, in completely convergent and irreversibilised networks, the actors become agents with precise objectives and instruments for establishing hierarchies, calculating costs and measuring returns. The trail is cold, and the story is economised. The states of the world – that is to say, the states of the network – are known for each point at each instant. Information as delivered by the translation inscribed in the intermediaries is perfect (the network is known and predictable) but limited (it does not go beyond the network under consideration). Controversy and disinteressment (to use the language of translation sociology) is highly unlikely.[43] The paradox is that the actors have no choice, since they are 'acted' by the network that holds them in place. Conversely, they are only in a position to act deliberately when there is imperfect and asymmetrical information.[44]

There are many intermediate situations between those two extremes – such as, for example, procedural rationality, or mutual anticipation of game theory (Thévenot 1989). This line of analysis deserves development. If it proves to be well founded then it opens up an entirely new space in the social sciences. It suggests that there is no theory or model of the actor, even in the plural. The actor has a variable geometry and is indissociable from the networks that define it and that it, along with others, helps to define. So it is that history becomes a necessary part of analysis.

Some will say that I have offered a method for *describing* TENs and their asymmetries, but not a theoretical framework for their *explanation*. But the opposition between description and explanation is in large part undermined by the method I have proposed. The more convergent and less reversible a network, the more the descriptions delivered by the intermediaries turn into explanations or predictions. Talk of explanation assumes that network evolution can be described using a small number of variables or concepts. But this requires a very strong assumption about the shape of the

network and the convergence of its translations. In a strongly convergent and irreversibilised network, the actors are perfectly identifiable, and their behaviour is known and predictable. The whole works and evolves in a regular manner as a function of a few simple laws and some well chosen information. In a divergent and reversible network the description has to cover all the details, since every detail counts. This is because each actor endeavours to translate the others and these translations fluctuate without ever stabilising. But anyone who looks for explanations under such circumstances will learn nothing about the mechanisms by which irreversibility is created. Thus those who oppose qualitative or strategic analysis to the search for laws and regularities overlook the way in which networks are not *in* the actors, but are produced *by* them. And they ignore the way in which networks only stabilise at certain places and at certain times.

Notes

1 For work showing this, see Gille 1978; Hughes 1983; Perrin 1988; Katz and Shapiro 1985; Arthur 1989.
2 See Bijker *et al.* 1987; MacKenzie and Wajcman 1985.
3 See Callon and Latour 1981; Freeman 1982; Hughes 1983; Dosi 1984; Kline and Rosenberg 1986; Von Hippel 1988; Callon 1989; Gaffard 1989; Latour 1989.
4 For a characterization of the morphology of TENs, see Callon *et al.* 1990.
5 Obviously many, perhaps most, activities lie between these three poles and are somewhat similar to the compromises between natures described by Boltanski and Thévenot (1987). See also Law's discussion of interdiscursivity (this volume).
6 As I will argue below, the distinction between intermediaries and actors has to be treated with care.
7 This solution for linking sociology and economics differs from the notion of 'embeddedness' revived by Granovetter (1985). The networks he describes are pure associations between human beings.
8 On immutability which is central to action at a distance, see Latour 1989.
9 Like *The Sentimental Education*, a scientific article thus tells a story that takes the reader by the hand and more or less successfully moves him or her: 'But, truth to tell, he did not go very far that morning, since almost on top of the battery, where his student Li Gao had left it the day before, lay a freshly photocopied five page article from the pages of *Zeitschrift fur Physik*. Chu could barely contain his excitement when he reread the title: "Possible High Tc Superconductivity in the Be-La-Cu-O System".' (Hazen 1989: 24).
10 The equivalence between texts and the networks they describe has been meticulously established in the sociology of science. Note that texts include diagrams, laboratory notes, patents, user manuals, catalogues and market surveys (for analysis of patents, see Bowker 1989.) Note also that scientific texts are increasingly important in economic life. Indeed, much economic activity might be described as the conversion of scientific texts into marketable goods!
11 See, for instance, Callon 1981; Latour and Coutouzis 1986; Akrich 1987; Law

1988; Law and Callon 1988; and the contributions by Latour, Woolgar, Webster and Clegg and Wilson in this volume.

12 Equally, there is 'textualization' when objects generate controversies – that is explicit but contradictory network structures. Rival descriptions and accusations are a chaotic mixture of the technical and social: there are just as many contradictory interpretations of a controversial nuclear plant as there are of Baudelaire's *Les Fleurs du Mal*. Technical objects are no more nor less transparent or opaque than literature. And if the nineteenth century was the age of literary criticism, then the twenty-first century will be the age of 'technology criticism' in which we decode and comment on the networks brought together in artefacts.

13 Examples include: the alarm clock which rings, stops with a verbal command, and then starts again and rings until the button is pressed; the chains which prevent the machinist from letting go of the grinder; the dead-man's handle in a locomotive; the TV image which evokes a gesture of solidarity.

14 Semiotically, we might say that there is a return to the emitter from the recipient.

15 A play on words in the original between 'lit' (read) and 'lie' (links). Translator's note.

16 Note that the impure service sector is becoming more important to the economy as a whole.

17 Furthermore, the production of 'material' objects and 'non-material' services may be described in the same terms.

18 This is related to the concept of speech act (Austin 1970) and text act (Coleman 1988). There are many examples of texts which consistently give rise to acts: a signed cheque leads to a transfer from one account to another; a signature at the foot of a notarised document opens the doors of a flat to a new occupant; an instruction typed on the keyboard of a computer starts a printer.

19 It is very rare to find groups of humans with no non-humans. A non-human almost always inserts itself between two bodies. But even an unmediated interaction between two bodies – a pure association of humans – which in reality only occurs in the act of sex (and then often in the presence of condoms which take the little factor/intermediary of the AIDS virus into consideration) can give rise to contradictory imputations. Is the other person simply a vessel for base instincts, with no conscience? Is s/he just a faithful intermediary for his or her genes? Or should one of the partners impute control to the other, and so transform the act into a message of love? Who can answer this difficult question definitively? Who can say where the actor is?

20 The intermediaries discussed here include texts, technical objects, bodies or money. But a general network theory would include all possible intermediaries, ranging from the free association of the analyst's couch, through whispered confession and repentance, to the accusations of an Azande sorcerer. All are intermediaries, all bases for communication, and all organise networks and link their component parts. The old woman who repeats the same list of sins for the nth time to a tired priest contributes to a world peopled with humans and non-humans. There are priests who pardon, Gods, saints and angels, who love, punish or redeem, there is Satan who tempts, and there are neighbours who consent to be the object of good or bad actions.

21 Imagine that the client on the analyst's couch or the penitent in the confessional is no longer thought to be the author of his or her actions. (This is perfectly plausible: psychoanalysis dissolves the person into a series of authors, and exorcism seeks to uncover the agency of Satan.) At this point, agency shifts. The client becomes a medium through which the unconscious expresses itself, a set of symptoms to be decoded. The penitent is robbed of free will, and possessed by the devil.

22 The list of possible intermediaries, combinations, actions, and coincidences is endless.
23 The economics of conventions, which has gone so far to undermine the standard model of economics, stops short when confronted with the actor: 'The authors of this issue agree that the role played by common conventions should not lead to an abandonment of the principles of methodological individualism. Only people can be actors, whether or not these are taken as members of a group or an institution, or in the exercise of a function as representatives of a group' (Dupuy 1989).
24 The fact that human bodies are a class of intermediary does not mean that they are not also actors!
25 This definition leaves a number of thorny questions unresolved, and in particular the distinction between humans and non-humans that has obsessed and continues to obsess the so-called human sciences. A good example – here taking the form of fear of the big bad wolf – can be found in Bourdieu, who writes: 'It suffices to think what would happen if, as in the fable, dogs, foxes and wolves were allowed their own say in the classification of canines' (Bourdieu 1982). As a number of contributors to this volume imply, the habitual distinctions between human and non-human and living and non-living cannot account for the division between actors and intermediaries. Human beings are often 'reduced' to the status of intermediaries, just as non-humans are elevated to the dignity of actors (as when rights are accorded to legal entities and inanimate objects). In principle all configurations are possible, though conventions and legal rules reduce the legitimacy of some imputations.
26 For discussion of translation, see Callon 1976, 1980, 1986, 1989; Callon and Law 1982; Latour 1984; Law 1986.
27 Elsewhere I have described intermediaries as translation operators, or techniques for inter-esting.
28 Machines, human bodies, and texts, in their role as intermediaries, lie at the root of misunderstanding, disagreement *and* (re)conciliation. The telephone creates a common space that integrates as much as Durkheim's religion, or Bourdieu's habitus. And nuclear plants generate conflicts just as intense as those to do with the rights of 'man'.
29 They are not just a simplificatory device.
30 In the market pole, users are aligned if they all seek a standard product (substitutability) or their choices are mechanically linked to those of others (complementarity). The first represents the conditions assumed in neo-classical orthodoxy, and the second is close to those described in the sociology of consumption or the economics of network externalities. But to analyse market structures as defined in economics (the link between supply and demand) we have to add the technical pole to that of the market, and explore their hybrids. This creates additional configurations, some but only some of which are explored in economics.
31 These may be assigned to the company for which they work.
32 The operation, and to some extent the development and interpretation of these rules, depends on groups that Antoine Hennion calls mediators which work to focus attention on certain targets. They may be human (lawyers, notaries, barristers, industrial property offers), texts, or technical objects. For instance concert halls direct the attention of the audience to the singer and scientific journals print the names of the authors in bold. Mediators lie half-way between actors and intermediaries. They do not simply 'pass on' or 'transmit', for they also intervene. On the other hand, imputation does not stop with them. Mediators orchestrate the recognition that separates an actor from the crowd. See Hennion 1989; Hennion and Meadel 1986.
33 The notion of translation regime is somewhat like the 'natures' described by

Boltanski and Thévenot. The three main categories that I have distinguished in part span their six axioms defining a *scale*. But there are at least three essential differences. First, I see no need to furnish an *a priori* list of the various possible regimes. Second, I do not really see why one should seek ideal types – a translation regime may be more or less homogeneous and mutable. And third, since translation is more general than the regimes themselves it is able to explain how different regimes are articulated with one another. I need neither 'devices' nor 'noise' to make sense of the constitution of TENs. I should also add that the concept of the translation regime allows us to distinguish between the three poles. Each is shaped by specific regulations and its own set of intermediaries.

34 The distinction corresponds, generally, to Thévenot's (1985) notion of 'investments of form'.

35 In a convergent network basic scientists are well aware that their problems coincide with a network of expectations and demands from beyond the laboratory walls.

36 Beta's team in material science is the archetype of a TEN. At one end there are users seeking a heat- and pressure-resistant material which can be glued and soldered. At the other there is strategic research on the physics of materials. Between the two there are materials made to order, research efforts on generic technologies such as gluing and soldering, and collaborations, alliances and the rest. In other words, there is a chaonne from basic research to the user passing through a series of carefully articulated intermediary stages (Cohendet *et al.* 1987).

37 As is obvious, this definition is not like that used in classic clustering algorithms. These draw the boundaries of clusters as a function of a threshold in the intensity of relationships between elements.

38 Co-word analysis makes use of this kind of calculation. See Callon *et al.* 1986.

39 See Gaffard 1989.

40 There are many examples of such standardisations which link all the classes of possible groups:

(a) In the case of groups made mostly of humans one may speak, following Riveline (1983) and Oury (1983), of management parameters that define norms and regulate agents and their relationships. For instance: the salesman has to contact more than 20 potential clients each month (minimum threshold); the production engineer should not have more than X rejects (maximum threshold); the size of the pay cheque of a freelance journalist (measure of the relative attachment of the company to the employee) is proportional to the number of lines written.

(b) Examples of norms between non-humans include the sub-system that disconnects itself if the current exceeds a specific value (a fuse); the impossibility of plugging an appliance in unless the plug and the socket match.

(c) Norms organising the relations between scientific texts include reproduction of the conventions of the journal on each page in the article, and the standardisation of references and diagrams.

41 For instance: if you can reach 10MHz then the desktop publishing market opens up and the price will be over $10,000. Such correlations may cover all or part of a TEN and the different elements that make it up.

42 Thus non-linearity and path-dependency are integral to the dynamics of the economy.

43 The economists would say that moral risks and adverse selection are improbable.

44 Dupuy (1989) develops a similar argument. This could be expressed differently: the existence of the neo-classical market assumes the existence of a series of

alignments (notably users/clients) that preprogram the actors and make market studies possible in practice.

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Strategies of power

Power, discretion and strategy

John Law

Abstract

This essay starts with a brief review of some of the main approaches to power, and identifies four: 'power to', 'power over', 'power/storage' and 'power discretion'. It argues that these are all viable, but that they should be linked to a fifth – that of 'power/effects' – with its stress on the continued performance of social relations. But how are such relations stabilised? It is argued, in answer to this question, that social relations are never purely social in character: rather they are heterogeneous, being embodied in a series of corporeal, textual, natural and technical materials. Finally, certain strategies for ordering these relations and their power effects are examined for the case of a formal organisation, and it is argued that such strategies are always, and necessarily, discursively impure.

Introduction[1]

Power is surely one of the most contentious and slippery concepts in sociology. Used, re-used, and endlessly abused, it is unsurprising that there are many who believe that it should be dropped altogether from the vocabulary of the discipline.[2] However, though I sympathise with such self-denying ordinances I remain committed to the idea that a useful notion of power can, indeed, be retrieved from 'the shipwreck of sociology':[3] this, at any rate, is what I seek to do in the present paper.

In the first section I offer a brief and highly selective account of approaches to the notion of power. My object is not primarily to review the literature – I am indeed aware of huge omissions[4] – but rather to distinguish four different themes in the sociology of power – 'power to', 'power over', 'power storage' and 'power discretion'. My argument is that *all* these notions are viable, and that power to and power over may indeed (under certain circumstances) be stored and used in a discretionary and calcula-

tive manner. But it is also that these forms or uses of power should in addition be treated as relational products – that to store power, or to have discretion in its development, is to enjoy (or suffer from) the effects of a stable network of relations.

But what can be said about the character of relations? How are they stabilised? I have, of course, no final answer to such global questions. Nevertheless, in the second section of the essay, in common with a number of other contributors to this volume, I press the view that the network of what we call 'social' relations is never purely social. For, though it is social, it is also and simultaneously technical, architectural, textual, and natural. Indeed, the division between such categories is itself a relational achievement rather than something given in the order of things. Thus to understand the social and, more particularly, to understand what it is that stabilises social relations to generate power effects we have, I suggest, to make sense of the way in which the 'social' interacts with and is constituted by these other materials. And, in particular, we have to explore the way in which discursive ordering strategies (in part) shape, and are embodied in a range of different materials.

Finally, I briefly and empirically explore the character of certain discursive ordering strategies. Using some recent fieldwork in a medium-sized formal organisation I argue that no single discourse or ordering strategy is complete; that, in practice, several are juxtaposed together and instantiated in any particular part of the network of relations. This, I suggest, is true for interactions, for agency, for devices and for organisations. It is also true for materially-heterogeneous systems such as management accountancy, which are crucial to the formation of discretionary power-effects.

On power

Barry Barnes writes that:

> Social power is the added capacity for action that accrues to individuals through their constituting a distribution of knowledge and thereby a society. (Barnes 1988: 57)

His argument is that, by virtue of being competent members of a society, individuals in that society are able to do things that would otherwise not be possible. Barnes does not deny that the added

capacity to act is unequally distributed: such is typically the case. But overall, his point is that, by virtue of our membership of a society, we are *all* able to do things that would not otherwise have been possible. Furthermore, the society is able to do things that its members, individually, could not. In Barnes' view social 'power to' is a non zero-sum consequence of a distribution of knowledge – a non zero-sum social property. It is an added capacity for action.

A primary concern with 'power to' has, at least until recently, been unusual in sociology. Of the theorists widely known to sociologists only Parsons (1967)[5] and perhaps more interestingly Foucault (1982) treat power in this way as an *enabling* phenomenon.

> The term 'power' designates relationships between partners (and by that *I am not thinking of a zero-sum game*, but simply . . . of an ensemble of actions which induce others and follow from one another). (Foucault 1982: 217, my italics)

As is well known, Foucault is suspicious of generality and abstraction. Power needs, or so he argues, to be tied to its instances. Nevertheless, his studies of the ways in which strategies of power operate – through objects including bodies, between partners, and in relationships of communication – to produce (for instance) drilled soldiers and effective military formations reveals a thoroughgoing concern with discipline – that is the generation of new and enabling forms of power, agency and novel abilities (Foucault 1979). One should not be distracted by his nominalism:[6] though it may neither be possible to *measure* 'power to' in Foucault's world, nor treat it as a capacity, discipline is none the less empowering.

These two authors thus share a concern with the productive and enabling character of power or 'power to'.[7] This concern – in effect the relational notion that the whole is in some sense greater than the sum of its parts and operates to empower its parts – sets Barnes and Foucault apart from the many social theorists who are concerned more or less exclusively with 'power over' and who thus adopt, whether expressly or not, a zero-sum view of power. Thus Lukes limits the term to those circumstances in which one actor exercises 'power over' another in a manner contrary to the interests of the latter (Lukes 1974: 27), and complains that Parsons and Arendt:

> . . . focus on the locution 'power to', ignoring 'power over'. Thus power indicates a 'capacity', a 'facility', an 'ability', not a

> relationship. Accordingly, the conflictual aspect of power – the fact that it is exercised *over* people disappears altogether from view. (Lukes 1974: 31)

He correctly observes that Parsons is so concerned with the social system that he fails to see that the latter may be a product of conflict between parties with different interests, and differing degrees of power. Lukes, then, firmly distinguishes between what he calls power (here 'power over') and influence (here 'power to'). It is not, he says, that there is no such thing as influence or 'power to'. It is just that that if we think of power in this way it deflects attention from the relational and contested character of what we normally think of as power relations.

How seriously should we take Lukes' decision to confine power to 'power over'? My response is, not very. First, the fact that Parsons' particular theory of the social order is flawed does not mean that societies do not empower their members. Thus, as Barnes shows, even in a society filled with egoistic and self-interested individuals – the worst possible case from the 'power-to' point of view – there would normally be a workably shared distribution of knowledge. This is because even selfish calculation depends upon the ability to predict the actions of others and so a knowledge of *their* knowledge – something far-removed from normative or even cognitive consensus. And if this part of Lukes' argument carries little weight, then his other reasons for excluding 'power to' are even less persuasive. Thus unlike him, I do not accept that the central definitions of power relate to 'power over' – a claim that tends to reveal the insularity of social theory and its ignorance of both natural scientific thought and dictionary definitions.[8] And again, though I accept that the two concerns draw on different traditions in social theory (Giddens 1979: 89; Clegg and Wilson this volume) I can see no reason for supposing that concern with 'power to' should necessarily *exclude* concern with 'power over'. Rather, like Barnes it seems to me that relations and capacities go together – that the two are indissolubly linked. Indeed, it seems to me that the ways in which they relate together represent a crucial research site in sociology.

This, however, raises a further question – the issue as to whether or not agents are able to store up 'power to' or 'power over'. This, then, is a third aspect of power – the question of 'power storage'. Can one say, as Lukes would like us to, that some *are* more powerful than others? And if so, then what would this mean?

Foucault's nominalism pushes him to the view that power cannot be, or at least is not normally, stored. In his view, power is an achievement, an end product:

> power is exercised rather than possessed; it is not the 'privilege', acquired or preserved, of the dominant class, but the overall effect of its strategic positions. (Foucault 1979: 27)

And Latour (1986b) adopts a similar position. These writers want to reverse a long-standing convention in social theory which assumes the unequal distribution of power and as a consequence tends to ignore or conceal the techniques, strategies or 'microphysics' by which it is created:

> The analysis, made in terms of power, must not assume that the sovereignty of the state, the form of the law, or the over-all unity of a domination are given at the outset; rather, these are only the terminal forms power takes. (Foucault 1981: 92)

Treated as a cautionary methodological injunction this is unexceptionable. It does not do to assume that which one seeks to explain. Latour puts it this way:

> These explanations [posed in terms of power] are as tautological as the 'dormitive virtue of the opium poppy' dear to Molière's physicians. (Latour 1986b: 265)

Neither is it helpful to *assume* that power is a fluid which trickles down from the top. Foucault's insistence that power is ubiquitous, an aspect of all relations, is surely right. Its strategies and methods deserve study wherever they are deployed – that is everywhere. But Foucault's injunction is also restrictive, making it difficult to talk about the distribution of power, something which we do routinely in both social theory and daily life. It makes it difficult, for instance, to refer to the way in which the discipline inscribed on the body of the soldier has different consequences for the soldier himself on the one hand, and the general who commands the army on the other.

The problem is that Foucault presents us with an either–or. He tells us that *either* there is a unity of domination (in which case power has annihilated itself) *or* there are conflicting strategies of power. The parallel between this and Lukes' well-known complaints

about Parsons' assumption of a unified normative order is close. But so, too, are the counter-arguments. Thus one does not need to assume a moral consensus to make observations or limited predictions about the relative success with which strategies are deployed. Indeed, as lay people we work routinely on the assumption that both 'power over' and 'power to' can indeed be stored, even if the methods by which they are stored are never entirely secure and we know our store may spring a leak. If this were not the case we would never open bank accounts, we would never accept promises at face value, and neither would we say (surely with some reason, at least most of the time!) that Prime Ministers have 'more power' than back benchers. We would, of course, also turn ourselves into isolated, a-social organisms.[9]

I am suggesting, then, that 'power to' and 'power over' may be stored and treated by social analysts as a potential or a set of conditions so long as we do not forget that they are also an effect, a product of a set of more or less precariously structured relations. My argument is that so long as we understand that there is no necessity about these relations then there is no reason why we should not treat power as a condition, a capacity, something that may be stored, as well as an effect or a product. Here, then, I part company with Foucault, though not, I think, in practice, with Latour (see this volume).

But the notion of storage, capacity or potential may be taken to imply something further – the idea that potential 'power to' or 'power over' may be held back to be switched on and off and directed by the agent to which it is credited. The directors of a bank may choose to extend credit to third world countries and property companies rather than, for instance, to manufacturing industry in the United Kingdom. And the general and his staff may choose to deploy their forces on the Eastern rather than the Western front – or indeed to hold them in reserve as a threat. This, then, is a fourth picture of power – that of *power/discretion*: it is, as it were, the 'power not to' act.[10]

But how are such switching decisions made? Barnes distinguishes between authorities and powers:

> Social power *is* the capacity for action in a society, and hence is predominantly . . . identifiable as that which is routinely possible therein. Social power is *possessed* by those with discretion in the direction of social action, and hence predominantly by those with discretion in the use of routines. (Barnes 1988: 58)

For Barnes, then, the powerful (whom he calls 'powers' or 'power holders') concentrate not only capacity for action, but discretion in its use. They hold the potential not only to act (which we all have) but the potential to choose between lines of action. Barnes' 'powers' are thus to be distinguished from agents – he calls these 'authorities' – which switch routines on and off without having discretion:

> Authorities may be considered, in the first instance, as mere relays in developed systems of control. They direct routines in response to external signs or instructions. (Barnes 1988: 73)[11]

Barnes' distinction between powers and authorities is important. It fits, for instance, with the kinds of distinctions that we routinely make between representatives and delegates, or between policy-makers and mere functionaries. Having said this, it also poses difficulties – in particular around the issue of what it means to have discretion.[12] Barnes' solution to this is explicitly simplificatory: as I have just noted, he suggests that whereas authorities are 'mere relays' that mobilise routines, as it were 'automatically', as a result of receiving signs, powers mobilise routines as a matter of choice or calculation (Barnes 1988: 64–5). In short, he appears to be saying that if the decision to mobilise is taken 'inside' the agent, then that agent is a power. If it is taken elsewhere, 'outside' the agent, then the latter is an authority. Or, to put it another way, he seems to be suggesting that it is the *source* of compulsion that is all important. If compulsion comes from within (an argument or calculation undertaken quietly and in private on the basis of pre-established criteria?) then the agent is a power. If, however, compulsion comes from outside (a show of physical force, or a new and overwhelming argument?) then the agent is transformed into a mere authority.

This account poses several problems. For instance it is, I suggest, sensible to avoid making an *overall* decision about whether a given agent is, or is not, a power. This is because most agents are typically treated and experienced as powers from some points of view, whereas they look like authorities from others. Accordingly, the distinction (or continuum) is best treated as a *relational* matter. Again, and more importantly, there is the issue of calculation. Should a habit etched into the mind (or the body?) be treated as a calculation? Is there not, in fact, a large territory between explicit calculation on receipt of signs on the one hand,

and 'automatic' response to the input of signs on the other, a territory that may pertain to *both* of these? If this is right, then the distinction between powers and authorities is not a dichotomy. Rather, it is a continuum where some are (relational) powers, others authorities, but most are strung out between the two, borrowing and so *embodying* more or less explicit strategies of calculation.[13]

To summarize: I want to talk of power to and power over, of the way in which these are stored up and deployed. But at the same time I do not want to lose sight of the way in which these are also a set of precarious relational and transformational effects. Accordingly, for me the crucial research question has to do with *how it is that relations are stabilised for long enough to generate the effects and so the conditions of power*. Or, indeed, what 'for long enough' might mean.

On strategy and material form

Clearly power to and power over are relational: their character, their overall distribution, and the extent to which they may be stored and deployed by a given actor is a function of the network of relations – perhaps the 'circuits of power' to use Stewart Clegg's (1989) felicitous phrase – in which that actor is implicated. Indeed, the very character of that actor is defined by its relations – and its (relational) propensities, capacities, or whatever, to operate upon and within those relations.

It is not possible to explore most of the implications of this suggestion here. Instead, I want to touch on the *effects*, the *methods* and the *techniques* that actors use to store and secure discretion in the deployment of power to and power over. Such methods are, to be sure, only ever partial in their success: power effects, as Lukes indicates, are contested – they encounter resistance. But it is precisely this that makes their character, their deployment, the degree of their success such an interesting topic – and, of course, one of such importance in social life.

In the present context I want to press four suggestions.

(1) The first is a definition of agency: I want to say that an actor may be pictured as *a set of relations* which in some measure has the effect of (a) characterising, (b) storing and (at least in some instances) (c) offering a degree of discretion with

respect to 'power to' and 'power over'. In tying agency to power and relations in this way I am seeking to elide the agency/structure dualism. In this way of thinking, agents are both sets of relations, and nodes *in* sets of relations. I am suggesting that it is difficult to imagine the one without the other. I am also suggesting, to be sure, that agents are not co-terminous with people. Other entities may also be agents. Indeed, struggles over agency and its attribution are an important feature of social life.[14]

(2) The second is not definitional, but empirical – it has to do with the way in which agents (or other identifiable elements in structure) as a matter of fact usually are. It is that the relations that constitute agents are usually in some measure *strategically organised* – that is, may in some measure be seen as intentional – though, following Foucault, I assume that the location and character of that intentionality is also an empirical matter.[15] Accordingly, I have no difficulty with the possibility of non-subjective intentionality.[16]

(3) The third is again an empirical rather than a definitional matter. I would expect to find that the strategies that constitute agents are mixed. Or, to put it rather differently, I guess that, on the whole, the best (or only possible) strategies are almost always *discursively impure*, drawing on a series of different organising principles, strategies, logics or practices.

(4) Finally, and this takes us back to assumptions, I wish to suggest that the relations operated on are almost never (purely) social relations; rather they are *heterogeneous*, partly social, partly technical, partly textual, and partly to do with naturally occurring events, objects and processes – and most usually combine elements of all of these; this, of course, means that actors are similarly heterogeneous; and it means that there is almost never any such thing as a purely social actor – though the character of that heterogeneity, indeed its desirability, is also a matter for investigation.[17]

My suggestions thus amount to definition both of agency and of other relatively stable entities: I am saying that an agent is a structured set of relations with a series of (power) effects; I am saying that those relations are embodied in a series of different materials; and I am also saying that, as a matter of empirical fact we are likely to find that they are in some measure strategically (or multi-strategically) organised. Thus, unlike Hindess, my primary

definition of agency refers to relations and their power-relevant effects, rather than to strategies and intentions – but I am also suggesting that normally we may expect to find that agents of all kinds are interdiscursively structured and shaped.

My hypotheses thus suggest that we might try to characterise actors in two dimensions – on the one hand as a series of putative strategies with power storage and power discretion effects, and on the other hand as a series of materials which, in some measure, reflect those strategies – but also a series of other relational effects:

Relations/ Materials	Strategies 1	2	3	4
:				
Bodies :				
Texts :				
Interactional :				
Technical :				
Natural :				
:				

The two are connected in part simply because this is the way things are: on the one hand we live in and are constituted by a set of relations which are organised in a range of different ways and have a series of different effects; and on the other hand, we are embodied in a range of materials. But they are also connected in part because one of the best strategies for stabilising relations and their downstream power effects is (suggestion number three) precisely to embody them into durable materials: relations that tend, everything else being equal, to generate effects that last.

What, then, can be said about strategies, their effects, and their material forms? The answer is that in the abstract it is possible to say surprisingly little. It is tempting to say, for instance, that since some materials are less prone to decay than others, the relations and the effects that they embody are similarly more stable than others. However, this is not quite right. Decades of work on the labour process and in the history of technology suggest that though

the organisation of physical materials may be *directed* by (frequently conflicting) strategic concerns (in the narrower, intentional sense of the term), the *effects* of these arrangements may turn out to be other than what was expected. Devices, production arrangements, or architectures may load the relational network – may predispose it to adopt one shape rather than another, and so to produce certain power-effects rather than others – but that shape may change (or indeed work in a quite different way) under different circumstances.

The uncertainty of the relationship between (intentional) strategy and its power-effects is well-illustrated by a more or less stylised, supposedly empirical, case-study that has achieved wide currency in the history and sociology of technology. This tells of Robert Moses who was the highway engineer for New York for several decades starting in the 1920s. Moses was responsible for many major traffic engineering projects. One of these was the Long Island Parkway – a fine, well-engineered road which, however, is also noteworthy for the fact that the bridges that pass over it are particularly low. But why is this?

> Robert Moses . . . built his overpasses according to specifications that would discourage the presence of buses on his parkways. According to evidence provided by Moses' biographer, Robert A. Caro, the reasons reflect Moses' social class bias and racial prejudice. Automobile-owning whites of 'upper' and 'comfortable middle' classes, as he called them, would be free to use the parkways for recreation and commuting. Poor people and blacks, who normally used public transit, were kept off the roads because the twelve-foot tall buses could not handle the overpasses. One consequence was to limit access of racial minorities and low-income groups to Jones Beach, Moses' widely acclaimed public park. Moses made doubly sure of this result by vetoing a proposed extension of the Long Island Railroad to Jones Beach. (Winner 1986a: 23)

If we take this account at face value we learn that civil engineering is also social engineering.[18] If Moses indeed sought to keep blacks and working class whites in their 'proper' place, and in particular well away from the leisure facilities enjoyed by middle class whites, then setting that intention in concrete was, indeed, a plausible way of stabilising a relationship of inequality.[19] But we also learn that strategically driven material forms may generate

quite unexpected power-effects. Thus we are not here dealing with a zero-sum game – or if we are then the argument needs to be made with some care. And in any case, the power-effects of Moses' actions tended to diverge progressively from his aims.

The point is simply made. If it was to work, the racial segregation sought by Moses depended on a further distinction between the motor car and the bus. And again, of course, on the fact that it cost a great deal to run a car. The strategy of racial discrimination drew on and sought to embed itself in these material forms. But as the relative prices of automobiles declined, so an increasing proportion of the urban poor found that they could afford to run one, and the segregatory effects of the Long Island Parkway also tended to diminish. Indeed, at this point the Parkway moved from being a great divider to a great leveller. 'Anyone' could travel rapidly to Jones Beach. The combination of car and road brought a store of 'power to' new social groups. Or, to put it another way, those social groups managed, with increasing success, to resist Moses' strategy. If they could not, at least in the short run, hope to rebuild his bridges, they could undo – indeed utterly transform – the significance of those bridges by other material means.[20]

The conclusion, then, is that a simple distinction between the material (or the technological) on the one hand, and the social on the other, does not catch the subtlety of the way in which power (or agency) effects are generated. Rather, materials of all kinds (including human materials) are better pictured as offering a *gradient* of resistance. Bruno Latour is surely correct when he suggests (this volume) that the notion of a material infrastructure shaped by and yet shaping social relations will not do.

For all these reasons, the identification of strategies of power/agency, the ways in which these are embodied in materials, and their combined effects seem to me to be essentially empirical questions: we need to look, as Leigh Star elsewhere in this volume suggests, at actors, their actions, and their relations, and try to characterise their strategic mix – the methods and the extent to which they have the effect of securing a store of power to and power over, the extent to which they have the effect of generating discretion, and the extent to which that mix of strategies generates overheads. And we also, of course, need to explore the ways in which these strategies are embodied in, and are simultaneously limited by, relations that are set in relatively durable materials.

On discourse and power

Recently, I spent a substantial period as an ethnographer in a large formal organisation. Though I was free to move wherever I wished, I spent the bulk of my time with the managers, watching how they sought to make and implement decisions. As is obvious, the notion of 'decision' already implies some notion of discretion or calculation – plus, of course, some degree of ability to carry out or enforce that decision (Hindess 1986). Thus I started from the assumption that these managers stood in, and were constituted by, a set of relations which generated certain power effects: in Barnes' sense, they were 'powers' in that they were both able to store capacity and exercise discretion in its use. On the other hand, though I assumed that they were powers, I also assumed that this capacity was relational, precarious, always under threat – that in general it was quite problematic. Accordingly, I sought to explore the strategies, subjective or otherwise, by which it was more or less successfully buttressed and maintained.

Many of the problems facing these putatively powerful actors, together with the analytical questions with which I was concerned, are well illustrated in the following exchange which took place at the main management board, and had to do with a bid for a sum of money from the Librarian to put the archives in order:[21]

Andrew: 'What archives? I didn't know that we had any. Where are they?'
Tim: 'In the basement . . . It is full of them, box after box, that people have put down there when they ran out of space in their offices.'
Andrew: 'What's the problem with just chucking them out?'
Tim: 'The law says we can't destroy them. We have to keep organisational records.'
Terry: 'I've often wondered about that. When my filing cabinets get full, I go through my files and take things out, really as I think best. It's all rather random. Even my secretary doesn't know what I'm throwing away.'
Andrew: 'Who actually *uses* these files? I've never looked at them – I didn't know they were there. What use are they?'
Ben: 'They'll be used by someone who wants to write the history of the organisation. Or by a sociologist!' (laughter)
Andrew: 'But what's the system for keeping them? We don't

keep *everything* do we? What's the system that's used here?'
Tim: 'There's never been *any* system . . . That's the problem. In other places, when a file is full, you keep it and then, after five years, you've got a choice. You can decide to carry on keeping it. Or you can weed it. Or you can destroy it. And there are rules about who can weed it, and who can decide to destroy it. Only [senior management] can take the decision to destroy a file.'
Andrew: 'I didn't know *anything* about this! When I finished my last job I just threw out six filing cabinets of papers. You've no idea what a *relief* it was – it was like a great weight off my shoulders!'
John: 'If you want *my* opinion, we should just put a match to them!'
Terry: 'But it's worrying, if we're supposed to be keeping them.'
Andrew: 'Listen, this is quite a lot of money they are asking for to start organising these files. What's to stop us drawing a line in history at 1990 and deciding on what we *should* be doing from now on, and doing that? Meanwhile we'll say "no" to their [request for money] for sorting out the archives that are already there. Okay?'

This exchange is all about power to – and of course, its corollary, power over. It is about stores. And it is also about discretion. Think first about storage. The managers assume that they have a 'store' of power to act. Most obviously, this takes the form of money which may be deployed in order to achieve certain ends. Money, then, is a putative store of power to act in relation to others because it may be converted into or shape others – for instance into the effort of an archivist, plus a series of materials such as (one presumes) box files and indexes. It is relational, a capacity to act.[22]

We can, of course, explore that character empirically. For instance, we might consider the rates at which money may be converted into other forms of action (performed or stored). Indeed, when we look as these rates of exchange we are involved in an analysis not only of aspects of the networks of power to, but we are also starting to characterise resistance, power over, the character of distribution – the 'invisible work' that is ordered, shaped and deployed in the process of conversion. Thus some rates of exchange are more favourable (in this instance to the managers) than others – and all imply the direction of effort that

would otherwise have gone elsewhere.[23] It may, for instance, be fairly easy to hire an archivist – or relatively cheap – but the same is certainly not true for CAD draftpersons, who are few and far between in the local labour market, and exceedingly expensive.[24]

In this context money is thus a relationally derived store of power to act and (accordingly) power over certain others. It is not, however, the only such store. In the organisation, analogous relational capitals are also tied up in people, in devices, in architectures, in texts, in electronic data, in times, in office equipment and in a range of naturally-occurring objects. It is true, of course, that if the money were taken away then the organisation would rapidly cease to be an organisation: the network in interconnected actions would disintegrate. But – as those firms that have fallen victim to the theft of their microcomputers have found out the hard way – the same is likely to be true for the other components that make up the network. Money is convenient only because of its liquidity – the fact that it is relatively easy to convert it into a wide range of actions, which may themselves also be accumulated, deployed, and further converted.[25] It does not differ in *kind* from these, and there are, of course, many circumstances in which it cannot be used at all.

So much, then, for storage: the argument is that management 'has' a stock of power to and power over – though this is a relational matter, one of the effects of a heterogeneous network of sociotechnical elements. But as is obvious, to the extent that the managers are able to make a decision about whether or not to allocate funds in order to put the archives in order, then they are also 'powers' in Barnes' sense of the term – that is, they are able to exercise discretion. This, of course, is where intention becomes relevant. And it is the moment at which we have to explore the character of strategy in both its subjective and non-subjective aspects.

Go back to the exchange, and consider the matter empirically. One possible reading of the conversation is that several lines of reasoning – several strategies – are in the process of being displayed and explored. Tim, and to a lesser degree Terry, are arguing on administrative or legal grounds: '. . . the law says . . .'. They are saying that the organisation is supposed to treat its files in a way that conforms with due legal process, and they appear to be concerned that this is not actually happening. On the other hand, there is also a pragmatic line of reasoning that is pressed by Andrew, and perhaps by John. In this way of thinking, the issue

is not really a legal and a procedural one. Rather it turns around whether or not the records are of any *practical* significance. '. . . What *use* are they'? What kind of a stock are they? Could they be converted into anything that might actually be of value to the organisation?

As is obvious, not only are the two lines of reasoning quite different, but they are potentially incompatible. But having noted this, let us look at what is going on in a little more detail. It seems to me that:

(1) both forms of reasoning rest on the assumption that the managers as a collectivity have control over a *store* of power: that it is, indeed, possible to do something about putting the archives in order. But this is not the only point of commonality, for

(2) both forms of reasoning also assume that this is a *discretionary* power. They assume, that is, that as a matter of fact management might choose to put the archives in order, or it might choose to do otherwise. They both, that is, accept that they operate in a context of

(3) *discursive pluralism*. Thus the calculations lead in quite different directions in the two different logics or discourses. But, though this is the case, the managers do not assume that one mode of calculation, one strategy, will necessarily triumph over another – that the outcome of the management meeting is predetermined by or constituted in a particular form of calculative rationality. Rather, the prevailing assumption is that the meeting is some kind of *interdiscursive arena* in which different modes of calculation are deployed, as it were politically, to secure the best possible outcome.[26] But what are the politics of this deployment? Various features suggest themselves:

(4) the logics or discourses all operate on the assumption that the web of relations that makes up the organisation is *messy*, impure, and fails to conform in various ways to ideal principles of ordering – here principles to do with administrative due process on the one hand, and pragmatic utility on the other; there are various reasons for this. One has to do with the pluralism already mentioned – the very fact that there *are* several versions of ordering available means that organisational relations are most unlikely to conform to any one ideal conception of order. Another, however, is that:

(5) the spokespersons for the different modes of reasoning all appear to recognise that their stock of power, and indeed the extent to which they have discretion to direct it in one way rather than another, is strictly *limited*. Power to shape the world is restricted. And it is recognised that a decision to try to impose order on the archives would mean, if only implicitly, a decision not to try to impose order on other parts of the organisational network.

(6) The politics of discursive deployment not only reflect pluralism, imperfection and limits of ordering. In addition, as would be expected, they *embody* this pluralistic lack of perfection. Calculation from due process demands that the archives be put in order. Calculation from pragmatism seemingly demands that they should be left in their current state of disorder. The end product is the compromise spelled out by Andrew: that resources will be made available to put them in order henceforth, but henceforth only. To attempt to order them retrospectively would demand 'quite a lot of money', where (the conclusion is) quite a lot would mean too much. The two logics are thus juxtaposed: the arena of their juxtaposition is in part shaped by a workably shared sense of the 'size' of the stock of power; the discretionary possibilities are defined and valued, at least in part, by the two lines of discursive reasoning; and in the absence of a coup de grace from either of the two logics, an interdiscursive compromise is established.[27]

(7) So far, for the purposes of simplicity, I have assumed that discursive moves within the discussion might be expected to have power-effects, in part as a function of the discursive logic in which they were constituted, and in part as a function of the interdiscursive field in which they were deployed. But, as is obvious, this is a simplification, for the standing of its participants moderates these, and has its own series of power effects. To say this is not, however, to undermine the argument that I have been making about interdiscursivity, but rather to add to it. This is because *the participants themselves are constituted interdiscursively*.

Thus, it is not giving much away empirically to note that Andrew is the boss. But what does this mean in practice? The answer, surely, is that like the conversation itself, the identification of Andrew as the boss is a relational, heterogeneous, and interdiscursive effect. Andrew *is* the boss because he is constituted and reproduced as the boss within

several discourses which are themselves being deployed and reproduced in this conversation. Within a logic, a strategy, or a discourse of legal due process, Andrew is pictured and treated as an office-holder in the classic sense explored by Weber.[28] That is, he stands within a network of relationships that generate him (inter alia) as a superior office-holder. And, to the extent to which that network stays in place, it tends to generate a series of hierarchical, bureaucratically-ordered power-effects.

But bureaucracy is not the only form of hierarchy, and I take it that Andrew is also, at least in part, constituted as the boss in the other, more pragmatic, strategic logic explored above. Space precludes an extended discussion of this alternative strategy for shaping hierarchical organisational relations, but as the exchange above suggests, the latter tends to turn around questions of effective performance – let us say of 'enterprise'[29] – both on the part of the organisation as a whole, and among its members. The aim is utility, performance, and a concern to define and optimise the relationship between means and ends. Subordinates perform while superordinates hand out rewards or sanctions. And superordinates, in turn, are responsible for broad, strategic, thinking. They are responsible for laying out the goals and exploring and optimising the deployment of means to achieve those goals. The boss, then, is someone who performs, who judges and who hands out or witholds resources and brickbats.

There is an obvious relationship between the notion of discretion and this version of sociotechnical ordering. But in the present context my argument is that Andrew's role as boss is constituted in *both* a discourse of administration *and* one of enterprise: the power effects that his actions generate thus both draw on and help to reproduce an organisational hierarchy structured in large measure around these two strategies.[30] So Andrew not only mobilises specific lines of argument that draw on these strategies, but his relational location *within* those strategies – the fact that he is, in a double sense, 'the boss' – tends to add tactical weight to his part in the conversation. *In extremis*, it is more difficult for others to question him, or to express dissent: the presumption is that his arguments carry both bureaucratic and entrepreneurial authority[31] and he more than the others is able to formulate conversational endings, and to close topics.[32]

Discourses and materials

Clearly, if one wishes in this way to explore the construction and distribution of powers to act, or indeed to exercise discretion, then an important part of the analytic trick is to avoid reductionism. To assume that the boss 'has' power is only helpful if we also ask how that power is constituted relationally. Thus I have been arguing that the conversation and its participants are located in, instantiate, and are constituted by at least two discursive forms of strategy – one deriving from administration and the other from enterprise. But we also need to attend to the *material* forms of this instantiation. In the above I have considered the two materials – people and talk – with which sociologists are most familiar. But there are other materials that are equally important. Texts, machines, architectures – these are three that are also important in the generation of management power-effects.

Consider, for instance, the question of discretion. I have sought to argue that in some measure discretion grows out of interdiscursivity. If (as I would normally expect to be the case) several modes of reasoning or calculation are current, and agents are also constituted multidiscursively, then we may argue – as with the managers above – that they have a 'choice'. For whatever local reasons (and I am not sure that we are able to say much about these except empirically), they deploy the modes of reasoning to arrive at an action that combines elements of them all.

But how are calculations possible in the first place? A quick answer would be that there is need, on the one hand, for a set of calculative procedures; and on the other hand, for material on which those procedures may get to work. Sometimes both procedures and materials are exclusively inscribed in human bodies (or 'minds'). But this is unusual. More often, memories – so to speak the 'raw material' for calculation – are also inscribed in a heterogeneous arrangement of materials that include interactions, texts and other symbolic forms, and in topographical arrangements. And the same is also true for the act of calculating – though to separate out the materials of calculation from the process of calculation itself is somewhat misleading, since calculation in part constitutes its own 'raw' material.

There is a large literature on the importance of literacy, printing, and visual depiction for the (re)organisation of social life.[33] Essentially the argument is that texts, lists, and the like, represent

forms of time-space travel – that they bring bits and pieces together in one place by selecting from, simplifying and so representing what was previously both heterogeneous and distributed around different locations and times. But the argument is also that by concentrating, homogenising and simplifying, such representations generate new objects and relations. And these new objects may (though they need not) *generate discretionary effects* if they offer methods for generating and weighing up the relative merits of different options.

In the organisation which I studied, there are many such discretionary calculative technologies. For instance, there are machines and instruments controlled by operators who sit and watch dials, oscilloscopes and computer-generated displays which represent (or constitute) putatively important events that would otherwise be invisible. The calculations of the operators, together with their power to intervene is entirely dependent on these systems of representation. If, for any reason, the latter fail it is no longer possible to act at all. But the point is a general one. Thus the power-discretion of management is, for instance, in part a function of the elaboration of an accounting system. Consider the following:

> *John*: 'So we are moving towards our own accounting system where [different forms of income] will be blocked together. Staff costs *and* materials. We've never done that before.'
>
> . . .
>
> *Ewan*: 'At present [we get] random lists of numbers. In future, all these will appear in a block, manpower, overheads, not just [materials].'
> *John*: 'Donald's system could do this, could it?'
> *Ewan*: 'Yes, but we have to tell Donald what to do. *I* am doing it, because we need to get cost centres related to the [projects].'
> *John*: 'Yes. We have to do it. It is difficult to use Donald's print-out. You have to spend a morning ploughing through it. Anything that makes it easier to do is a good move.'

This exchange illustrates the intimate relationship between calculation on the one hand and the materials of calculation on the other. The managers are seeking materials of calculation that will generate a discretionary effect – one that will make it possible to monitor and intervene in the financial affairs of the organisation. Without such materials they might, perhaps, intervene, but they

would be doing so blind. Accordingly, I am saying that their power to intervene and in particular the capacity to exercise discretion when they do this are intimately tied up with the textual options opened up by accounting system. And (though I cannot illustrate this here) I would also want to make the argument that textuality is itself a product of a heterogeneous, multidiscursive and somewhat precarious network of materials including people, texts, computer hardware and computer software: under certain circumstances, as the managers know well from hard experience, *all* the components of this system offer resistance. Accordingly, it is a constant struggle, in the first place to keep the system running, and then to try to sharpen its discretionary effects in the way sought by the managers in the above exchange.

Conclusion

Power is a term central to and endlessly used, not to say abused, in sociology. There are those who believe that the term is so slippery that it would be best abandoned. But though I have some sympathy with this view, it is not one that I share. It is possible, as I have tried to show, to find several distinct and useful ways in which the term may be deployed. Furthermore, I hope that I have shown that these are not necessarily incompatible. Properly used, the term may reflect the classic sociological concern with inequality and exploitation, while also indexing the enabling character of social organisation. In addition, I hope that I have shown that not only power over, but also power to, can be treated *relationally*. Like agency, power in all its forms, including power storage and power discretion, is about the way in which objects are constituted and linked together. Power effects and power techniques (including discursive strategies) generate such relations, and so the very possibility of storage and discretion. Accordingly, there is no incompatibility between a concern with power as something stored up, and a concern with power as a set of methods. The two should be treated together.

If power is central to sociology, then a concern with technology and other material arrangements seems to find only a precarious niche at the margins, in the form of another specialist (indeed rather small) 'sociology of'. The other main part of my argument has been to suggest that this marginalisation is a mistake. I take this view because I believe it is impossible to understand power

(whether power-storage and discretion on the one hand, or power effects and techniques on the other) without exploring and coming to terms with the heterogeneity of what we like to call 'the social'. But the terminology is part of the problem. To talk of the way in which we live by speaking of the social is misleading. As agents, as stores of power, as discretionary centres of calculation, we are only possible in the first place because we are constituted in and caught up by a heterogeneous sociotechnical network. Indeed, I cannot imagine what a purely social relationship would look like: arguably, there is no such thing. This, then, is why I take technology – and, to be sure, other material arrangements including bodies and texts – to be so very important if we have a concern with power. If we want to make sense of the glue that sometimes, and precariously, holds both us and our societies together then we can no longer afford to ignore the material heterogeneity of arrangements such as accounting systems.

Notes

1 I would like to thank Vincanne Adams, Geof Bowker, Michel Callon, Katie Deverell, Ronnie Frankenberg, Gordon Fyfe, Bruno Latour, Harry Law, Sharon Macdonald, Alan Prout, Mike Savage and Leigh Star for the discussion, encouragement and collaboration that contributed to this paper. I am also most grateful to the ESRC for the substantial funding that made it possible to undertake the ethnographic organisational study reported below, as I am to the members of the organisation in question for granting me access to their management meetings.

2 See Latour (1986b) and Garfinkel (1967).

3 Bruno Latour's term.

4 Both sociological and, more importantly, feminist. See, for instance, Lee (1990).

5 Space precludes a discussion of Parsons which is, in any case, well handled by Barnes (1988).

6 One needs to be nominalistic, no doubt: power is not an institution and not a structure; neither is it a certain strength we are endowed with: it is the name that one attributes to a complex strategical situation in a society. (Foucault 1981: 93)

7 Another author who comes close to the view that power is productive is Giddens (1979: 91–2, 1984: 31–2). In the end, however, he chooses to say that power is instantiated in action, and does not amount to a resource in its own right. 'Resources are the media whereby transformative capacity is employed as power . . .' (1979: 92).

8 I am grateful to Ronnie Frankenberg for pointing out that 'power to' is actually the first definition offered for power in the Oxford English Dictionary.

9 Callon and Latour (1981: 283), and Latour in the present volume, also argue that society would be impossible without the formation of associations that last longer than the process that led to their creation (see also Clegg 1989). We should not, of course, *assume* that the formation of relatively durable

associations is either straightforward or without interest. This is the point of their argument. We need to look at methods and materials. But, unlike them, I am prepared to assume that the methods may hold in place long enough to talk of a 'stock' of power.

10 I am most grateful to Ronnie Frankenberg for drawing the connection between 'power discretion' and 'power not to' to my attention.

11 Barnes writes:

> Accepted wisdom . . . may be fairly summarized thus: either authority is power plus institutionalization, or it is power plus legitimacy.
>
> By contrast, I have defined authority as power *minus* – power minus recognized independent discretion. (Barnes 1988: 74)

This point is developed at some length in Barnes (1986).

12 Or, indeed, *lack* of discretion. As Barnes, drawing on Wittgenstein, indicates, authorities that are given a set of rules to follow nonetheless have to interpret those rules in practice.

13 I am deeply grateful to Geof Bowker whose point this is.

14 This position is close to that of Hindess (1986). However, I do not finally want to impose my own distinction between agents and others. In effect, I am arguing that any set of relations that is stable enough to generate power-effects of some duration is, by virtue of that fact, an agent. Here, then, though using a different vocabulary, I am close to both Latour (1988) and Clegg (1989).

15 Knights and Morgan (1990) suggest (surely correctly) that the notion of 'strategy' is specific to particular discursive formations, and has a series of hierarchical power-effects (which they tie, in particular, to professional interventions in military, and later management, practice). They go on to argue that if the term is applied elsewhere (as has sometimes, uncritically, been the case) then it is liable to import similar power effects in those domains. I sympathise with this caution, and in particular their argument that the notion of a division between means and ends is discursively constituted. Nonetheless, in the present context I am not ready to give up the notion of strategy – if only because it is indeed directly discursively applicable to contemporary organisations.

16 Foucault writes:

> Power relations are both intentional and nonsubjective. If in fact they are intelligible, this is not because they are the effect of another instance that 'explains' them, but rather because they are imbued, through and through, with calculation: there is not power that is not exercised without a series of aims and objects. But this does not mean that it results from the choice or the decisions of an individual subject . . . the logic is perfectly clear, the aims decipherable, and yet it is also the case that no one is there to have invented them, and few who can be said to have formulated them. (Foucault 1981: 95)

I follow Foucault in his suggestion that intentionality may be non-subjective. But I would want to argue, as I have suggested above, that power effects are potentially detachable from intentions, subjective or otherwise. For this reason I have distinguished between a definition – that power and agency *are* a series of effects – and the empirical proposition and that these are likely to be strategic and intentional. I would also want to add that intentionality (and so strategy) is an imputation that is highly contestable. See Woolgar (this volume) on the negotiation of the boundary between machines and people.

17 This point is explored by Leigh Star elsewhere in this volume. See also Donna Haraway's (1990) understanding of the creative character of the cyborg.

18 This is a point developed by Michel Callon (1980, 1986), Bruno Latour (1983, 1987), John Law (1987, 1992) and Donald MacKenzie (1990); also, in a more historical idiom, by Thomas Hughes (1983).

19 This illustrates the way in which the notion of a social structure which is not also a technical structure is almost unthinkable. The problem is that in its move from the technological determinism of certain forms of Marxism, in much of sociology the technical is treated as an uninteresting epiphenomenon, a simple expression of social relations. Indeed, it is seen as so uninteresting that it tends to slide out of view altogether (see the introduction to this volume). So it is that an author as astute as Anthony Giddens is able to talk about social structure in terms of its instantiated practices, and the memory traces of individual agents (Giddens 1984: 17) and overlook the way in which it is also instantiated in endless other material arrangements. Of course he is right that society would disappear if our memories were wiped clean (though the notion that memory resides simply somewhere between the ears is obviously unsatisfactory). But, as Callon and Latour (1981) elegantly argued a decade ago, so too would society disappear if all its extra-somatic components were whisked away and we found that we had to build a social order with our bodies alone. See also Latour (1986a) and Clegg (1989) for an extended commentary on the humanist character of Giddens' theory of structuration.

20 One tradition – that of the social construction of technology – would argue that technologies are multi-interpretable, with different interpretive significance for different groups. (For a representative position-piece see Pinch and Bijker 1987). I think that this is right, but in the present example it somewhat misses the point. Thus in the short run it was not what people *thought* about the bridges that mattered. Rather it was how they were influenced to act by them, whether directly or (the crucial point) indirectly.

21 The conversations reported in this paper are reconstructed from my notes, rather than from tape-recordings. Accordingly, though the general sense of exchanges has, I trust, been captured, they should not be treated as transcripts.

22 Note that to the extent it is a sustained capacity to act – that is, the managers, the management meeting, or the organisation as a whole achieve agency – it is also self-feeding: this is something explored in different ways by Marx (1946: 123ff) in his analysis of exchange value and the capitalist firm, by Bruno Latour and Steve Woolgar (1979) in their 'credibility model' of scientific production, and by Pierre Bourdieu (1980) in his analysis of symbolic goods.

23 On invisible work see Leigh Star (1991), and in this volume.

24 I would like to repeat the caution I explored earlier: we are not necessarily dealing with a zero-sum game. The fact that an archivist (as it were) puts up little resistance does not mean that the outcome is *necessarily* disempowering for that person. But this may well be the case. This is an empirical and attributional matter.

25 Its relatively liquidity can also be a disadvantage, precisely because it may leak away. Consider the many ways used by households to reduce the liquidity of their income (Lave 1986). And under certain circumstances similar strategies are used by formal organisations: one of the classic methods of seeing large-scale technological projects through to completion is to invest heavily in forms that will only be amortised if further investment is forthcoming.

26 Needless to say, what counts as the best possible outcome is a matter for (interdiscursive) dispute.

27 What would have affected the outcome of the discussion? One can imagine various possibilities: if Tim had said 'The police have said they will prosecute us if we do not sort out the archives', or if resources had been a great deal more abundant, then perhaps the archives would have been ordered retrospectively. Or, contrariwise, if it had been announced that the organisation was bankrupt, or indeed, that vital (say) health and safety work would have been prevented if money was spent on the archives then perhaps none would have been so spent. The latter gives some hint of the interdiscursive possibilities, since it would similarly have grounded itself in an argument from due process.

28 Weber wrote that legitimacy rests:

> on a belief in the legality of enacted rules and the right of those elevated to authority under such rules to issue commands. (Weber 1978: 215)

29 I use this term to refer to the idea that organisations are loci which obtain resources as a function of their performance, either in a market, or in some administered substitute for a market. And I also assume that similar concerns about performance drive internal organisational arrangements, and the formation of organisational agents. In particular, subordinates are granted resources, and are considered to be responsible for their performance which is, typically, monitored not for propriety (this is bureaucracy) but for efficiency or effectiveness. This conception of enterprise, which will be developed at greater length elsewhere, is broadly consistent with that of Russell Keat (1991), and the logic is similar to that of the low-grid low-group 'big man' societies described by Mary Douglas (1973).

30 Other strategies of hierarchy – and resistance to hierarchy – were also to be found in, and helped to constitute, the organisation. For simplicity, I confine my discussion to administration and enterprise in the present paper. Note that though there is no reason in principle why the two have to map onto one another, in practice, at least in the parts of the organisation that I studied, they tended to fit (or better to be fitted together) reasonably well.

31 Once again, I must enter the usual caution. It *could* be otherwise: indeed, it could be argued that Tim's arguments from due process somewhat shift Andrew's conclusions: it seems he knew nothing of this aspect of due process at the outset.

32 Truth or persuasion (the grounds of argument) shade off, here, into power, authority or force. The distinction (and the link between the two) is instantiated and reproduced in interaction. But, as I argued in the introduction, to note that this is the case is not to embrace moral or ethical relativism.

33 See, inter alia, Goody (1977), Eisenstein (1980), Ong (1982), McGaw (1985), Latour (1986a), Law (1986b) and Beniger (1986).

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Advanced manufacturing technologies: work organisation and social relations crystallised

Juliet Webster

Abstract

This paper considers the ways in which technologies are underpinned by patterns of work organisation and power relations in manufacturing industry. It takes as its starting point the emergence of manufacturing technologies during the Industrial Revolution, showing how these were imbued with the methods of factory organisation which were then gaining currency – the visions of industrial entrepreneurs, engineers and political economists. Technologies have continued to be associated with particular patterns of work organisation, both actual and envisioned. The major concern of the paper is with a contemporary manufacturing technology, Computer-Aided Production Management (CAPM). It shows how CAPM has developed according to the dominant templates of manufacturing organisation – first American and now Japanese.

It charts the growth of the 'enterprise culture' in the West – a discourse which stresses flexibility and prescribes production methods, such as just-in-time, which mimic those of the Japanese. It looks at the promotion of CAPM as a technology which can assist in this process and at the incorporation within CAPM of facilities for doing so. Finally, the paper shows that these manufacturing agendas are not easily implemented. CAPM user organisations find the technology inappropriate to their existing patterns of work, and so modify systems to fit these. CAPM technology therefore embodies patterns of work organisation at several levels. It incorporates both the dreams and programmes for work organisation which are promoted by the industrially powerful at any one time, and the actual practices of work organisation which pertain in the sphere of use.

Introduction

The 1980s have been a key decade for innovation in manufacturing. In Britain and Europe, as in the United States, there have been

dramatic changes in approach to industrial organisation, changes inspired largely by the rise to dominance of Japanese industry and its economy. British manufacturing industry, impelled by the Japanese example and by the Thatcherite political agenda, is embracing a new philosophy and language of production which, it is hoped, will help it reassert its lost competitive position: this is the language of the 'enterprise culture'. The 1990s promises the continuation of this agenda.

This new manufacturing discourse has also been expressed through technological innovation. Visions of dynamic production systems have coincided with a shift in emphasis from the simple, discrete, stand-alone technologies of the 1970s (machine tools, for example), towards more complex integrated systems which unite a number of separate technological components (CAD/CAM, flexible manufacturing systems and computer integrated manufacturing systems, for example). This paper examines the coincidence and interrelationship between the two.

Throughout the industrial era, particular ideas and programmes for how work should be organised have always been associated with certain industrial technologies; moreover, these programmes have altered through the different generations of technology. This paper explores the relationship of these visions to technological development – the ways in which the design and implementation of technologies incorporate the objectives and requirements of dominant industrial players for organising work. It suggests that we therefore ought to conceptualise technologies as more than hardware and software elements: the *organisation* of these elements into a structure which reflects and serves the needs of those implementing it is a crucial component of technology.

In the 1980s, the concerted programme for the resurgence of a more 'streamlined', responsive and dynamic manufacturing sector has shaped the development of modern computerised production technologies. The paper investigates one instance of such a technology, computer-aided production management (CAPM). It examines the incorporation of these ideas for the management of production into the design of CAPM, ideas which marked a significant change from previously favoured systems of work organisation. But it also shows how the implementation of this programme for work organisation in the guise of CAPM has by no means been an uncomplicated process of imposing the wishes and needs of dominant industrial groups upon less powerful organisations and individuals, for the latter have their own agendas and practices

for organising work which cut across the programmes inherent in the technology. Technology, therefore, encapsulates a complex range of social relations which are constantly in conflict with one another.

Social relations, technology and work organisation

From the beginnings of the industrial period, social and political commentators have been exploring the relationship between industrial technologies on the one hand and patterns of industrial organisation and broader social relations on the other. Throughout the years, many of these accounts have been devoted to promoting a strong vision of what could be achieved at industrial and social levels through the application of new techniques and devices. A central tenet of the early writings on industrialisation and the mechanisation of industry, for example, was the capacity of technologies to effect wholesale improvements in the organisation of production, to heighten industrial efficiency and to bring about overall advances in social conditions (e.g. Babbage 1835; Ure 1835; Nasmyth 1867–8). The vision of these apologists for technological advance was one in which the relative freedom of workers to organise production according to their own devices would be curtailed by applying an increasingly tight division of labour to industrial processes, and adding to this the regulation of mechanical systems. In this, these writers were articulating the aspirations of entrepreneurs to wrest control over the details of the production process in order to raise productivity:

> how vastly productive human industry [will] become, when no longer proportioned in its results to muscular effort, which is by its nature fitful and capricious, but when made to consist in the task of guiding the work of mechanical fingers and arms, regularly impelled with great velocity by some indefatiguable physical power. (Ure, *The Philosophy of Manufactures*, quoted in Berg 1979: 66)

The more critical accounts of writers such as Karl Marx, J. A. Hobson and Schulze-Gaevernitz were concerned to stress the various adverse aspects of mechanisation from the point of view of labour rather than to applaud the progress which it enabled capital to make in its organisation of work. Technologies were, for these

writers, weapons in the armoury of capitalist management against labour. Their function was as an aid to management in fragmenting and intensifying work, eliminating worker intervention in processes and thus wresting control over these from labour. Just as Ure had applauded the role of machinery in regulating the rhythms of industrial activity and thus breaking the power of 'self-willed' and 'intractable' labour, so Marx acknowledged from a critical standpoint that this was precisely its function – to place command of industrial processes firmly in the hands of management. However, he and his fellow-critics were quite clear as to the deleterious effect of these instruments of work intensification upon labour. The routinised, deskilled, stressful and increasingly hazardous nature of working with new machinery was identified in these 'pessimistic' accounts:

> Machinery, like everything else, can only teach what it practises. Order, exactitude, persistence, conformity to unbending law – these are the lessons which must emanate from the machine . . . Therefore, if you confine a man to spending his energy in trying to conform exactly to the movements of a machine, you teach him to abrogate the very principles of life. Variety is the essence of life, and machinery is the enemy of variety. (Hobson 1919: 351)

Both optimistic and critical accounts provide us with a broad brush analysis of incipient technological change, industrial reorganisation, and the whole raft of social relations underpinning these. They show how the development of technologies reflects and addresses the requirements of the owners of industry. Major industrial innovations often take place actually in the arena of application, and we are shown how they are the outcomes of the efforts of industrial proprietors to solve production problems, reorganise work and heighten manufacturing efficiency. Technologies have represented attempts by industrialists to develop newer and 'better' ways of organising work, and thus have become imbued with social relations of industrial ownership and control which could hardly be more stark. Indeed, certain innovations which were developed by prominent industrialists, such as Arkwright and Jacquart, have become almost synonymous with them.[1]

The relationship between technologies and forms of work organisation (and hence the social relations embedded in them) is also explored at a more detailed level in these writings. The

precise ways in which new technologies incorporate systems of work organisation are revealed. For example, in Ure's proclamation of the factory system as a 'vast automaton, composed of various mechanical and intellectual organs, acting in uninterrupted concert for the production of a common object, all of them being subordinated to a self-regulating moving force' (1835: 13–14), he was drawing attention not simply to the technical components of the factory system, but to the *arrangement* of these components in an organisational system.[2] Similarly, Marx's account of the mechanisation process in *Capital Volume 1* rests critically upon his exposition of the workings of the technical division of labour in the shop, an organisational as well as a strictly technical innovation which was designed to fragment, deskill and intensify work and so heighten capital's domination over labour. In fact, it is this process of work rationalisation which Marx presents as the decisive development marking the move to modern large-scale industry from small-scale handicraft production; the mechanisation process is actually dependent upon and supplementary to it (Webster 1986).

The development of technologies can therefore be traced, not only to the interests of industrial entrepreneurs in general terms, but to the specific ways in which they attempted to solve particular problems of production through the adoption of identifiable systems of work organisation and technical adjuncts. These systems evolved out of the prevailing ideologies and visions about the best ways in which to organise manufacturing activity which were being promoted by contemporary industrialists, engineers and political economists.

More recent discussions of technological development have pointed to this crucial relationship between the social organisation of the workplace and the use of implements or hardware. One of the most notable innovations of this century, the assembly line, is construed by Drucker not as a technology at all, but as an 'arrangement of physical forces', a 'principle of social order' (Drucker quoted in Thompson 1983: 5). Gartman's study of Ford examines the principles of work organisation which underpin the whole character of the assembly line. He too points out that in fact, originally, it was an entirely non-mechanical technology, in which operations were performed upon the cars and parts and then the workers themselves pushed them along from one work station to the next (Gartman 1979). British industrial sociologists of the 1950s and 1960s also explored the ways in which particular technologies were found to be associated with particular patterns

of work organisation (e.g. Blauner 1964; Burns and Stalker 1961; Woodward 1958). Blauner, for example, identified four different 'types' of technology characterising modern production systems, craft production, unit production, mass production and process production, which were similar to Woodward's three broad types of system. These technologies crucially affected work organisation, organisational structures and patterns of skill distribution. However, unlike Woodward, for whom technology and work organisation were inseparable, Blauner portrayed technology as essentially autonomous, both from patterns of work organisation, which it determined, and from the higher level social relations of production which might affect its use.

The labour process debates of the 1970s and 1980s pursued this question of a close inter-relationship between technologies and patterns of work organisation. Braverman (1974) noted the role of technology in degrading and deskilling the labour process, thus heightening the real subordination of labour. He did not regard this solely as an exigency of new hardware devices, however, but related it crucially to capital's pervasive use of scientific management methods of work design. In the labour process debate which ensued, this relationship between technology and capitalist work design was further articulated (for example, in Brighton Labour Process Group 1977; Edwards 1979; Levidow and Young 1981): the requirement of capital to achieve suzerainty over the labour process was seen as critical to the development of innovations (Marglin 1976). These accounts differed, however, in their views of how much technologies are actually *imbued* with capitalist social relations, an issue which was directly confronted by Young (1977). He took the view that 'science *is* social relations', initiating a new area of debate within the labour process tradition. Labour process accounts also differed in their views of which particular methods or principles of work organisation would be brought into use by individual capitalists in their search for control over the labour process. Braverman took Taylorism to be the fundamental principle of monopoly capitalist work design, while subsequent writers in the labour process tradition argued for the recognition of more complex models.[3] However, much of the literature on the application of information technologies has faithfully followed Braverman, and has seen scientific management as the underlying vision behind the development and implementation of these technologies (e.g. CSE Microelectronics Group 1980; Barker and Downing 1980; Huws 1982).

The weakness of some of this literature, particularly that dealing with the implementation of new information technologies, is that the relationship between technologies and work organisation is often characterised in a somewhat deterministic fashion, as one in which the technologies themselves (rather than, say, the strategies of management or the conditions of production within particular plants) would have dramatic consequences for the organisation of work and the quality of working life:

> the current wave of technological innovation has three distinct consequences: a) it destroys jobs, b) it deskills and degrades the jobs that remain, and c) it is designed to increase managerial control. (Cooley 1983: 4)

So, from the industrial revolution to the monopoly capitalist era, technologies have been associated with certain patterns of work organisation. The various writers clearly differ, however, in the particular models which they privilege in their respective accounts of industrial activity, and in the extent to which they relate them directly to the strategies and interests of corporate owners and management. Moreover, though many of these accounts explicitly articulate only the ways in which technologies create and extend particular patterns of work organisation, underpinning their analyses is an implicit recognition that technologies do incorporate and make use of these patterns. There is an unacknowledged suggestion that pressure for particular working practices shapes the application and use of technologies, just as much as the use of technologies prompts the implementation of appropriate systems of work organisation and task design. Even in the technologically determinist models, there is an implication that *technological change is driven by visions of how work should be organised*. For example, labour process accounts, despite not really 'opening the black box' of technologies but concentrating instead upon their effects upon workers, suggest that their antecedents lie in capitalist managements' requirements for greater control over labour processes – in whatever form this control takes. Technologies embody these work organisation objectives. Clawson's (1980) study therefore provides an important corrective to the technological determinism in the labour process perspective: he emphasises the point that organisational change is logically and historically prior to, and influential upon, technological change. The latter has to be seen in the context of human agendas for conducting manufacturing

activity. If technological development has a logic, it is not an autonomous logic, but one which arises from attempts by corporate managements to organise production to meet their particular objectives:

> It is not the technological change which has forced industry to adopt a certain form of organization; not that machinery, independently developed following an inner technological imperative, has required organizational innovations in order to be successfully used; rather, capitalism has selected and developed a certain form of organization which fits its purposes. The new capitalist organization of work 'creates the material conditions for the existence of machinery'. Technological development takes place within the framework of a capitalist organization of production. (Clawson 1980: 60)

It is the purpose of this paper to show how contemporary systems of manufacturing organisation are not only responsible for creating the framework within which computerised production systems are developed, but also are actually incorporated within these new technologies. Technologies, according to this perspective, are constituted out of structures of work organisation as well as hardware and software. Hill's conception of technology is therefore a particularly useful one which draws together these organisational and technical elements:

> In the first place, technology embraces all forms of productive technique, including hand work which may not involve the use of mechanical implements. Secondly, it embraces the physical organisation of production, the way in which the hardware of production has been laid out in a factory or other place of work. The term therefore implies the division of labour or work organisation which is built into, or required for efficient operation by the productive technique. Thirdly, machinery and the organisation of production are human products, in the sense that they have been consciously designed, which should be an obvious point but which is unfortunately obscured when people refer to technology as if it were something with a separate existence, with its own laws of development and its own logic in use on the shopfloor. (Hill 1981: 86)[4]

Technological determinism in its various forms has been the subject of a sustained critique (Noble 1979; Wilkinson 1983;

Winner 1985; Edge 1988), and approaches which emphasise the impacts of technologies without consideration of the contexts within which they arise are seen to be unhelpful, ahistorical and one-sided (Webster 1990). Attention has now turned to the 'social shaping' or 'social construction' of technologies (Mackenzie and Wajcman 1985; Bijker, Hughes and Pinch 1987), to 'opening the black box' of technologies and examining the social, economic and political components contained within. The ways in which structures of work organisation influence the development of technologies are now recognised as constituting an important area of investigation. Moreover, technologies incorporate knowledge as well as patterns of work organisation (Layton 1974; Dosi 1982): expertise is required in order to build systems in the first place, and know-how is needed to get them to work and to keep them working in particular environments. This theoretical proposition that technologies both embody and are embedded in social structures and relations has, however, to be demonstrated empirically, by disentangling the stages of this process through analysis and description of particular technological changes.

In the case of production technologies, analysis of this shaping process reveals how their development is influenced by particular visions of what can be achieved in the workplace, and even in society generally. Initially, the technology has a certain trajectory based on a programme for its advance which is not simply concerned with the functioning of equipment, but embodies expectations of what it will accomplish in terms of the organisation of work. We can understand this trajectory by tracking the ways in which such technologies are designed and promoted. However, when the technology comes to be applied, it is subject to modification in order to make it work in useful ways, so the initial trajectory may become fragmented, diverted or reversed (Fleck, Webster and Williams 1990). The visions underpinning technologies thus become modified by other work organisation templates and objectives at the point of implementation,[5] such that both the work organisation visions and the technology itself are altered at this point. Thus, the objectives and programmes of large corporations, technology suppliers and industrial policy makers – groups with power at the macro-level of industrial practice – are modified by the needs and requirements of local users – those who influence the organisation of work at the micro-level – applying systems to work in the context of their own designated patterns of production and work organisation. The non-linear character of technological

change, and the influence of different interest groups at different times, can thus be demonstrated. The remainder of this paper analyses this evolution process and examines the driving forces, industrial influences, and power structures shaping the development of one particular production technology – Computer Aided Production Management (CAPM).

Computer-aided production management – design and development

Computer-Aided Production Management systems are software systems which automate the planning and control of production resources. They range from simple programs designed to run on a microcomputer and to handle department-based functions such as stock control, to complex systems designed for mainframe computers which integrate functions right across the manufacturing company. These latter CAPM systems – which are now the most commonly sold to users – are 'configurational technologies' (Fleck 1988), in that they are composed of a number of applications modules (or discrete system elements) relating to the various production control functions (e.g. sales order processing, materials, management, production scheduling), which may be used in various combinations. The choice and configuration of individual modules which are on offer is the prerogative of the CAPM user company, which will select, mix and match elements of these systems according to its requirements and current practices. The outcome is a technological artefact which embodies local organisational structures and manufacturing techniques. The case of CAPM illustrates how industrial automation systems can be 'organisationally shaped', both at the point of design to incorporate dominant and generalised patterns of work organisation into a generic technological offering, and then again at the point of implementation when these dominant patterns are modified and overlaid with local and particular ones (Fleck, Webster and Williams 1987).

CAPM systems are first imbued, then, with patterns of work organisation when they emerge as new technological products. Their very design and structure incorporates identifiable manufacturing methods and practices, and they are launched onto the market accompanied by clear visions of how production ought ideally to be carried out.

CAPM systems first emerged in the U.S. in the 1960s, in the heyday of management science. During this period, there was a strong emphasis on reducing production problems to quantitative dimensions, and applying algorithms to decision-making. The early CAPM systems arose from the needs of accounting departments to keep close track of key areas of production assets, such as raw materials stocks. They were developed in one of two ways: either in-house by large companies' DP departments, or by computer hardware suppliers who took up the idea for marketing and who at that time were building large-scale, DP-oriented systems to be run on mainframe machines. So the essence of CAPM was accounting calculation, and they consisted of large-scale file handling systems which centralised a number of record-keeping functions such as stock control. As such, the early CAPM technologies were the product of an interaction between the dominant paradigm of production control and the state-of-the-art in computing: they combined both technical and non-technical elements.

This early form of CAPM relied upon and presupposed work organisation systems most characteristic of U.S. large-scale industry: strictly formalised methods of production control, sophisticated data collection practices and appropriate levels of resources, highly centralised production co-ordination and patterns of authority. These characteristics were thus embedded in the first generation of CAPM, and many of them have been inherited by subsequent generations, as we shall see. The early technologies were mainframe systems which ran on detailed and regularly-collected data: like the structures of work organisation which they relied upon, they were centralised, formalised and highly monolithic.

During the 1960s and 1970s, new application areas were developed as shortcomings were revealed in existing systems. These took CAPM beyond the realm of simple *monitoring* of production resources and into the domain of *balancing* requirements and resources, workloads and capacity. CAPM thus developed out of a purely accounting tool and into a production planning one, through Material Requirements Planning (MRP) and Capacity Requirements Planning (CRP). A financial dimension was added which could express these manufacturing plans in cash terms – hence Manufacturing Resource Planning (MRPII) systems. The American Production and Inventory Control Society (APICS) defines MRPII as follows:

> A method for the effective planning of all the resources of the manufacturing company. Ideally, it addresses operational planning in units, financial planning in pounds, and has a simulation capability to answer 'what if' questions. It is made up of a variety of functions, each linked together: business planning, production planning, capacity requirements planning and the execution system for capacity and priority. (quoted in Waterlow and Clouder Richards 1988)

CAPM in this form continued to reflect the work organisation patterns of large-scale, highly centralised, highly formalised U.S. corporations. It incorporated a top-down approach to manufacturing organisation which relied upon the availability of detailed and accurate production data and also a certain level of in-house expertise to maintain this formal planning and control process, to implement the system, and to guide the organisation through the changes in practice which might be required to support the system. The organisational principles which underpin the early CAPM systems need to be interrogated and made explicit, rather than being seen as natural facets of a linear technological development process. Far from being inevitable and universal, they are culture-bound and intricately connected with the production 'push' methods associated with Western (and especially U.S.) manufacturing. As such they represent one particular, but not the only, way of carrying out production. As Clark and Staunton have argued:

> the frequently cited and QWERTY-like genealogy of the sequence of production 'push' techniques which include program evaluation and review technique, material requirements planning and manufacturing resource planning should be the subject of a critique which exposes their silent origins about the best methods of organising firms. If a genealogical approach is used, then modern techniques like computer-aided production management are presented as the unproblematic end points in a linear process: the pro-innovation bias. (Clark and Staunton 1989: 75)

In the U.S., CAPM was heavily promoted by APICS, which acted as an enabling agency for the introduction of these systems into industry. The image of CAPM which it peddled – as a centralised, 'push' system of production control, heavily reliant upon computer

hardware and software and thus providing a technological fix for production problems – was taken up by and promoted with equal fervour by the Society's counterpart in Britain, the British Production and Inventory Control Society (BPICS). Though the latter occupies a rather less influential position in British industrial policy development than APICS does in the U.S. (Clark 1990), it has nevertheless mimicked APICS's promotion and expectations of CAPM, to the extent of circulating APICS literature wholesale under its own cover in its quarterly journal, *Production and Inventory Management.*

The 1980s saw the decline of management science, and the emergence of a new discourse of production. Business organisation was now to encompass individual corporations, plus the wider range of companies within particular supply chains. In part, this discourse shift can be attributed to the declining influence of U.S. corporate paradigms for production, management and technology, and to the rising influence of Japanese corporate practices, most significantly in the U.S. itself, but also in the rest of Europe. Companies such as Nissan and Toyota provided the West with a vision of manufacturing in the late twentieth century which involves a radically different approach to the organisation of work and technology oriented towards the fundamental changes occurring in world markets and consumer behaviour. American and European companies have in their turn eagerly taken up this new rhetoric of production, which they see as the key to improving manufacturing competitiveness. In Britain, management consultants, professional associations, academic organisations, and industrial agencies have made both prescription and prediction about the desirability and take-up of an array of new manufacturing methods. British industries are therefore receiving very clear messages from public and private policy agencies about the ideal business behaviour for the 1990s.

The new business discourse

The business discourse of the 1990s starts from the premise that major changes are occurring in the location and nature of markets, and it calls for increased responsiveness to these. It suggests that highly designed, high value-added products with shorter life-cycles will replace the old basic commodities, that Europe will be a site for significant market growth, and that the Pacific Rim producers

will join the Japanese as the key competitors for British manufacturers. The most significant proponent of these ideas is the Department of Trade and Industry, which recently commissioned the PA Consulting Group to produce a substantial policy report, *Manufacturing into the Late 1990s*. This identifies imminent trends in markets, economies, products, processes and appropriate technologies, and suggests 'the key responses required by manufacturing industries to prosper in this decade of change' (1989: 3).

In order to meet growing international competition and the increasing demands of new markets, it is argued that companies have to develop manufacturing 'excellence' by generating 'continuous improvements' in production processes. They are encouraged to re-evaluate their business and manufacturing strategies and their corresponding utilisation of technologies (Ohmae 1988). They are advised to review systematically their product lines and product changes, to review their competitive position, to work more closely with their suppliers, to attend more closely to the needs of their customers, and to develop new products and processes to cater to increasingly sophisticated and fast-moving markets for customised, high quality, reliable goods with shorter life-cycles:

> In the 1950s, in a world economy characterised by scarcity, price was the most important criterion. People were happy to become the owners of basic products, most of which now seem primitive. These were mass produced in the cheapest way possible. During the 60s and 70s, there was a sharp rise in prosperity; quality became as important as price. Now, increasingly consumers are demanding quality products more closely tailored to their individual needs and tastes. As lifestyles and affluence develop, so products must be continuously developed to reflect the changes.
>
> Cars are a prime example, where combinations of body, style, trim, engine size, colour and optional features result in a choice for any one model measured in hundreds of thousands – virtual customisation. Individual product ranges now have a life of around five years during which there will be major revampings and introduction of new features. In the 60s and 70s, life cycles were more like 10–15 years. . . . Manufacturing corporations that do not work to shorten product life cycles in this way will almost certainly be leapfrogged by the competition. (DTI/PA Consulting Group 1989: 28–9)

If one were to be cynical, one might suggest that 'shortened product life cycles' could also be seen as good old-fashioned built-in obsolescence, a tried and tested technique for ensuring markets for new products, and thus raising profitability.[6] Such cynicism is not to be found in DTI quarters, however, nor does it come from the range of business analysts who subscribe to the rhetoric and offer advice on the specific practices which companies should adopt in pursuit of excellence. In order to meet new market demands, a growing flexibility in production must be practised: responsiveness to markets will be achieved by speedy product changeover, slashing lead times, batch sizes and stock levels, rapid detooling and retooling, and stringent quality control (Dear 1989; Wheatley 1989). Manufacturers will have to adopt a new philosophy of production, making only what is needed for sales rather than amassing high levels of finished goods stock (*Financial Times* 14 November 1989: 21).

This discourse has been strongly influenced by the post-war success of Japanese industry and the increasing economic power of that country. Manufacturing methods developed in Japanese companies have been imported into Western thinking, and are seen as providing the means by which companies may transform themselves and achieve this excellence in manufacturing. Practices like Just-in-Time (JIT) and Total Quality Control (TQC) are commonly prescribed as techniques which will streamline production, eliminate waste, shorten lead times and improve the service to the customer.[7] They are promoted as serving broader organisational strategies which emphasise increased flexibility of production and process, and closer links with suppliers in order to enhance responsiveness to customers and to the market. The DTI/PA report advises its readers to:

1. Handle excessive UNCERTAINTY including . . .

- fewer people, fewer skills
- environmental factors and risks
- technology substitution
- shorter product life cycles

2. Handle increasing product and market COMPLEXITY including:

- multi-technology products

- multi-niche products
- more knowledge based products
- greater service content
- more choice and customisation

. . .

4. Achieve all-round EXCELLENCE –

high standards of customer satisfaction, plus total quality and reliable delivery, all at low cost. (1989:58)

The DTI also runs a series of workshops around Britain to promote what it refers to as 'Competitive Edge Manufacturing' (or CEM) (*British Business*, 10 February 1989: 20–4). Also, under the auspices of the Enterprise Initiative, it has published an entire series of reports and handbooks with the theme of 'Managing into the 1990s'. These aim to raise business consciousness on a number of subjects which are part of this putative new approach to industrial production in Britain – the Deming Philosophy, Just-in-Time manufacturing, Computer-Integrated-Manufacturing and Manufacturing Resource Planning, for example.[8]

The latest generation of computer software systems are predicated upon and reinforce these various productive innovations. They provide up-to-date management information to enable companies to develop responsive and flexible production methods (Bessant and Lamming 1984; Macbeth 1985). Stocks can be monitored, materials can be ordered only when necessary, priority ratings for orders can be modified, and machines and labour utilised optimally. Increasingly sophisticated information systems can be developed across functional boundaries, demanding the integration of activities across departmental lines (information on sales, for example, being used to determine production patterns); it is suggested that this in its turn will lead to decentralised decision-taking and the consequent flattening of company hierarchies (Applegate *et al.* 1988). Manufacturers will intervene much more closely in the practices of their sourcing companies, while simultaneously using direct electronic links for quotes, orders and invoices in order to 'lock their customers in' to their products (Houde 1990). The manufacturing organisation of the future, then, will apparently be the 'integrated organisation' – integrated not only internally in terms of information systems that draw together previously separate activities and islands of automation,

but also integrated increasingly externally with suppliers and customers. Ultimately, the vision is that an order entered in a car dealer's computer, for example, could automatically instruct computers at parts suppliers and factories to adjust assembly line robots at the appropriate time to produce a customised car, and enter the transaction in the firm's books (*The Scotsman* 27 November 1990).

The climate of manufacturing within which CAPM systems have been developed and applied in Britain has therefore undergone a substantial transformation over the last decade. From being one in which highly formalised, routinised and centralised manufacturing was regarded as the ideal-type for production, the principles of work organisation which are now seen as the key characteristics of contemporary manufacturing rest upon flexibility (of production and of labour), decentralisation and integration (of organisations and of technology). As such, the structures, methods, and patterns of expertise which enjoyed a hegemony in Western manufacturing until the 1980s and which shaped the initial generation of CAPM technologies, have been superseded, at least in theory, by a new culture and practice of production containing elements which have been imported from the powerful Japanese manufacturers and translated to suit Western conditions. The growing popularity of such rhetoric and methods of production can be explained in terms of their role in re-orienting British capital towards regaining some competitive advantage and domination in the marketplace, heightening its ability to maintain and reproduce itself.[9] This has coincided with and been part of a more general emphasis within Thatcherite British society upon the resurgence of capital, the growth of the private sector, the primacy of market forces and the renewal of 'enterprise'.[10]

The second generation of CAPM

It is within this climate of change in the dominant ideas about how production and society generally is best organised that CAPM suppliers now design and market their systems, and they have been quick to incorporate the new rhetoric and practice into their latest product offerings. Arthur Andersen's sales brochure for MAC-PAC, an MRPII production control system, exemplifies this:

> The systems that support this dynamic manufacturing environment are changing as old practices and approaches give way to new concepts and methods. Many companies are moving to MRPII, Just-in-Time (JIT), Distribution Requirements Planning (DRP), Computer Integrated Manufacturing (CIM), and to a new generation of systems that can combine all of these methods. To survive in this volatile marketplace, forward-thinking companies need mission-critical operations support systems that share information throughout the entire organization. As a manufacturer moving into the 1990s, you need to have all aspects of your manufacturing process integrated, sharing information, and changing as the industry changes.

From having been initially designed and promoted as systems which provided central monitoring and control of key resources, and thus rigidifying and formalising production, CAPM systems are now designed and marketed as aids to manufacturing flexibility. They are sold on the basis of helping companies to diminish stock, rather than simply monitoring it,[11] of increasing the visibility of parts, processes and problem areas, of facilitating product variation and general orientation towards customers, and of generally promoting dynamic manufacturing:

> MAC-PAC weaves the 'pull' orientation of just-in-time (JIT) manufacturing with the 'push' of MRPII . . . No matter what your combination, MAC-PAC coupled with JIT techniques can help you achieve faster throughput and lowered work-in-process inventory. These improvements can help make sure your schedules are met on time, every time. MAC-PAC can help you not only boost customer service through on-time production, but also improve your bottom line with reduced inventory and more efficient, paperless processing. (Arthur Andersen sales brochure for MAC-PAC)

CAPM packages are expressions of the visions and programmes of work organisation which dominant industrial players wish to have adopted within British industry. This has meant that organisations adopting them are faced with importing the whole raft of organisational practices upon which they are based – the formalised production systems characteristic of the first generation of CAPM or the flexible production systems inherent in the latest technologies.

There is, moreover, a further dimension to this incorporation of the practices of the dominant manufacturers into CAPM which has posed problems for the implementation of the technology: commercial CAPM systems were initially designed for and used by large corporations – principally the motor manufacturers. In the U.S., General Motors was one of the major early CAPM users, while in the U.K. it was the Lucas and Rolls-Royce corporations which pioneered the adoption of CAPM. The systems were built to suit the production conditions of these kinds of industries: they handled discrete multiple components and multiple products very well, but were not ideal for the serial processing of few basic materials (Burbidge 1990).[12] So the conditions in large companies involved in batch manufacturing provided the template for CAPM, imposing standard manufacturing methods upon the technology, which then reproduced these as *the* software standards.[13]

As the use of CAPM systems has spread to a range of industries, this design to suit the conditions and needs of one particular type of industry has become an increasing problem. Standard CAPM systems are inappropriate to other industries (McGarrie and Kochhar 1990); moreover, the JIT and related techniques which are being promoted in tandem with them are only suitable in circumstances where, for example, companies can impose particular quality and delivery practices upon their own suppliers. Significantly, both CAPM and JIT have been most successfully implemented in 'T-type' industries with conditions similar to those of the motor manufacturers – electronics assembly companies, for example.

Companies which do not share these characteristics have therefore been faced with problems in getting these standard CAPM systems to work for them. They have had to take a generic technological offering which embodies the production environment of dominant industrial companies and is imbued with the visions of how work should ideally be organised which are held by influential industrialists and policy makers. Users have had to modify this generalised and idealised technology to suit their local and specific circumstances. The current design of CAPM systems thus incorporates and extends one particular form of work organisation which is being heavily promoted as the template for manufacturing in the 1990s. This template for manufacturing and hence CAPM system design has altered substantially in recent years in line with developments in production management approaches and shifts in computing from mainframe and centralised processing to PC-based and distributed processing. In addition to building in this

work organisation programme, the design of CAPM systems incorporates a production environment typical of the large and dominant assembly industries. In its design, CAPM therefore already follows a particular trajectory, albeit one that has changed direction and incorporates a number of dimensions: a broad programme for work organisation and a detailed set of functions relating to the production environments of particular users. However, the visions and programmes which CAPM systems embody at the outset have to be negotiated with the reality of manufacturing practice. What, then, happens to the trajectory of this technology when it is put into more widespread use? What are the power structures, work organisation patterns and production environments reshaping this technology at the site of its implementation?

The implementation of CAPM – a technological vision blurred

When companies embark upon a programme of CAPM use, they bring with them a legacy of their existing patterns of work organisation, production environments and information handling practices. Unless they are already familiar with computerised production control systems, they invariably do not have all the necessary data handling and other work practices in place that are required to operate these systems. Nor are they necessarily the flexible, responsive, or lean organisations that, we are informed, are the ideal practitioners of manufacturing excellence in the 1990s. On the contrary, their organisation of production can be idiosyncratic, highly informal, often highly inefficient and lacking in strategy. Loose and pragmatic production practices meet tightly organised and strategic systems which rely on very detailed and coherent information. A negotiation process has to take place so that these two diametrically opposed sets of conditions can be made to work with one another. Formal systems embodying strategies for manufacturing organisation must be modified to fit informal production control practices operating in quite different organisational environments, and these in their turn have to be reconceptualised and restructured to permit them to accept CAPM. How, then, are CAPM systems and organisations reconfigured and restructured to suit each other?

Most companies introduce CAPM for very similar reasons: they see computer systems as enabling them to cure problems caused by

inefficient use of manufacturing resources and thereby to improve their service to their customers. In buying CAPM they are buying a 'technical fix' for their production problems, a package that they hope will automatically iron out all sources of inefficiency and inconsistency in their manufacturing. At the same time, because they are invariably highly susceptible to the sales pitch of CAPM suppliers and to the ideology of manufacturing excellence current in UK industry, they are buying the dreams of work organisation being peddled in industrial, policy and even academic circles about how manufacturing industry *ought* to operate in the 1990s. In doing so, the adopters of CAPM technologies often themselves champion these visions and dreams within their own companies.

The dreams very soon become tempered by reality. Though the responsibility for acquiring CAPM systems may lie with middle or senior managers who have been persuaded by the ideas of streamlined production, their implementation is then delegated to people who conduct the day-to-day operating of the plant and who have a very detailed but highly contingent knowledge of manufacturing. They are faced with the task of fitting these idealised techniques into their real production environments. For example, McKnight,[14] a small Scottish furniture maker, inherited a CAPM system from the company's previous owner, an industrial magnate. McKnight, by now a small and independent company, was therefore faced with a technical inheritance which it had to implement. In theory, if it was to make the CAPM system work, it would have to institute a number of changes in both its production environment and its information handling practices.

McKnight's production environment was not a straightforward one of assembly of multiple components into multiple standard products, and this posed problems for its implementation of CAPM. In fact, the company had two broad product lines which were organised completely differently from one another and catered to totally separate markets. On the one hand, it made domestic furniture to stock, and had standard products which were machined and then assembled. On the other hand, it made educational furniture (desks, chairs and even science labs) to local education authority order, and many of its products were customised permutations of standard components. The company used a 'push' system of production control, meaning that the impetus for the movement of materials along the production line came from upstream, rather than them being 'pulled' through the plant by empty spaces downstream in the line.

McKnight delegated the implementation and operation of the CAPM system to a former machinist from the shopfloor. His understanding of furniture production was excellent, but he had no experience of implementing or using computer systems, with all the additional data collection and clerical activity which this entails, and no organisational muscle to secure the co-operation necessary to get these information systems up and running. Moreover, McKnight was a small company with few resources, and had always conducted its production planning on a personalised and relatively casual basis: as each product was nearing its final assembly, it was matched to a list of sales orders to be met. Work was expedited by the production manager who patrolled the shopfloor regularly and relied upon his personal relationship with the craftsmen and his understanding of the status of the jobs in hand to get orders through the plant in time to meet sales orders and delivery deadlines. All forecasting and planning was done on the back of an envelope. The chaos which these methods created meant that in practice this production manager was constantly having to reorganise and reschedule tasks, pulling his men off one job and putting them onto another in response to some crisis or other. The production planning manager commented about the materials shortages that the company was constantly faced with:

> When we used to put down manufacturing orders . . . to pick kits to assemble, it was then that we knew if we had a shortage. The shortage was close up, you had a couple of days' visibility . . . We relied on physical inventory, men's knowledge and stuff like that.

So the organisation and management of production was extremely ad hoc, and the CAPM system was designed to provide co-ordination and control of the process. It was also designed to work in an idealised environment, not in a mixed environment such as this. This presented McKnight with its first implementation problem, which it overcame by applying CAPM to only some parts of the production process: raw materials and machine parts stores, the machine shop itself. Paradoxically, the assembly shop (the part of the process most likely to benefit from the application of CAPM) was left under the control of an existing manual system developed in-house, so that formal and informal systems were now knitted together and worked side by side. Already, the configuration of the CAPM system had changed: the technology was superimposed

upon and evolved from, first, the previous technology, and second, the peculiarities of the McKnight production environment. The poor development of the company's information handling procedures contributed to the reshaping of the CAPM system. Because the company collected no data on the status of key areas of production – set-up times, run times, for example – and had not resources to institute such a practice despite it being necessary to the operation of the CAPM system, it was unable to make proper use of the scheduling and planning facilities provided by the system. To solve this problem the company rewrote parts of the system to make it work with the much vaguer information (eg. historical output value per week) which McKnight had already collected. Thus, a system with the characteristics and approach of American large-scale data processing was modified to suit the conditions and staff expertise of a small and under-resourced British company, in the course of which the technology was fundamentally altered and lost much of its potency. It was altered as much as if not more than the company's existing manual system of production control, which, as we have seen, dictated the template for the automated system. Furthermore, the image of increasingly dynamic and flexible manufacturing was subverted by the reality of a plodding and laborious system of manufacturing in which improvement was affected much more slowly and painfully than is allowed for by the ideology of excellence.

This is by no means an isolated example of a CAPM system being substantially transformed by its users. In another case, that of BEC, a company within a large engineering group, CAPM was acquired with the expectation that it would provide a coherent technological solution to problems of poor work scheduling and delivery record. It was also hoped that it would integrate the functions of design and production by transmitting design data from the computer-aided design (CAD) element of the system to the bill of materials module in the CAPM element. However, the system integration was massively oversold by its suppliers. More importantly, BEC itself was unable to develop the systematic collection of data and production control practices which were essential to the integration both of the system and of the different functions within the organisation. Like McKnight, the culture and practice of production control was too informal; for example, production information such as materials requirements and quantities were kept in people's heads and never explicitly specified. The control and scheduling of work was the personal domain of

the production manager who used rule-of-thumb methods to schedule jobs and personal authority to expedite them. BEC was ultimately forced to abandon its dreams and implement a much downgraded and heavily modified system which would work in these very informal circumstances.

Shore and Company, a manufacturer of diaries, also bought a vision of systems and organisational integration with its CAPM technology. It wanted to link the functions of sales and manufacturing by means of a database of all the possible production permutations, which could be used both as a sales tool and as a bill of materials for production. It also wanted a system which would enable it to schedule work more effectively and so eliminate the accumulated piles of diary insides which lay all around the shop. But in order to achieve these objectives, the company needed to take not one CAPM package, but two – sold by the same supplier as modular elements in a 'fully integrated system'. In fact, these products were written in different languages, so they first had to be reconciled to each another, and then an entirely new customised section had to be written to provide the database. In all, so substantial were the modifications needed, that this took Shore over two years to complete. And after all the company's efforts to realise its dream of an integrated, streamlined and responsive production system, it was still beset by its perennial problems of enormous levels of idle inventory and a poor record in meeting delivery deadlines. The computer system had been reshaped, but the organisation of work was transformed very little. Unfortunately for a diary manufacturer, Shore was still meeting orders not just-in-time, but just too late.

Manufacturing technologies – or pragmatic compromise?

CAPM is designed to promote dreams and aspirations for new patterns of work organisation. When it is implemented, however, it has to mesh with existing ones. These serve to tone down and often completely submerge the original dreams of new production systems which are promoted by management consultants and industrial agencies. The dreams of these actors are subverted, and are not implemented in a straightforward fashion. Apparently powerful groups do not entirely successfully impose their agendas upon the world of manufacturing.

There is a tension between the current idealised visions of

production as coherent, strategic and dynamic, and the reality of company practice which is much more ad hoc and pragmatic; between the structured vision of technological systems and their actual, problematic, and often chaotic application. The ideology of market-oriented, flexible, integrated production marking a 'post-Fordist' era is not being unambiguously implemented. It incorporates a set of techniques which, as we have seen, are simply not appropriate for every single manufacturing context. Just-in-time, for example, does not suit highly seasonal product markets such as those for diaries or school furniture. And quality standards or daily deliveries are hard to impose upon suppliers who are large multinational corporations. Moreover, companies are much more hesitant and unstrategic in their application of these new techniques and structures than this technological programme allows for – they are often locked into their existing practices or unaware of the potential of new ones.[15]

Retrospective analysis of industrial and technical change over the last two centuries has shown that the Taylorist vision associated with certain technologies, often portrayed as *the* epitome of capitalist management strategy, was by no means universally applied. Not all manufacturing managements needed or wished for that kind of control over the production process. In some industries, elements of Taylorism were applied, in others, old control systems persisted (Webster 1990). Similarly, the techniques of manufacturing excellence and continuous improvement are not implemented in a straightforward fashion, but are modified to suit particular industrial contexts. In the course of this, these dreams and their expression in technologies like CAPM are renegotiated and recreated. Therefore, instead of revolutionising and superseding systems of work organisation currently in use in industry, CAPM technologies incorporate and build upon them.

What, then, can we say about the incorporation of work organisation practices, dominant ideologies and power relations into technologies like CAPM? Is the dominant agenda for manufacturing (currently one of flexibility in production, shorter lead times and product cycles, reduced inventory and just-in-time supply) which is promoted by certain industrial corporations and consultants at first crystallised and then diluted in these systems? Certainly, technologies such as CAPM have embedded within them a plethora of local and particular manufacturing practices and requirements; but this does not mean that they cease to incorporate industrial power relations when they reach their site of

implementation. It simply means that there are several layers to these relations as opposed to one single layer. Any framework which addresses the shaping of technologies by relations of power and dominance within industry has to allow for the existence of these multiple layers.

At the design stage of their development, technologies clearly incorporate programmes for work organisation and ideologies of manufacturing which have prominence and influence in particular eras. These programmes and ideologies are themselves multifaceted. In the case of CAPM, they include preferred broad approaches to manufacturing ('pull' systems currently being favoured over 'push' systems), and approaches to production control at a more detailed level (decentralised and visual systems now gaining prominence over centralised and mathematical ones). At this stage in their development, technologies also incorporate more mundane technical improvements on existing methods of conducting tasks.

When industries come to implement what are in essence manufacturing programmes in the form of technologies, they overlay them with their own local structures and manufacturing practices which are in effect articulations of local power relations, patterns of expertise and skill, and managerial prerogatives to organise production in ways which best serve the interests of the corporation and have grown up out of custom and practice. So one set of social relations and resulting work organisation systems becomes overlaid, like geological strata, with another. Technologies are thus both an expression of practices already in use in industry and a plea for future ones. They represent an extension of existing production methods and an exhortation – a prescriptive programme – for new methods. In the course of their development, they undergo a shaping and reshaping process in which *both* sets of social relations become embedded within them.[16] These social relations are mediated through the systems of work organisation which are promoted alongside and implemented in conjunction with new technologies – systems which are both practised and striven for. Technologies can therefore be seen as hierarchies of work systems and power relations, and at all levels actual as well aspired for relations are expressed within them.

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Notes

1 In the apologia for these new technologies, this very specific connection between the needs of industrial proprietors and the emergence of innovations was masked. They were often justified in terms of their broader benefits to the labouring as well as the owning classes:

> The blessings which physico-mechanical science has bestowed on society, and the means it has still in store for ameliorating the lot of mankind, have been too little dwelt upon; while, on the other hand, it has been accused of lending itself to the rich capitalist as an instrument for harassing the poor, and of exacting from the operative an accelerated rate of work. It has been said, for example, that the steam-engine now drives the power-looms with such velocity as to urge on their attendant weavers at the same rapid pace; but that the hand-weaver, not being subjected to this restless agent, can throw his shuttle and move his treddles at his convenience. There is, however, this difference in the two cases, that in the factory, every member of the loom is so adjusted, that the driving force leaves the attendant nearly nothing at all to do, certainly no muscular fatigue to sustain, while it procures for him good, unfailing wages, besides a healthy workshop *gratis* : whereas the non-factory weaver, having everything to execute by muscular exertion, finds the labour irksome, makes in consequence innumerable short pauses, separately of little account, but great when added together, earns therefore proportionately low wages, while he loses his health by poor diet and the dampness of his hovel (Ure *The Philosophy of Manufactures*, quoted in Berg 1979: 69).

In fact, a rhetoric of technological development for the benefit of the common good, bringing about a higher level of civilisation, was articulated (Babbage, 1835). In much the same way, as we shall see later, computer-based manufacturing technologies in the late twentieth century have become the subject of an ideology which obscures their origins as the tools of corporate owners, suggests their neutrality, and promotes their benefits for the economy overall (Webster 1990).

2 In fact, Ure's vision is based upon the implementation, first of the technical division of labour – an organisational innovation – and subsequently, and more importantly, of machines. In this respect, he quotes at length from the writings of Adam Smith on the organisation of pin manufacture, and asserts that this division of labour forms the template for the application of machines:

> The principle of the factory system then is, to substitute mechanical science for hand skill, and the partition of a process into its essential constituents for the division or graduation of labour among artisans. On the handicraft plan, labour more or less skilled, was usually the most expensive element of production . . . but on the automatic plan, skilled labour gets progressively superseded, and will, eventually, be replaced by mere overlookers of machines. (Ure *The Philosophy of Manufacturers*, quoted in Berg 1979: 67)

3 For example, Edwards' (1979) concept of 'technical control' and Friedman's (1977) concept of 'direct control' are attempts to theorise what Coombs has referred to as 'the room for manœuvre inside the control methods exercised by capital' (1978: 84).

4 This complexity in the constitution of technologies is illuminated by Fleck's (1988) concept of 'configurational technologies'; he emphasises the arrangement of mutually interacting components into a whole system complex which matches the circumstances and objectives of the organisation within which the technology is situated. This concept is particularly appropriate for understanding the shaping of manufacturing software systems like Computer-Aided Production Management (CAPM) which consist of various modules which can be arranged in a number of different patterns.

5 Indeed numerous implementation studies have shown the ways in which initial technological 'trajectories' have been frustrated or diverted at the site of implementation (see, for example, Badham 1990; Fleck, Webster and Williams 1990; Webster 1990; Wilkinson 1983).

6 Even though manufactured goods are becoming more durable, this is surely of little use if spare parts, add-ons and peripherals are withdrawn from the consumer after a shorter period.

7 TQC was actually originally developed by an American, Edwards Deming, but was implemented to particular effect by the Japanese and subsequently reintroduced to the West.

8 Perhaps one of the most notable growth areas in the British business sphere over the last few years has been the huge proliferation of conferences and workshops run by consultants and academics to educate manufacturing management in these various strategies and techniques. 'Improving Your Competitive Edge: MRPII and JIT Working Together', 'Managing the Uncertainty in Customer Demand', and 'Caring for the Customer: Improving your Supply Chain Management' are typical examples of seminars run by consultants, software houses and the production control professional association, the British Production and Inventory Control Society (BPICS), in the last two months alone. The Xerox organisation even runs a national competition to find the 'JIT Champion of the Year'. Academic conferences on the subject are also proliferating (see, for example, Schonberger 1982; Voss 1987), while the management journals contain increasingly frequent articles on such topics as 'What's your excuse for not using JIT?' (Walleigh 1986) and 'Ideal Practice (building JIT into every area of production)' (Dear 1989).

9 As such it represents perhaps less of a departure from the previous 'Fordist' industrial paradigm than is often supposed, since it relies upon the strictest control of those elements likely to confound the unbridled growth of capital, whether on the shopfloor or in the economy more generally. Indeed, Japanese and 'flexible' production methods appear to be characterised, not by a new industrial democracy as the rhetoric suggests, but by altered and increasingly sophisticated methods of controlling labour (Turnbull 1988; Crowther and Garrahan 1988).

10 The rhetoric of 'entrepreneurialism', 'competitiveness' and 'responsiveness to markets' is not confined to the manufacturing sphere, moreover. It has permeated the management of the public sector as well, which increasingly seems to be subject to attempts to impose, if not privatisation itself, then the ethos and practices of private enterprise. The structure and administration of the health service has been radically reorganised to incorporate business techniques. Those in the education system are under increasing pressure to conduct courses and research which reflect and cater to the needs of business (there is, for example, an MSc in 'Entrepreneurial Studies' offered at Stirling University), and are subject to evaluation methods such as performance indicators which are reminiscent of those used in the private sector.

11 In the current manufacturing climate, marked by high interest rates and drives for leaner production, stocks are seen as costs to be reduced, not assets to be added to profit and loss statements as in the days of the hegemony of accountants.
12 Eli Goldratt, a management 'guru', identifies three basic production systems which are summarised by the acronym, VAT. 'V' plants are those in which few raw materials are diversified into many different products. Steel plants would be type 'V'. 'A' plants are those in which many raw materials are assembled into few finished products, or sophisticated and unique products like ships, while 'T' plants have a number of components which can be assembled into a multiplicity of products with the same basic design. In the early 1980s, Goldratt devised a software system and manufacturing method, OPT (Optimised Production Technology), which were largely implemented in the automotive (a 'T' type) industry.
13 It has incidentally been these same large and influential companies who spearheaded the move towards Japanese production systems (Parnaby 1987; Oliver and Wilkinson 1988) and who have served as exemplars of the new manufacturing practice.
14 All company names mentioned in this paper are pseudonyms.
15 This is not to argue that real improvements have not been made in any industry. The production and operations management literature is full of cases where stock levels have indeed been reduced, where defects have been reduced and lead times cut through the use of techniques like MRP and JIT. But it is still an oversimplification to talk of the implementation of these innovations as if this were a straightforward process, and we need to recognise the real obstacles to this: the factors which militate against the implementation of innovations – technical or organisational.
16 This process whereby technologies are reconfigured at the site of their implementation is discussed in detail in Fleck, Webster and Williams (1990).

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Power, technology and flexibility in organizations

Stewart Clegg and Fiona Wilson

Abstract

This paper critically reviews arguments about technology and their relationship to some positions which have recently been established in the sociological analysis of power. These positions reformulate the relationship between concepts of power and concepts of the organization. Each is seen as integral to the other rather than power being a merely contingent feature of some organizations. Emphasis is placed upon notions of practices and disciplines, ideas developed in order to link power and knowledge. The conception of organization analysis offered is as a cultural study, with power/knowledge inextricably intertwined in central focus. The paper reviews four broad positions in the debates on flexible manufacturing and articulates the conceptions of power and organization upon which each is premised. At the core of the paper, however, are issues surrounding the conceptualization of power.

Power

It has been established elsewhere (Clegg 1989) that there is a conventional and mainstream view of power. It emerges most clearly with Hobbes' account of the mechanical foundations of power, yet, despite this relative antiquity, traces of this mechanical position may be found at the core of recent critical considerations. These days, engagement in these debates is more often than not with the mechanicalism of the contemporary political scientist, Robert Dahl (1968), rather than Hobbes. However, the continuities in domain assumptions between Hobbes and Dahl are well-established (Clegg 1989). Whereas Hobbes may appear to some to be a historical curiosity, Dahl is a figure whose central position in current debates about the 'dimensions' of power has been assured by the role cast for his model of power as the object of Lukes'

(1974) reflections. Stripped to its core the Hobbesian echoes are evident, albeit mediated through subsequent conceptions of causal analysis.

A constant feature in mechanical analysis of power is a classically Humean conception of power as a causal phenomenon: someone getting someone else to do something which they would not otherwise have done, where their 'doing' is signified as a reaction to the causal action of the initiator. Frequently one will find this causal view of power coupled with a concern to identify the available power resources within a given arena. In this way one prepares the analytical focus for a zero-sum power game in which one party can only ever profit at the expense of the other. The reaction in the other is contingent upon another's actions which is in turn dependent upon the possession of some scarce and valued resource.

The zero-sum conception of power exemplified by Dahl was one hedged around with cautious empirical protocols whose net effect was invariably to produce a 'pluralist' account of the distribution of power in any social setting. Power may be zero-sum but there were a great many arenas for its exercise and a great diversity of initiations and reactions on the part of people involved in these. Consequently, because resources were specific of arenas, of which there were a great many, and because people were distributed across these arenas rather than being contained within any one arena, then Dahl was able to argue that across the board no one person or group was ever likely to have the majority of resources in the majority of arenas. This view became known as 'pluralism', for obvious reasons.

For as long as the debates about power were confined either to broadly theoretical issues or to highly plural arenas such as urban space, with its mass of civil, associational, governmental and private organizations, they were unlikely to connect with debates about technology. Once one stepped inside some of these organizations, so to speak, then the connections were more likely to be made. This did not mean that they would necessarily be made. Just as there was a conventional mainstream view about power which was close to an analytical orthodoxy, so there was a convention about the place of technology in the analysis of organizations.

Technology and power

To a generation of researchers who followed in Joan Woodward's (1965) footsteps, even when they disagreed with her findings, technology could be regarded in a neutral key. It was the imperative necessity of technology which unlocked the mystery of organizational design: it explained why different organizations were structured as they were. At least this is how it seemed to some of the generation of organization theorists who followed Woodward. Woodward's (1965) findings now seem remarkably commonsensical, although prior to Woodward's work they had not been grasped. It is clearly a measure of her achievement that they now seem so obvious. Batch production organizations will tend to be smaller, in part because they employ less specialists. Decision-making will tend to be taken 'on the job' for each item of production. It will tend to have product-specific rather than system-wide implications. An elaborate bureaucracy will not be required. The converse is true of mass production. The nature of the product demands less decisions to be actually made, but their consequences will be system-wide and have a longer term impact, because production runs are fewer and bigger. The low levels of skill formation in the workforce mean that it requires more standardized and formalized mechanisms of coordination. Woodward thus provided not only a description but also an explanation of structural differences in organizations, one which has been subject to considerable subsequent support (e.g. Harvey 1968; Zwerman 1970) and influence (e.g. Perrow 1967; Thompson 1967; Hickson *et al.* 1969; Van de Ven and Delbecq 1974; Blau *et al.* 1976) as well as some criticism (e.g. Marsh and Mannari 1981: 37; Tayeb 1988: 11–12).

There is an implicit theorization of power at work in Woodward's views. It is one which links the time span of managerial discretion (Jacques 1951) – the capacity for specific management errors of judgement to reverberate and amplify around the organization system for more or less time – to a conception of managerial trust (Fox 1974) founded on the appreciation of the skill-capacities of the workforce. Yet it was not really developed by Woodward nor was it to be developed by her empirically oriented critics within the Aston School who were more concerned to conceptually limit the determinant power of technology in favour of the impact of size on organization structure (see Aldrich 1972).

Woodward's implicit organization theory of the politics of technology contrasts markedly with an orthodox managerial and engineering view in which politics are most notable by their absence. Power is elided through an implicit warrant of principled integrity premised on the autonomy claimed for science in its applied advance of pure knowledge. The 'engineering' argument would say that technology equalled progress: it is natural, neutral and inevitable and needs only to be managed in its introduction to minimize irrational problems of social adaptation to it. Technological development is inherently good and to be welcomed; any opposition is illegitimate. The engineer knows the 'best' method of production, the most efficient and effective mode of production; they will have 'objective' data to back their decisions, for example cost justification exercises will be performed. The development of 'scientific management' from F.W. Taylor (1911) to present day ergonomics is the best example of this tendency.

Scientific management coupled with technological advance can lead to greater control over the work process through specialisation of work and removal of decision making from the operator. This frequently means greater control by management with loss of autonomy and decision making for the operator. The individual is typically viewed in purely instrumental terms as an operator who can be manipulated and adjusted through training and incentive; their actions must be primarily orientated towards organizational goals. Labour is a medium of production, like technology, to be used as efficiently and effectively as possible. Efficiency can be quantified in a scientific and value free manner, unlike more secondary considerations, such as the individual's social-psychological dispositions. Where engineers perceive a disillusioned, disaffected employee who displays a lack of commitment to work this can all too easily be interpreted as idleness and unreliability. That the disaffection may have been created by the mode of work organization, by the way in which technical change is introduced, by the lack of employee involvement in the decision and a lack of managerial concern for employee's dispositions, may be evidence of a potentially vicious circle of increased power to tighten control calling forth greater resistance.

Such views of the relationship between power and technology are well established. Talcott Parsons (1951) had noted that technological advance almost always leads to an increasingly elaborate division of labour and an increasingly elaborate organization. Conceived as an autonomous force technology determines

system needs. Of course, the autonomous force must be the result of managerial choices concerning the division of labour as Dreyfuss (1938) recognized. Warner and Low (1947) noted that control problems appear to be simplified to the extent that machines appear easier to control than people. Moreover, as Durkheim (1964) recognized, mechanisation not only disrupts the social solidarity of less skilled workers but also helps destroy the feeling of security that craftspeople once derived from their special technical abilities.

The insight available from Durkheim was to become an unrecognized and tacit corner-stone of an influential account of the 'labour process'. It was an account which simultaneously accepted a conventional 'zero-sum' view of power, expressed through the medium of technology. Moreover, it was one which proposed itself as a radical analysis. The current in question was that of neo-Marxian analysis. Technology and power were drawn together into one model in the wave of 'labour process' work initiated by Braverman's (1974) *Labour and Monopoly Capital* (also contemporaneously succoured in work by writers such as Marglin (1974) and Stone (1974)). In this genre power and technology were combined through the intermediary concept of control. Power was exercised in the normal zero-sum and causal way of its mainstream conceptualization while technology was the medium through which it was mobilized. Control, in terms of the reproduction of the existing capitalist control of the means of production in the day-to-day supervision of the labour process, became the end to which power and the media of technology were oriented.

The classic historical examples have been offered by Marglin and by Gorz. Marglin (1974) cites the case of cotton and wool merchants who constructed a role for themselves using technology in order to control the activities of their workers rather than merely to enhance efficiency. A very different technology would be developed if maximum control had not been the main aim (Gorz 1972). Amongst writers who have had a contemporary as well as historical focus Braverman (1974) has also argued that technologies are typically chosen for reasons other than increasing efficiency. Machinery offers management the opportunity to pace and control according to centralised decisions which are in their hands. Usually these arguments are most frequently made with respect to factory work and blue-collar workers. Beynon (1974) and Nichols and Beynon (1977), for instance, describe the effects

of the imposition of technology on work tasks. If the technology can make redundant judgement, discretion, decision-making then the individual's opportunities for resistance are eliminated or reduced. Thus managerial control can be increased through technological change. However, there are examples drawn from other sectors. For instance, Watanabe (1990) describes how labour was de-skilled and degraded in the Japanese banking sector. Watanabe is not alone in this view of significant de-skilling in the financial sector. Knights and Sturdy (1987) argue that there has been a massive increase in routine work in the insurance industry leading to a polarisation of skills. (However, these accounts should be qualified by other research, such as that of Lane (1987) and Price (1988), which is more positive in drawing conclusions for de-skilling from studies of the banking sector conducted elsewhere.)

Not all researchers into managerial strategies have represented the transformation of the division of labour in the direction of mass production as a process which succeeded immediately and in full. Sometimes the potential unleashed by the introduction of new technology into the workplace enabled workers, rather than employers or managers, to increase the margins of their control. Zeitlin (1983) has cited the case of the British engineering industry during the period 1890–1920. The employers remained heavily dependent on skilled labour and vulnerable to craft militancy during boom periods. Despite this vulnerability, over the long term the employers were able to subvert the reproduction of craft regulation through such measures as changes in payment systems and in apprenticeship, despite short term marginal gains by skilled employees. Similarly Lazonick (1983), looking at mass production industries in the 1920s in the US, argued that new technological structures, while exacerbating mass production methods, at the same time created new problems of control for employees. Nonetheless, technological change did undermine the technical bases of craft control and thus created the possibility for the development of mass production methods in the first place.

Technological change was central to the rise of corporate capitalism from the 1880s but it would be difficult to maintain that it dictated the political and cultural content of the institutions which emerged. The shaping force appears to have been the attempts by disparate corporate capitalists to secure the cooperation of working individuals to the processes of production, while simultaneously seeking to deny them the right to control their working lives. It was not a seamless or foolproof process which had

any necessity attached to it. Sometimes the putative controllers would find themselves hoist with their own petard, as occurred in the history of the British cotton industry. The highly competitive character of the industry in the 1860s enabled mule spinners to retain rigid craft control of the pace, organisation and remuneration of work. This craft control, Lazonick (1979) argues, permitted the self-acting mule spinners of the late 19th century to resist unremunerated intensification of labour at work and to protect themselves from a habitual reserve army of mule spinning labour which the employers constructed. However, in the longer term the actual craft basis of their control was substantially undermined, as the employers crafted a new and central role of supervision for the manager. The earliest case studies by writers like Marglin had suggested that employers, as merchant capitalists, had created a role for themselves in the earliest applications of textile technology in the British industrial revolution. Now it appears to be the case that a hundred years later the extension of their impersonal and formal control meant a simultaneous reduction in their personal control. New intermediaries of power appeared on the scene.

It has been rare that the intermediation of power in organizations has been a central topic of labour process analysis. In the labour process literature control invariably means capitalist control of the labour process, thus reprieving themes for organization analysis which had lain neglected in Marx for a hundred years. The initiators of power were metaphorically conceived as 'capital' and its emissaries; the reactors to power were equally metaphorically conceived as 'labour'. In what were taken to be more sophisticated conceptions of this approach labour was later to be allowed its own initiation of a specific type of action: resistance. However, because power was always exercised in an extant structure of capitalist control this resistance could never amount to a basis for overturning power's present control of resources; nor could it ever alter the direction in which that power flowed.

In the emergent genre of labour process studies control was always regarded as problematic. The difficulties for its achievement arose because it was exercised over human subjects who retained control over their own embodiment and subjectivity, despite renting their time to an employer. The employer, usually rendered as a capitalist (a designation which has its own problems for any analysis of other organizational forms, such as state-enterprises, the public service or co-operative sector), had to be able to try and convert the rented labour-time into effective labour power.

Effective use of the rented time meant returning a greater surplus value than was consumed in the rental – the exchange value or wage-cost of the labour. The achievement of effectivity required close supervision of the labour process in which this alchemy of value-transformation was to occur. It was proposed by Braverman that historically a major means in the accomplishment of the alchemy had been 'the degradation of work in the twentieth century' through processes of 'de-skilling'. De-skilling, or the reduction of the skill content in work, was the means whereby labour was cheapened, disciplined and outflanked in its organizational and cognitive capacities. The means whereby this was achieved was through technological innovation. Rather than technology being something which was composed in a neutral key its inner-most rhythms were implicated in a key of domination and control. At best the orchestration allowed occasional gaps in or interruption to the design purpose. In some writers such as Burawoy (1979, 1985) even these apparent glimpses of other possibilities were to be regarded as yet more complex forms of harmonic counterpoint to the main theme of domination. Unorchestrated resistance functioned in hegemonic harmony even when on the surface it appeared to be discordant.

Technology is clearly not the sole source of control. Edwards (1979), for example, argues there are two forms of 'structural' control. Consciously contrived controls could be embedded in the physical structure of the labour process, producing 'technical control', or could be found in the social structure, producing 'bureaucratic control'. It is assumed that managerial strategies are formulated with the idea of reducing the power of labour's role in the production process in mind. The focus in Littler's work is also on systematic managerial strategy and control in relation to labour and technology, again refining the specific locations within the system of productive relations. In terms of power the result is zero sum. In many such schemata management was somewhat of an analytical embarrassment, something signified most clearly in the difficulties Marxian class analysis had in classifying these positions deemed 'contradictory class locations' (Wright 1976).

For a self-consciously radical movement within social analysis much of the 'labour process' approach was surprisingly orthodox in its appreciation of power. Power was zero-sum: capitalists could only have more of it at the expense of labour having less. Power was also a causal phenomenon which was based on resource control. It was revealed in concrete acts of initiation and reaction

(rendered as resistance). Technology also had a specific role to play. Technology was conceived in quite concrete ways as machinery and related processes which were the means whereby power was initiated and control frequently (re-)accomplished. Technological changes were indices of changes in the control of work. While they were not the only indices or means of control (which could be 'sedimented' in quite complex levels and layers (Clegg 1981)) they have been an object of particular focus for labour process writers (see, for example, the contributors to the volume edited by Knights and Wilmott (1990)). Some researchers, such as Storey (1985: 206), have in fact seen in some forms of 'new' technology the potential for a device capable of integrating the whole range of controls to which an organization typically has recourse. From this perspective one would assume that all power would thus flow through technology and that the future of organizations which adopt such technology will be one of increasing control of power and thus the increasing marginalization of resistance in an ever-more 'one-dimensional' universe, much as Marcuse (1964) predicted. We will argue that such predictions are spurious and that their error is inherent in the limits of the theories of power with which they are constructed. The error can be traced back to the mechanicalism of the conceptual orbit in which so much theorizing (of) power has naturally gravitated since Hobbes.

Alternate theories of power

Modern theories of power tend to be Hobbesian in their provenance. Where they are not they will usually turn out to implicate a more Machiavellian design. In a nutshell this is the meta-argument of a recent book on 'power' by Clegg (1989b). In this section of the paper we will seek to elaborate this argument and demonstrate how there are more possibilities for theorizing power and technology than those that end up in the scenario of near total control which Storey (1985) depicts.

The difference between Hobbes and Machiavelli can be expressed in simple terms. Where Hobbes and his successors may be said to have endlessly legislated on what power is, Machiavelli and his successors may be said to have interpreted what power does. The distinction between 'legislators' and 'interpreters' is derived from Zygmunt Bauman (1987). It is meant to capture the difference between a knowledge whose origin is wholly implicated with state

power and one which is quite divorced from it. Hobbes, the archetypal early modern theorist of power, was in these terms a classic legislator. He provided a rationalized account of the order which state power could produce. In addition, he was a servant of state power. Hobbes' *Leviathan* was 'a relatively autonomous, self-managing discourse' (Bauman 1987: 2) which generated an explicit model of order. Machiavelli's concerns, by contrast, were of necessity at some remove from the role of legislator. Not only did he not serve a strong unified state power, he was spurned by the state power in which he resided. Nor did he seek to produce a legislator's model of order. Machiavelli, by contrast to Hobbes, wrote only to interpret the strategies of power rather than to fix and serve power. By Bauman's (1987) criteria he was 'post-modern' before even modernity! An intellectual writing on the state and on power, but, through the politics of his time and place, separated from both power and the state. Perhaps this is why Machiavelli seems such an alluring model to some contemporary writers on power.

It is not just recent writers on power who have found Machiavelli of value. For instance, the Florentine's emphases accorded in some respects with the strategic, local, practical concerns implicit in Gramsci's (1971) invocation of 'The Modern Prince'. These non-totalizing concerns with strategy were also to be an attraction for late twentieth century writers, such as Laclau and Mouffe (1985). In Foucault's dissection of discursive practices one would also find a strategic and non-totalizing concern with power. This is not to say that Foucault was in some sense a lineal intellectual descendant of Machiavelli. What an irony that would be considering Foucault's (1972) strictures on the myth of origins in *The Archeology of Knowledge*! Rather, it is to acknowledge that both writers confronted a similar problematic. For Machiavelli, this was interpreting that strategy and organization which seemed most likely to secure an ordered totality of power in a scene characterized by a flux, a vortex, of politics. Foucault's concern in his later work was with how such ordered totalities as existed in institutional form and discursive practice, such as secured the 'birth of the clinic' and the power of the 'medical gaze' as well as the 'medical subject', could have been constructed. What strategies and what organization secured these powerful outcomes? The continuity, such as it is, is one of problematic rather than anything else.

Hobbes, by contrast with Machiavelli, sought to legitimate a

myth of order premised on sovereignty. Writing over a hundred years after Machiavelli it is not surprising that the terms in which he did this reflected the most powerful tools for constructing order which were then available to early modern scholars: the discourse of mechanics, the early formulation of what was to become the core of modern 'science'. Given the enormous success of the scientific project, then it was hardly surprising that in conceptualizing power, as in much else, the early political and social scientists sought to emulate in their principal terms and metaphors those notions conceived in mechanics by Hobbes' contemporaries. Machiavelli, the frustrated schemer, the calculative would-be adviser to a Prince of a minor and irrelevant power was naturally consigned, outside of certain European traditions, to a primarily historical role in political theory rather than to one which could later be seen to be metaphorically constitutive of the modernist project of power.

Given the context in which these early modern debates were situated and to which they were addressed, when one looks at them contemporaneously it is not difficult to recapture a sense of Machiavelli's project. It represents a full blown if somewhat marginalized way of seeing power: one with perhaps more relevance, in these allegedly 'post-modern times', than the victorious modernist project whose ground was sketched by Hobbes. The latter project has been characterized by a narrative sweep orchestrated from that mythical, heroic, modernist law-bringer whose role was so central to Hobbes' *Leviathan*. The apotheosis of these tendencies is the radical perspective of Lukes (1974). Here, power extends even into the other's thoughts and consciousness. No more sovereign sweep could be imagined than is encapsulated by this indebtedness to a Marxian problematic of 'false consciousness'. Within a conceptual orbit in which a central role is cast for technology the same project of capture is accomplished by changes in control wrought through technological innovations which in the long term, despite resistance, invariably erode that potential for autonomous action of a working class which once resided in skill and knowledge sustained in craft control of the labour process. The creation of inauthentic jobs becomes the precursor and causal explanation of compliant action where the theory would have preferred revolutionary bodies.

Projects more aligned to those of Machiavelli tend to undercut the sense of a total score in favour of more interpretive, contingent and local interpretation. It is in this sense that Foucault's 'post-

modern' world of flux and discontinuity is more closely aligned with the early modern world of Machiavelli's Florence. It shares an analytical focus on and fascination for shifting, unstable alliances, a concern for military strategy and a disinclination to believe in any single, originating and decisive centre of power. Hence there is some distance from these perspectives to the mythical world of order represented so positively by Hobbes. Hobbes' representations have left their mark on modern theory in their insistence on the causal, atomistic and mechnical nature of the relations of power, as well as the implicit concern with the originary centre of power. In the case of the labour process theorists this is expressed through a conspiracy of control by the mythically unified subject of 'capital'. 'Labour', by contrast, loses the power of action in other than the sense of reaction or resistance.

Both Hobbes and Marx would represent archetypal modernist thinkers. Both were committed to notions of the necessity of order. Marx, of course, differed in his conception of the likelihood of it ever being achieved under the existing political economy, given the tendencies to disorder which prevailed in his conceptualization of capitalist circuits of production. Many subsequent Marxists have explained the persistence of these circuits in terms of the ruling hegemony which capitalist social and state relations are presumed to have ensured. Of late these accounts have lost considerable intellectual credence. They have come under renewed political attack in Western Europe (which, of course, is nothing new), spurred on by practical developments in Eastern Europe, as well as a broad front of intellectual critique. Some of these attacks have been concerned with the empirical problems involved in the search for the holy grail of hegemony (Abercrombie *et al.* 1980; Chamberlain 1982). Other attacks have come from the 'postmodern' world of 'post-Marxism' and 'post-structuralism', a world in which no space has been left for belief in a rational, guiding architectonic of action. No originating source of action inhabits the post-structural world, just an endless series of contingencies. Although this is most evident in the work of Laclau and Mouffe (1985), some critics such as Perry Anderson (1983) have seen these tendencies as already implicit in Foucault. As has been commented elsewhere it is in this respect that, having de-centred the loci of power, Foucault is perhaps to be considered as a distinct pluralist (Clegg 1987).

Foucault's work has been a rallying-point for a transformation in

current conceptions of power. From a mechanical world-view of power centred on those assumptions which Hobbes did so much to articulate there has recently been a shift towards one more receptive to the strategic views first explored by Machiavelli, subsequently opened up into a 'circulatory' conception of power in Parsons' work, to be tied ineradicably to the circulation of knowledge through discourse by Foucault (Clegg 1989b). At the core of Foucault's later views is an abiding concern with the relation of power and meaning, or, as he prefers it, power and knowledge.

Contemporary views of meaning see it as existing in the difference between rational terms which current representations defer to. However, there is no reason to expect that representations will remain contextually and historically stable and every reason to think that they will shift. Power will thus be implicated in attempts to fix or uncouple and change particular representational relations of meaning, a thrust which develops most explicitly from Foucault's (1977) historical ontology of some of the subjectivities which have been constituted through practices of power and knowledge. The knowledge that is used to structure and fix representations in historical forms is the accomplishment of power.

In constructing the knowledge/power relation as the object of analysis one might seem to be celebrating a relativism in which any fixed point is dissolved, as some of Foucault's critics such as Perry Anderson (1983) insist. However, this is too extreme a reaction. What are dissolved are notions of any transcendent position which can be constituted outside of discursive practices. Within these, then some representations will achieve a power far greater than others, a power which is neither an effect of a human subject and its volitions nor of a structure which works its will behind the backs of such subjects. It is the representations themselves, the fundamental discursively formed ways of constituting relations, which have a historically specific character, which are the object of analysis. At base, the concern is with strategies of discursive power, where strategicality becomes seen as an effect of distinctive practices of power/knowledge gaining an ascendant position in the representation of normal subjectivity: forms of surveillance or psychiatry, for instance, which constitute the normal in respect to a penology or a medical knowledge from whose 'gaze' and rulings no one can subsequently escape, whether prison or medical officer, or one carcerally or medically confined.

In Foucault's (1977) *Discipline and Punish* power is conceived of

as a technique which achieves its strategic effects through its disciplinary character. Foucault (1977) sees the methods of surveillance and assessment of individuals which were first developed in state institutions such as prisons as effective tools developed for the orderly regimentation of others as docile bodies. This is so, he maintains, even when they provoke resistance. Resistance merely serves to demonstrate the necessity of that discipline which provokes it, according to Foucault. It becomes a target against which discipline may justify its necessity by virtue of its lack of omnipotence. These disciplinary practices become widely disseminated through schools, the army and the asylum, and eventually into the capitalist factory. They become strategic to the extent that they are effective constitutions of powers. As a form of knowledge they work through their own ontogenesis. Because they are knowledge constituted not just in texts but in definite institutional and organizational practices, they are 'discursive practices': knowledge reproduced through practices made possible by the framing assumptions of that knowledge. Moreover it is a very practical knowledge: it disciplines the body, regulates the mind and orders the emotions in such a way that the ranking, hierarchy and stratification which ensues is not just the blind reproduction of a transcendent traditional order, as in feudalism. It produces a new basis for order in the productive worth of individuals as they are defined by these new disciplinary practices of power.

These new disciplinary practices of power are not, however, to be regarded as an intentional effect of any will, least of all of that traditional central condensation of power, the state.

> There is not, on the one side, a discourse of power, and opposite it another discourse that runs counter to it. Discourses are tactical elements or blocks operating in the field of force relations; there can run different and even contradictory discourses within the same strategy; they can on the contrary, circulate without changing their form from one strategy to another, opposing strategy. (Foucault 1984: 101–2)

To assume that there are fixed interests, on the one hand, and definite discourses representing them, on the other, would be mistaken. For instance, what was the 'capitalist discourse' of privatization and de-regulation may become posited as the 'socialist discourse' of a reforming Treasurer, such as Paul

Keating, the present Australian Federal Treasurer. The certainty of interests, one might say, is not secured by mouthing what must in time, irrespective of their content, become political platitudes. 'Discourses have no fixed referent in particular values or systems of morality' (Weedon 1987: 123).

If there is no given elective affinity between discourse, practice and interests, then power cannot be understood as a 'single, all-encompassing strategy' (Foucault 1984: 103). Power will be a more or less stable or shifting network of alliances extended over a shifting terrain of practice and discursively constituted interest. Points of resistance will open up at many points in the network (Foucault 1984: 95) whose effect will be to fracture alliances, constitute regroupings and re-posit strategies (Foucault 1984: 96). In such formulations power is to be seen in

> the multiplicity of force relations immanent in the sphere in which they operate and which constitute their own organization; as the process which, through ceaseless struggles and confrontations, transforms, strengthens or reverses them; as the support which these force relations find in one another, thus forming a chain or a system, or on the contrary, the disjunctions and contradictions which isolate them one from another; and lastly, as the strategies in which they take effect, whose general design or institutional crystallization is embodied in the state apparatus, in the formulation of the law, in the various social hegemonies. (Foucault 1984: 92)

Central to Foucault's conception of power is its shifting, inherently unstable expression in networks and alliances. Rather than a monolithic view of power, the focus is much closer to Machiavelli's strategic concerns or Gramsci's notion of hegemony as a 'war of manoeuvre', in which points of resistance and fissure are at the forefront.

Foucault's conception of power is one which attempts to break decisively with the 'mechanistic' and 'sovereign' view. He writes of the creation of new forms of social power which crystallize in the seventeenth and eighteenth centuries, outside of the terms which by now have become quite conventional for addressing and constituting 'power'. What emerges during this period is a 'capillary form' of power, a power which 'reaches into the very grain of individuals', a 'synaptic regime of power, a regime of its exercise *within* the social body, rather than *from above* it' (Foucault 1980: 39).

'Disciplinary power' is one of two distinctive conceptions of power which Foucault (1979) argues have characterized the 'modern' epoch, from the early nineteenth century onwards. (The other is termed 'bio-power' (Foucault 1984: 140–4).) Disciplinary power is targeted at particular individuals or collections of individuals. The distinctiveness of Foucault's conception is that it presents, in its historical enquiry into disciplinary power, an alternative view of power practices. While the modernist trajectory remained fixated on the mechanics of apparent objects, Foucault is suggesting that, unviewed by this conception of power, a real world of new and distinct practices of power was in fact emergent. Looked at in this way, then we can begin to conceptualize the relationship between power and technology quite differently to the way in which it has been configured in labour process theory. There, it will be recalled, technology is the medium of power exercised to re-assert control. Control is invariably seen as capitalist control, and the medium of technology, by implication, as a capitalist tool (Marglin 1974; Braverman 1974).

Foucault's (1977) conception of disciplinary power developing to replace the older sovereign power of which Machiavelli's (1958) precepts in *The Prince* were a veritable, although sketchy, handbook, is not inconsistent with Weber's (1978) account. Nor, as has been remarked elsewhere (for example, O'Neill 1987; Clegg, Boreham and Dow 1986: 57), is Weber's account of the development of capitalist discipline and control inconsistent respectively with either Foucault (1977) or recent 'labour process' descriptions of industrial discipline, provided we relax certain assumptions that see this 'discipline' originating in the cunning of capitalists (Clegg and Dunkerley (1980) make this error; also see Marglin (1974) and Stone (1974): contrast it with Rueschemeyer (1986) who arrives at similar conclusions via a different route).

Disciplinary power, particularly in its 'time-discipline' (Thompson 1967) clearly emerged from the monasteries as Keiser (1987) argues. However, it is equally clear that it was rapidly adapted in the competitive learning environment of early capitalist industrialization. A general transition may be said to have taken place from a domestic economy premised on the 'putting out' system to one which was factory based (Clegg and Dunkerley 1980: 49–56, 59–70), even though it is clear that, as O'Neill (1987: 47) observes, citing Laslett (1965) and Wall *et al.* (1983), it would be a myth to regard this family as a 'natural' economy. However, it is evident that the chronology of the world was transformed, often in a

generation, from one of Holy days, local feasts and the unremitting but seasonably variable rhythms of agricultural production into one based on the rhythms of the industrial machine, overseer, and the clock of factory discipline applied to factory 'hands'. (Workers were, literally, interchangeable 'hands' recruited as such.) In the competitive ecology of nineteenth century production regimes, the possibilities for theft, casualness and ill-discipline of the putting-out system of domestic production compared unfavourably with factory control (Marglin 1974; Landes 1969). The keynote of this factory control was what Weber (1978) referred to as 'military discipline'. Equally, as we have seen, this discipline had not only military but also had monastic roots, particularly in the subjugation of one's own time to an externally imposed discipline of the master's time.

O'Neill (1987: 47–8) notes, after Smelser (1959), that certain technological changes such as steam power and mule spinning cemented the loss of workers' control and the ascendancy of the master's, in the spinning trades. These changes were gradually emulated in the weaving trades, with women and children replacing previously craft based male labour, labour whose resistance was stubborn, violent, political and drawn-out. Indeed, some writers who focus on class struggle at the point of production, on the division of labour and the bureaucratic hierarchies rather than just technical change (Burawoy 1978, 1979, 1985; Littler 1982; Edwards 1979; Clawson 1980) see a battleground in which a dialectic of capital control and worker resistance to it is played out, one which is structurally irresolvable as long as capitalist relations of production are reproduced. Yet, other finer-grained observational data has revealed a clear pattern of operation of occupational and job controls, strategies of closure aimed at excluding women (Cockburn 1983; Witz 1986), rather than anything quite so grand and totalizing as a class struggle. Nonetheless, the introduction of new technology can still be seen to have been done in ways which degraded and eliminated traditional skills rather than adopting a strategy to enhance skill and control. Defensive measures may have been employed by alarmed male craft unions (Cockburn 1983), but, what this should alert us to, more than anything, is the importance of always seeing relations of power not only in 'class' terms but also as signifying the importance of more situated phenomena, such as place and gender (e.g. Bagguley *et al.* 1990). The case studies collected in work such as that arising out of the research initiative into *The*

Changing Urban and Regional System of the UK should be sufficient to convince one that an approach to power which looks at it only in terms of the great battalions of the class struggle, arraigned across the social terrain in such a way as to obliterate particularities of place, of gender, of ethnicity – in a word – of identity, is no longer an appropriate sociological perspective (if it ever was).

While the dialectic of power and resistance is given a precise structural location in Marx's (1976) general theory of capitalism as relations of production, from this basis only quite general theories of capitalist organization and control of the labour process can be developed (Clegg and Dunkerley 1980). Such an approach has not, in the past, been noticeably attuned to difference organized around identity. If it had, it would have posed a major problem of analysis: why has the identity of class not been more salient for those individuals whom the theory would designate as class actors? Why have other, more situated identities frequently been of more moment in the empirical life-world? Short of a lapse into what should by now be discredited problematics of 'false consciousness' (Abercrombie *et al.* 1980; Clegg 1989b) to explain away reality and save theoretical face there appears little escape from the cul-de-sac of this particular question. The question itself presumes an answer to the structuration of power which makes the empirical world entirely unproblematic through its irrelevance. Empirical irrelevance is hardly an auspicious basis for social theory, however impeccable its lineage.

The Foucauldian twist to the theorization of power is a useful corrective in making the processes of power and resistance far less instrumental than is presumed by those accounts which are attuned only to the salience of one assumedly overarching identity. Foucault's (1977) conception of disciplinary power, although not incompatible with the Marxian focus on control and resistance in the capitalist workplace, differs from it in two important respects. First, control via discipline is not seen as developing in the factory first, but in various state institutions. It is adopted by the capitalist masters from the prison masters, the beadles, and the superintendents of asylums. Second, it is not a control which is functionally oriented to capitalist exploitation but to the creation of obedient bodies. Foucault spends considerable detail on the 'embodiment' of power (Clegg 1989b). (This focus was not entirely novel, as Marx (1976) was only too well aware of the violence done to human bodies by the new capitalist discipline, as many of his more

descriptive passages indicate. Gramsci (1971) was also aware of the impact of the 'Fordist' system on workers' bodies. Weber (1948: 261–2) too was aware of the 'tuning' of the 'psycho-physical' apparatus produced by the 'ever-widening grasp of discipline', although his focus was more on the role that Protestantism could play in producing a morally tuned and willing apparatus.)

From an orthodox labour process approach the relationship between technology and power is one in which the former is always sheathed in the latter, and the sheath is one which protects capital's interests. When one contrasts this with the orthodox 'engineering' view of technology as an unsheathed, neutral instrument it appears to have much to recommend it. Yet each perspective is inherently flawed. From the orthodox engineering perspective power is invisible: it simply does not exist. From the orthodox labour process perspective it is all pervasive and utterly predictable. It clothes technology in such a way that the zero-sum see-saw will always weigh heaviest on capital's side. The cunning of capital will be revealed beneath the surface of any cover it might have as the architectonic point of leverage which invariably determines the outcomes.

One important antidote to either of these views is immediately visible from the brief account of Foucault provided here. First, the historical certainties that the neo-Marxian accounts evince towards the power of capital as the central point of control and innovation diminishes. Institutional isomorphism rather than outright innovation may more adequately characterize the initial development of capitalist labour process control. Second, once the role of capital as a metaphorical centre of control is relaxed then there is no a priori reason why organizations may not be seen as more plural arenas of power rather than as monadic sites of control. Recent revisions to labour process 'theory' which go so far as to admit something like these possibilities, as for instance Armstrong (1986), with his account of inter-managerial competition, simply provide a gloss on existing 'strategic contingency' approaches but in a disguised functionalism and determinism as Storey (1985: 196) recognizes. Cunning passes from the knowledge of individual capitalists inside their organizations to the knowledge that different trans-organizational professions have to offer as resolutions of the recurrently evolving crisis-ridden capitalist mode of production. Knowledge is still treated in an instrumentalist mode, as a handmaiden of power with the status of a chattel. It has no role

of its own to play. It lacks autonomy. A pure instrumentality of knowledge lacks a theory of power; a pure instrumentality of power lacks a theory of knowledge.

Each of the pure instrumentalities of power and of knowledge has a correlative position in recent debates about the relation of technology to organizations. On the one hand there is the instrumentalism of knowledge perspective, a recognizably 'managerial' view of the world in which technological changes simply require social adaptation to new forms of knowledge. On the other hand, there is the instrumentalism of power perspective, a recognizably Marxian view in which technological change is invariably the powerful medium for enhanced control disguised as social adaptation to new forms of knowledge. Each view is too one-dimensional in its conception of either power or knowledge as its principal term.

Power, rules and resistance in organizations

An alternative approach seduced neither by the sirens of instrumental knowledge nor instrumental power is necessary. What is required is a more adequate synthesis of power/knowledge in an organizational framework, for which Foucault's notion of 'disciplinary practice' provides an initial key (Clegg 1989b).

The concept of disciplinary practice is meant to render those micro-techniques of power which inscribe and normalize not any individuals but also collective bodies such as organizations through the calculation of modes of rationality, seen from distinct auspices of power/knowledge. Any formally efficient organization will normally attempt to construct some overall strategic practices of discipline. A storehouse of disciplinary techniques is available for organizations in achieving this aim. Not only are there the services of those many agencies who specialize in selling specific disciplinary techniques on a consultancy, advisory or sub-contracting basis. There are also the enduring sediments of previous practice which have been selectively structured into the rules of organization control (Clegg 1981). Not only are such practices capable of quite precise targeting within organizations, they are also buttressed by quite generalized but no less effective sanctions available as a result of the career structure and movement through it. Such practices will not be simply constraining: they do not only punish and forbid; more especially they endorse and enable obedient wills

and constitute organizationally approved forms of creativity and productivity through a process both transitive (via authoritative externalities such as rules, superiors, etc) and intransitive (via the acquisition of organizationally proper conduct by the member).

The transitive element in the production of disciplined obedience has long been the central focus of organization theory, as evidenced in the classical concern with the role of technology in determining the formal structure of organizations. Doubtless such representations do have a limited heuristic value when used by researchers. However, in practice authoritative structures rarely if ever conform to their depiction in the organizational programme. The reasons for this are many: things change imperceptibly over time in ways which are not captured by a static idealization; organizational membership changes and so particularly competent 'power-players' may make more of a position and a technology than a less competent predecessor, and so on. However there is a more fundamental reason than these conjunctural events as to the inadequacy of these depictions of the formal structure of the organization. Recalcitrance is implicit in the intransitive processes which constitute organizational disciplinary practices in an hierarchical field.

Any superordinate member of a complex organization will be just one relay in a complex flow of authority up, down and across organization hierarchies. Ideally, in any rationalistic view by organization elites, planners and seemingly many theorists, such relays should be without resistance, offering no impedence whatsoever, no 'problem of obedience'. This is implicit to the instrumental view of knowledge in the conceptualization of technology. Rarely, if ever, will it be the case that this is so, as organization researchers have long known (Coch and French 1948). Resistance, to continue the metaphor, will tend to be pervasive. Authorities, to use the term as a plural noun, will rarely if ever be resistance free and passive relays. Rather, they will be active agents, agents who may well have an interest in securing the strategicality of their own interests.

Agencies interested in maximizing their strategicality must attempt to transform their point of connection with some other agency or agencies into a 'necessary nodal point': a channel through which traffic between them occurs on terms which privilege the putative strategic agency. Otherwise, strategic inclinations will be unconsummated. Strategic agency will not be successfully achieved. From these observations follow the central

points of strategic contingency theory (Hickson *et al.* 1971; Hinings *et al.* 1974). The achievement of strategic agency requires disciplining the discretion of other agencies. The articulation of interests by strategic agencies is thus the medium and outcome of unique positioning over the discretion of others positioning in the organizational field. It has to be reproduced for existing structures of power to be reproduced. Indeed, its reproduction is a significant component of the phenomena of power; its transformation effective resistance to it. It should be evident that such reproductions are always already structured: never flat, one dimensional topographies. Topography in this instance will always be the result of previous and current contest. In organizational life such field structure has to be reproduced by strategic agencies or it will be open to transformation. Agency may be evident in any circuit in a network of practices. Typically, but not necessarily, these circuits will be human: but they may be departmental or inanimate. One consequence of the position taken here is that organizational locales will more likely be loci of multivalent powers than monadic sites of total control: contested terrains rather than total institutions. Barnes (1986: 184) puts it thus: 'To retain discretion over a large number of routines requires delegation. But for the maximum retained discretion over any particular routine the requirement is that authority be delegated but not power.'

The theoretically most powerful delegation of authority depends upon the delegated agent acting as one who is 'obedient'. Other than this, there is no way that the delegated routines will be directed without discretion. 'Obedience' cannot be guaranteed, if only because of the complexity and contingency of agency, as a nexus of calculation. Discretion need not entail dissent: it may be organizationally creative, productive, reproductive. None the less, to increase the power of a delegating agency does mean authorizing delegated others and delegated authorities cannot be guaranteed to be loci of wholly predictable and controlled agency, other than if they are dutiful servants. Important implications flow from this relationship between power and discretion. Power will be inscribed within contextual 'rules of the game' which both enable and constrain action (Clegg 1975). These rules may be taken to be the underlying rationale of those calculations which agencies routinely make in organizational contexts. Action can only ever be designated as such-and-such an action by reference to rules which identify it as such. Such rules can never be free of surplus or ambiguous meaning: they are always indexical to the context of interpreters

and interpretation. Where there are rules there must be indexicality, as has been demonstrated by texts as diverse as Wittgenstein (1968), Garfinkel (1967), Clegg (1975) and Barnes (1986). Rules can never provide for their own interpretation. Issues of interpretation are always implicated in the processes whereby agencies instantiate and signify rules. 'Ruling' is an activity. It is accomplished by some agency as a constitutive sense-making process whereby meaning is fixed. Both rules and games necessarily tend to be the subject of contested interpretation, with some players having not only play-moves but also the refereeing of these as power resources. Consequently, where rules are invoked there must be discretion. Thus, it is not only embodiment, labour power, which is the source of resistance. It is not only the gap between the capacity to labour and its realization in which power and the organization of control is implicated; it is also inherent in the regulation of meaning.

Here we confront the central paradox of power: the power of an agency is increased in principle by that agency delegating authority; the delegation of authority can only proceed by rules; rules necessarily entail discretion and discretion potentially empowers delegates. Technological change, with its introduction of new knowledge and its discontinuation of existing knowledge in organizations, will be central to these paradoxical politics. Events and others must be rendered routine and predictable if negotiation is to remain an unusual and out of the ordinary state of affairs. Routines arise not so much by prohibition and intervention into states of affairs, but through the knowledgeable construction of these states of affairs so that subordinate agencies know what is to be done on their part if they are to minimize whatever sanctions might be directed at them by superordinates, or indeed by any others involved in their circuits of power. It is not only power that is premised on knowledge, or its exclusive control or privileged access. It is also subordination: as Barnes (1988: 103) puts it, such agencies 'must recognize that the output of appropriate action which they produce is what minimizes the input of coercion and sanctioning which they receive'. It is for this reason that wherever questions of time-space extension become necessary for securing organization action, it becomes important that there be some form of rules of practice to which agents can be held. The freedom of discretion requires disciplining if it is to be a reliable relay. Whether this be achieved through what Foucault referred to as 'disciplinary' or some other modes of practice is unimportant. It

may be direct surveillance, the interiorized normalizing gaze of professional self-regulation, a standardized reporting scheme, common economic interest or client reports which serve as the rules of practice. In the absence of these, their evasion or malfunction, then organizations are ill-advised to put their trust in agencies, as Machiavelli knew only too well.

Power is implicated in authority and constituted by rules; the interpretation of rules must be disciplined, must be regulated, if new powers are not to be produced and existing powers transformed. In fact, given the inherent indexicality of rule use, things will never be wholly stable; they will usually exhibit tolerances to stress, strain and strife in rule constitution whose limits can only ever be known for sure in their ill-disciplined breach of regulation.

Resistance to discipline will be irremediable because of the power/rule constitution as a nexus of meaning and interpretation which, because of indexicality, is always open to being re-fixed. This is what couples power/knowledge in Foucault's (1977) formulation, because, at its most pervasive, power positions the subject, through the organization of disciplinary practices which constitute the potentialities, incapacities and correlates of specific forms of agency. Given the general level of pervasiveness and acceptance of the 'institutional' approach in contemporary organization studies (see Clegg 1990) it is appropriate to christen the perspective being proposed here as a 'power/institutions' approach. It is with, and drawing from, the institutional frameworks of available knowledge in and around organizations that the multiplicity of potential centres of power within organizations might seek to enhance their strategicality and thus their power. Within the organizational arena agents with varying strategies are seen to struggle to constitute the capacities of the organization in policy terms which represent their conceptions of their interests. In so doing, they will bargain with whatever resources can be constituted as strategic. Such resources may be located either within or without the organizational arena. It is not just that there are resources waiting to be activated: rather, these are constituted in struggles which may be represented discursively as diverse ways of being 'rational' in Weber's sense of substantive rationality. Hence they may be termed 'modes of rationality'.

For institutional forms of knowledge-practice to become 'structures of dominance' they will articulate around more or less abstract cultural values and achieve their expression through organizationally situated actions and vocabularies of motive (Mills

1940). These are the normal ways of accounting for action (where 'accounting' is not being used in the technical sense of the discourse of accountancy). It is through such 'accounting' that one may make reference to the socially available and publicly accountable complexes of reasons with which one might seek to justify organizational actions. Such 'rationalities' when considered collectively may be seen as 'modes' of rationality. No assumption of 'unity' or 'coherence' should be read into this designation. It is quite conceivable that organizations, and the agents located in and around them, may construct diverse and simultaneous rationalities which cohere neither across space nor through time. Modes of rationality are built out of locally available conceptions which embed economic action. These may be derived either from local custom or practice, as these have been shaped either by culture or by the institutional framing of available vocabularies of motive.

The debates on 'flexible specialization': linking power and technology

Many criticisms have been made of the idea that flexible manufacturing systems may be ushering in a new era of organization. To the extent that these criticisms hit either of the deterministic and instrumentalist arguments on the head, they are quite right to do so. Unfortunately, in so doing they often use too blunt an instrument, with equally deterministic effects. Under appropriate environmental conditions, it will be argued, where institutional frameworks restrict the free play of managerial discretion and labour market functioning, rather than new technologies being introduced to de-skill workers they may be the vehicle for enhanced skill formation and participation on the part of the organization's labour force. Or they may not.

There are three broad positions in the debates on flexible manufacturing systems. These positions may be characterized as: one of neo-romanticism; one of neo-managerialism and one of neo-Marxian critique. The latter two we have already encountered as instrumentalisms of managerialism and of power, respectively. While managerialism posits a neutral instrumentality and Marxianism a negative instrumentality there is also a position which advocates a positive instrumentalism. This is the neo-romantic position marked by the triumph of optimism over realism. A fourth position builds

on the power terms sketched above, linking them with a view of organizations as arena around and within which various forms of knowledge will be utilized by agencies seeking, with variable effectivity, to secure what they take to be their interests. Unlike the other positions it begins from no a priori assumption about whether or not the technology of flexible manufacturing is 'a good thing' but looks instead to analysing how, and through what variables, configurations of power/institutions structure empirical instances.

Neo-Romanticism

The neo-romantic argument derives from the contribution of Piore and Sabel (1984), with their insistence that we are at a critical divide in human history, one whereby the utopian aspects of community lost with the nineteenth century demise of craft work in domestic industry may be regained. The romanticism resides in this retrospective vision. At base their theory is consumption-driven. It contrasts the modernist regime of mass consumption through standardized markets premised on mass production bureaucracies organized around low trust relations with changes which began to occur in the late 1970s. By this time a conjuncture of several factors made the absolute ascendancy of the older production regime impractical. Amongst these factors were numbered the continuing post-1974 recession and the increased competition from Japan and the other NICs. It was from Japan in particular that the new ideas were to gain their legitimacy.

What was in question was the 'mass' base in both production and consumption of the previously ascendant system of organizing economic action. On the one hand Japanese manufacturers seemed to be outflanking other Western manufacturers with their emphasis on high quality and product differentiation; on the other hand the West seemed unable to respond competitively to the extent that it remained wedded to a mass production, low profit margin and standard product system. Moreover, aspects of the mass production system itself seemed to be increasingly dysfunctional – notably the costs associated with inventories and fault rectification.

The market changes emanating from Japanese product competition are the key to understanding flexible manufacturing in the Piore and Sabel account. A more consumer oriented and differentiated market meant that flexible organizations would steal

a competitive edge. The term 'flexible specialization' is thus introduced to characterize such organizations. The 'flexible' aspect refers to the restructuring of the labour market and the labour process, while the 'specialization' aspects refers to the ascendancy of niche or specialist markets and marketing, as opposed to mass markets. It is the 'push' of the latter which is seen to require the response of the former. Changes to more differentiated consumption cause production changes away from organizations based on tight managerial control through surveillance, de-skilling and mechanization (Smith 1989: 204). As Sabel (1982: 220) initially proposed it, these changes would be in the direction of a new type of 'high technology cottage industry' in which craft forms of production would be enveloped by new forms of technology, fostered by local state initiatives. The Benetton-type models of Emilia-Romagna are the paradigm case. In the collaboration with Piore (Piore and Sabel 1984) this is extended somewhat to also include not only high technology cottage industry but also restructuring mass production industry which is adopting new technologies and new practices, premised on new forms of knowledge. This element of the theory is reminiscent of some of Bell's (1974) views about 'post-industrial' society. Smith (1989: 210–11) sees a distinct shift from Piore's (1986) utopian romanticism of 'high technology cottage industry' to a more contemporary romanticism in Piore and Sabel's (1984) adoption of the ideology of 'corporate community and solidarity'. In the later work the focus is not on small business and craft production but on the engineering, industrial relations and production restructuring of Boeing, General Electric, GM, and Ford to meet the Japanese challenge. At the heart of this restructuring will be flexible specialization enabling a new organicism as a haven in the hitherto heartless world of large organizations. They propose that organization is increasingly coming to be characterized by flexible, market-responsive manufacturing based on generalist skills and technologies rather than ones which are highly differentiated. Later still, in Katz and Sabel (1985) and Piore (1986) the major blockages to the realization of this new organicism are argued to be labour institutions which have not changed to accommodate the new production systems, as they have in West Germany and Japan. The synthesis of worker and employer interests in the 'flexible specialization' typology, suggests Smith (1989: 210), is resolved in favour of the employers. With Pollert (1988) he is equally sceptical about the extent to which there is a marked tendency towards

product diversification in mass production industries such as industrial foodstuffs.

The determinism of the neo-romantic argument is in seeing the product-market determining organization restructuring and the spread of flexible specialization.

Neo-managerialism

The neo-managerialist writers are preponderantly British, characterized by the work of writers such as Cross (1985) and the National Economic Development Office (NEDO) Report of 1986. Whereas the neo-romantics tend to emphasize the forces of consumption and the product market, and the neo-Marxians tend to emphasize the forces and associated relations of production, the neo-managerialist school takes on board both production and consumption as forces pushing towards flexibility.

The emphasis on consumption is similar to that found in Piore and Sabel (1984). In order that organizations have the flexibility to respond to changing market conditions they have had to develop a core of committed and flexible employees, on the model of 'Japanization'. Consequently, employment security has been developed for the strategically contingent elements of the workforce at the same time as there has been a peripheralization of other workers into casualized or part-time employees who are mainly female (see the excellent discussion by Lever-Tracy 1989). Company specific skills are developed for the core workers; as a corollary of this employers invest heavily in training costs which they protect, as an investment, through offering the core workers security, retraining and every opportunity to integrate into an organization culture. Peripheralized workers by contrast are usually unskilled and enjoy none of the benefits of those in the primary sector. Management is simply responding to changed patterns of rational choice in the market by changing its rational choices concerning the arrangement of organization and production relations.

The more technologically determinist version of the managerialist argument even denies agency to management, while others would allowed least some 'strategic' choice. Technology determines the structure of organizations and management has little or no role to play in it other than to respond to the dictats of contingencies. For Blauner (1964: 9), often labelled a technological determinist, the

single most important factor that gives an industry its distinctive character is its technology, which sets limits on the organization of work. Child has argued that the relationship between technology and structure is correlational but not causal (Child, 1973). Argyris (1972) is in accord with Child when he argues that there is choice in the determination of organization structure and that choices will reflect the interests of those with the power to make the choices. Child (1972) argued a case for focusing on social action in the labour process, on the work itself, the planning and ordering of work and its meaning for those involved. Latterly Child (1984) has concentrated on management's strategic purpose in technical change, noting that managers normally have several goals in mind when introducing new technology. The emphasis between these is likely to vary according to the priorities and purposes of their organization and the context in which it operates. This is the classical contingency view and represents state-of-the-art contemporary managerial theory. It certainly does not ignore politics nor does it assume that the process of technical change is inevitable and politically neutral. It comes close to the neo-Marxian views of more critical writers in the versions developed by Child.

Neo-Marxian critiques in the debate on flexible specialization

The neo-Marxian critique connects concerns which have found expression in the 'labour process' debate with the more recently developed debate on flexible specialization. In doing so it has taken off from a number of contributions from French theorists of the 'regulation' school, notably the seminal contribution of Palloix (1976). From this perspective the phenomena which writers like Piore and Sabel concentrate on do not represent a 'great divide' between epochs, but rather some significant shifts of emphasis which occur, however, within the same framework. For this reason they refer to neo-Fordism rather than to post-Fordism. The phenomena of more collective working and skill enhancement are seen as new techniques of control, in which managerial prerogatives remain unchallenged and in which workgroup autonomy becomes an internalization into the collective workers of what had hitherto been external surveillance (Coriat 1980: 40). Company interests will predominate in any restructuring these writers suggest.

Old and familiar themes about the incorporation of workers, their integration into the organization, and the cunning of capital

in coming up with new technology to further the intensive exploitation of the workforce: these are the themes which come through the neo-Marxian literature on new forms of flexible manufacturing. Neo-Fordism, for writers like Aglietta (1979), represents a capitalist solution to scientific management's greatest problem, from the capitalist's point of view. The problem is how to regain, re-utilize and re-control the workers' formally excluded but tacitly traded-on knowledge of the production process, and use it in order to further capitalist restructuring.

For the neo-Marxian school the major explanatory focus, not surprisingly, is on production relations rather than product markets. Neo-Fordism solves the contradictions which the previous Fordist regime developed and was unable to resolve. The major contradiction was that the Fordist regime had reached the limits of its ability to increase productivity. Without somehow re-integrating the active consent and knowledge of the workers back into the production process Fordism had run up against the obstacle of its own design. This became apparent as labour productivity began to slow down in the 1960s and 1970s, as the post-war long boom wound down. It was in those countries which developed new forms of accumulation regime, based on enhanced participation by the workers, notably Japan, that productivity increases were gained. This pointed the way to a new accumulation regime which had effected a temporary resolution of capitalism's contradictions, as they had developed in the previous regime. At its core was the material technology of new productive forces, the flexible manufacturing technology of CAD/CAM, for instance, as well as changed relations of production which incorporated rather than alienated the worker.

A number of critiques of the idea that organization through flexible specialization offers anything that is at all novel have been developed in the neo-Marxian literature. Amongst these are contributions by Williams *et al.* (1987), Pollert (1988), Bramble (1988), and Hyman (1988). There is almost universal agreement that trade unions have exercised little influence over the process of technological decision making and new work organization (Cressey 1987; Daniel 1987; Deery 1987; Dodgson and Martin 1987; Willman 1986). As Deery (1989) notes, there have been some exceptions where unions have been able to negotiate agreement safeguarding jobs and protecting skill levels, but even the provision of statutory rights has done little to guarantee effective participation in the introduction of new technology (Cressey 1987;

Tallard 1988; Levie and Moore 1984). Technology agreements reached in Denmark and Sweden did not give unions any substantial influence upon the introduction and use of new technology. The main gain was that they imposed a duty on the employers to inform employees about any major technological change 'in due time' before it took place (Bansler 1989). In Sweden a bill was passed but it did not limit management's right to manage in any substantial way. Unions are rarely seriously involved in organizational decision making (Wilson *et al.* 1982). As Manwaring (1981) notes, 'Unions have been largely unsuccessful in securing a share of the benefits from new technology'. Any influence made informally over technological change has come by stealth (Moore and Levie 1985; Wilkinson 1983).

While managers report that they see participation as 'complementary' to their right to manage and not a challenge to their power (Cressey *et al.* 1981), they want to retain the initiative in decision making and complete discretion over subject matter. Participation means 'Telling workers what the needs of the business were [and] persuading them to accept the new technologies and new working practices that went with them' (Edwards 1987). Neo-Marxian arguments claim that management have not attempted to maximise discretion and minimise control, trust workers' judgements, hold positive assumptions of workers' reliability, or allow self organization. The emphasis in technical change programmes is on educating the workforce, not in involving them in the decision before it is made – that is a managerial prerogative. All is under managerial control. Who does discretion lie with during technical change? – certainly not the workforce, they would argue. Why should managers experiment with unproven techniques of control that can be both threatening and problematic and which can lead to a deterioration of their power and a reduction in their control? Pollert (1988), for instance, in common with Shaiken *et al.* (1986) in the United States and Bramble (1988) in Australia, argues that in practice (rather than in the ideological theory of writers like Piore and Sabel (1984)), microprocessor technology has been used to deskill work under the guise of flexibility. The tendency is to see new technology in the service of some old objectives of class exploitation.

At the core of these neo-Marxian critiques is the grave suspicion that flexible specialization is simply yet another instrument by which capital can further exploitation of workers. It will do this through speeding up the pace of work and intensifying it,

increasing work related mental stresses and physical strains; through creating a new labour aristocracy of core, skilled workers and a growing periphery of de-skilled workers who receive none of the high trust/high power/high responsibility trade-offs of those incorporated in the core. The union movement is thus seen to be split as the workforce is split, between those prepared to go down the 'new realist' route of flexibility and those who, unable or unwilling to make single industry deals or become quasi-enterprise unions, can only represent workers whose position is in relative decline. Above all the critics condemn 'technocratic optimism' but unfortunately they often do so through 'relapse into old ideological stances', as Badham and Matthews (1989: 247) suggest.

Flexible manufacturing, power/institutions

Within organization theory generally it is now widely recognized that there is more than one way to achieve goodness of fit between technology and structure, and that the way chosen may well be for reasons of power as much as efficiency (e.g. Child and Tayeb 1983; Child 1984). The intersection of institutional factors with power in the delimitation of these choices comes out quite clearly in comparative work on 'flexible manufacturing systems' (FMS). These are automated self-contained cells of machine tools controlled by computers (Computer Numerically Controlled – CNC – machines) which increasingly are being used in Japan as the technological base of flexible manufacturing (Jaikumar 1986). The technology of FMS is not confined to Japan, however, although their utilization is much greater in this country than elsewhere, other than Sweden. (Why Sweden should be so far advanced in its adoption is another question for which there really is not the space to provide an answer here. Suffice to say, however, that where a conjunction of power/institutions has made Swedish labour amongst the most powerful and expensive in the world, then Swedish employers have ample incentive to minimize its cost in their enterprises.) In the United States Kenney and Florida (1988: 140–1) point to the fact that there are half the number of FMS systems compared to the situation in Japan. Japanese systems had much higher rates of capacity utilization (84 percent as opposed to 52 percent with some used untended on a third shift bringing utilization up to 92 percent). What was most striking was the quite

different ways in which the same technology was being used in the two countries:

> U.S. corporations were not using FMS to accomplish what it is supposed to. The U.S. companies used FMS to produce relatively standardized parts rather than to produce high volumes of a wide range of parts. The average number of parts produced by FMS in the United States was 10; in Japan it was 93. The annual volume per part in the United States was 1.727 versus 258 for Japan. In effect, U.S. corporations were using FMS to mass produce parts. (Kenney and Florida 1988: 141)

In the United States FMS was used to further the de-skilling of workers, to increase management's power relative to them and to produce large batches of a standardized product. Child (1987) has emphasized that it is unlikely that FMS will produce much organizational difference in such cases of large batch standardized production, particularly, one might add, where the product is one with a low profit margin. It will be only in those cases where there is product variability that one would anticipate significant changes in organizational structuring. The crucial consideration appears to be whether or not the changes in product and methods of production are unpredictable, as Badham and Matthews (1989: 223) suggest. In line with this point case studies conducted by Shaiken *et al.* (1986) in the United States demonstrate that this new technology has been used to diminish the autonomy and the responsibility for planning of shopfloor workers. In Japan the situation has been quite different even though the technology is the same. There it has been used to further re-skilling rather than de-skilling, has been harnessed to multi-level and multi-skilled work teams, has allowed shopfloor operatives to become involved in doing routine computer programming. In short, it has been used to transform workers into 'think-workers' (see Jaikumar 1986). The reasons for these differences should be apparent. Kenney and Florida (1988: 142) spell it out clearly enough:

> Japan's response to restructuring has in large measure been determined by the organizational and institutional arrangements that first emerged in manufacturing. By creating the social space and flexibility in which organizational innovation could occur, Japanese industrial organization has paved the way for a synthesis of production and innovation and for integrating new technologies into manufacturing.

From the perspective on power which has been developed here there is no a priori reason why power and technology should ever be implicated in specific ways in their inter-relation. No necessary mode of rationality of de-skilling or neutrality connects them. The nature of the relationship is likely to be far more open and indeterminate, at least in principle. The difference that is made by adopting this framework is apparent when one comes to consider some recent debates about the relationship of power and 'new' technology associated with flexible specialization in work practices. This is because the nature of the new working practices is tightly coupled to the introduction of new technologies. The different types of work practices are formally different ways of arranging the power/discretion relations within organizations, according to different institutional frameworks of rule-criteria.

The analytical point is obvious. Technology, like any organizational contingency, will not necessarily determine anything. Technological determinism has been a stalwart of organization studies, but clearly it is not time to put the old horse out to grass. It has been flogged near to death and there is little life left in the beast, particularly when exposed to the recent debates on 'new production systems' (Badham and Matthews 1989). What is at issue are situational contingencies and their fabrication in specific modes of rationality. As Badham and Matthews (1989: 201) put it, these contingencies will not have determinate and predictable effects on work organization, even when they appear to unambiguously empower workers:

> For example, effective control over broader production plans and work scheduling, health and safety, forms of social interaction (working conditions) or pay, job security and career paths (employment conditions) may be reduced by a decrease in the individual or collective bargaining power of workers – due to increased unemployment, a lack of an external labour market for acquired skills, a decline in the competitive strength of the enterprise, the use of new technology to replace worker skills, reductions in legislative safeguards, increased managerial strength, a drop in the membership, finances and organizational strength of trade unions, or changes in political parties or politics.

It will depend upon the framework of institutions and power as to how elements in organizational practice, such as technology, are

actually fabricated into modes of rationality. A further case can make the point. Sorge *et al.* (1983) studied the adoption of CNC machine tools in a range of British and West German organizations. They matched the organizations and found that some of the difference in the way in which CNC effected skill polarization and equity could be attributed to organization contingencies such as batch production and firm size. However, there were broader national differences which cut across these. In Germany, in the context of institutional commitments to co-determination, CNC was used in such a way that it developed a common team focus between foremen, chargehands, workers and planners, in a postmodernist prefiguration. In Britain, quite the reverse: here it was used in such a way as to maintain departmental and personnel group autonomy. As Sorge and Streeck (1988: 26) suggest, what is required is 'a concept of how a society or economy is populated by technical and organizational types, and how this population changes over time'.

From the accounts and original source material available in English, it would appear that the approach which Sorge and Streeck (1988) call for, is, in fact, best developed in the West German literature, particularly as it has developed around the contributions of Kern and Schumann (1984). Useful accounts in English include Kern and Schumann (1984), Littek and Heissig (1989), Hoss (1986) and Campbell (1989). It is the latter which is the most detailed. West Germany has been a rich site for a number of organization studies which have built on the fundamental insights of the Aix school into the importance of national-institutional differences in the structuring of organizations, paying particular attention towards systems of education and training and industrial relations in shaping organizational workforce contingencies (Maurice, Sorge and Warner 1980; Sorge *et al.* 1983; Sorge and Streeck 1988; Lane 1988). In addition, in the contributions of Kern and Schumann (1984) it has also had an empirically well-grounded discussion of the flexibility debate.

Initially conceived as a study which would follow up work they had done a decade earlier on de-skilling in West German industry, Kern and Schumann's (1984) *Das Ende der Arbeit-steilung?*, which translates as *The End of the Division of Labour?*, in fact found that in the automobile, machine tool and chemical industries new social phenomena of enhanced skill-formation and restructuring were under way. Whereas in the past, under what the literature is wont to call Fordist auspices, the intelligence of the

worker was only tacitly acknowledged, often oppositional and frequently marginalized, new forms of re-structuring in the core sectors of the economy are producing new forms of work organization and 'new production concepts' in which the intelligence of the workers is implicated and enhanced rather than opposed: 'The skills and expert competences of the workers are productive forces that should be more fully utilized' (Kern and Schumann 1984: 19; translated by Campbell 1989: 255). This is occurring through a re-skilling of production work into tasks requiring broad and multi-skilled personnel. In the automobile industry this is due to task re-structuring into more integrated processes; in the machine tool industry it is due to the opportunities for skill enhancement opened up by CNC machines; in the chemical industry the production workers are becoming more professionalized, developing a 'more comprehensive knowledge and competence in the mechanical as well as the chemical area, so that more extensive repairs and corrections can be made without calling in specialist teams' (Campbell 1989: 256). In common is a process of enhanced and concentrated skill-formation creating a new type of worker through greater training, one who is qualitatively different from the craftsperson ideal, by virtue of being far more tightly coupled into an overall structure of managerial control.

Several factors are utilized to explain the shift, including the stress now familiar from Piore and Sabel (1984) on the product market. However, implausible romances concerning craft labour are avoided and additional factors are highlighted. These include changes in the labour market, due to the development of structural unemployment, which strengthen managerial control. Rather than utilizing this in the oppositional way of the past, at least in the core sectors of core, high-margin organizations in the economy, the emergence of new technology, through a major increase in the ratio of constant capital to the variable capital of labour power, means a more facilitative attitude towards the latter is possible. Indeed, it is necessary if costly interruptions to production are to be avoided and because the new processes require a far more skilled workforce – even in the interstices of the new technology (Campbell 1989: 257). However, this re-structuring cuts two ways: just as a core of more privileged workers are produced, others, by virtue of industry and organizational location, and perhaps as a result of discriminatory characteristics and human capital formation deficiencies on their part, will be consigned to the underside of the

new labour market segmentation. The two tendencies are not unconnected as aspects of capitalist re-structuring.

One aspect of the Kern and Schumann (1984) argument is the need to recognize that there are political struggles in and between management as to whether new production concepts will be introduced. They advocate that the labour movement, rather than opposing change, should seek strategic alliances with the progressive forces in management, and hasten the development of the productive forces and social relations in and of production. In effect, what they are recognizing is that the traditional Marxian conception of the politics of production as being a zero-sum game is no longer very useful. Under conditions in which returns both from and to labour depend far more on the formation of skills and capital than they do on extensive exploitation of brute labour power, the zero-sum conception of the labour process as a locus of class struggle has little other than a rhetorical purpose to play. Not only is it the case that the politics of production can give way to the production of politics in the political arena, through the practices of political trade unionism and bargained corporatism (see Boreham and Dow 1986; Boreham *et al.* 1986), it is also the case that the workplace level negotiations may produce win-win situations for both labour and capital in terms of the conditions under which they operate. Certainly, such changes do not seem to hasten the revolutionary impulse or refresh the jaded palate of those many workers blasé to the requirements of class struggle. The past history of labour relations and democratic politics in the advanced societies should serve to make us very sceptical about not only the potential of past politics and modes of struggle as means of delivering these outcomes but also the extent to which there is any broad-based support that these are desirable means or even outcomes. Nor should one readily have recourse to arguments of hegemony to save the means and the ends from the indifference of those whom they are represented as serving, as has been argued at length elsewhere (Clegg 1989b).

Kern and Schumann's (1984) suggestions for how trade union policy should be developed with respect to the opportunities of 'flexibility' calls for the following strategies:

1. concerted use of the broadened total mass of skilled functions associated with the new technologies in order to establish complex work definitions for as many workers as possible.

2. influence over the entry requirements for the new areas in order to lessen competition and division in the workforce.
3. creation of appropriate and satisfactory replacement jobs for those displaced when new technologies are used to abolish restrictive jobs.
4. development of training processes based on a comprehensive concept of qualification, distinct from the process-specific demands of individual situations in the workplace. This implies an orientation to autonomous professional work and an acceptance of the applicability of the acquired knowledge and skills outside the workplace.
5. disclosure and regulation of new performance demands, in order to prevent any one-sided determination on the part of management and to avoid any blocking of the possibility of more comprehensive job definitions as a result of pressures for intensification. (Campbell 1989: 261)

Campbell (1989: 273) makes some salient criticisms of implicit aspects of Kern and Schumann's (1984) approach. They are dealing with tendencies and whether or not these tendencies will be epoch-making is a matter of empirical rather than theoretical conjecture. Too much emphasis should not be placed on the managerial control of the labour process: labour may well be a marginal cost in many high technology industries and hardly the central focus of strategic attention. It is not only questions of managerial control and labour autonomy which are at issue but complex issues of production more generally.

Analytically, the writers who have come closest to capturing the distinctive processes involved in the technological core of the new production systems, conceived as the central focus of putative postmodern organizations, are Badham and Matthews (1989). Building on the work of writers including Child (1987), Perrow (1971) and Sorge and Streeck (1988), they construct a model of three dimensions which will be at the centre of any bargaining between representatives of management and labour in struggles over the shape of organization.

Badham and Matthews' (1989: 207) model is constructed in three-dimensional space, built around the degree of: product innovation; process variability, and labour responsibility. Product innovation is identified by the frequency with which products are changed and the degree of variation between products. Process variability is identified by the frequency and degree of changes in

production methods, and the degree of difficulty, in terms of the learning time that new systems require, that such switches entail (Badham and Matthews 1989: 212). The dimensions are conceived as capable of changing independently of each other, although being only relatively autonomous; that is, they are not wholly independent but each sets variable limits upon the other.

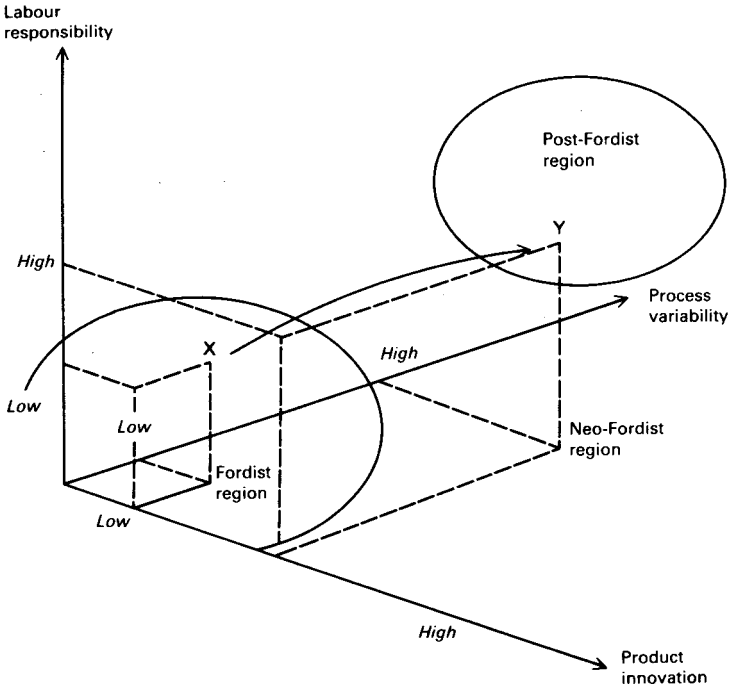
Conditioning the limits of relative autonomy of these two dimensions are the power/trust relations which Fox (1974) conceptualizes as mediating between management control and employee consent. As is well known, these can be highly variegated from high trust/high discretion configurations down to the low trust/low discretion configuration which is so conducive to a 'vicious cycle of control' (see Clegg and Dunkerley 1980: ch. 9).

A number of environmental variables will effect the calibration of organizational control as more or less premised on the polarities of either high trust/high autonomy/high responsibility or low trust/low autonomy/low responsibility. Conditioning the use of these will be not only specific substantive features of the occupational groups in question, such as their strategic contingency, but also more general aspects of the political configuration, particularly as these are focused on conceptions of 'citizenship rights'. These can be more or less restricted with respect to the spheres of industrial and economic democracy. The obvious case in point would refer to Sweden (see Clegg *et al.* 1986: ch. 9), where these rights are most extensive. Together with questions and labour market structure (solidaristic vs. segmented), the issue of citizenship will be closely related to the organizational capacities of the labour movement, and issues of how much organizational slack is available in the resources which they, and other participants, are prepared to commit to the organizational arena in question.

Any organization, sector or industry could be characterized in terms of this model, either in terms of its production process (where it actually is operating at any given point in time) or its production strategy (where its preferred operating point would be at some future point in time). The concept of production process refers to the performance of a number of functions associated with design, co-ordination and manufacture (Kaplinsky 1984). These functions include 'the combination and organization of raw materials, equipment and personnel to design, plan and manufacture a product' (Badham and Matthews 1989: 209).

The notion of production strategy represents the outcome of those processes which determine the boundedly rational calculation

Figure 1 *Badham and Matthews' production system model (Badham and Matthews 1989: 207)*



of more or less coherent and preferred goals by the mandators of the organization. A decisive element in the setting of limits and possibilities on the boundedness of the incremental processes involved in formulating these strategies will, of course, be the power of other strategic actors in and around the organization, as well as the institutionalized acceptance of what is possible, desirable and rational in terms of the cultural capital implicated in the process. The sources of these are many, involving not just state organization specifications (such as might derive from instrumentalities responsible for health and safety, equal opportunity, restructuring and so on), but also from professional/occupational conceptions of rational desiderata, as well as from other key actors such as the various media of information transmission in consultancies, universities, journals, magazines and other media. Some researchers, such as Perez (1985), would include in this list of

institutional factors overarching architectonic forces which are regarded as clustering distinct 'techno-economic paradigms' around key points in long waves of technological innovation. Postmodernity would thus be characterized through the structuring and keying provided by the relative availability and cheapness of new microelectronic information technology, much as the availability of cheap oil was the architectonic point of the previous long wave. One does not have to accept this more macro perspective in order to see that it is through processes of power/institutions that possible rationalities which connect processes and strategies are negotiated and fought over. The 'long wave' view merely provides an epochal explanation of the availability of modes of rationality in their historical specificity.

In the model, point X represents a production process with medium levels on all three dimensions, while Y represents a production strategy whose preferred options are high on each dimension. Given these notions of production process and strategy the model is amenable to an overall conceptualization in terms of embedded modes of rationality. Crucial to these will be the negotiation of not just material aspects of production, such as product innovation and process variability, but the far more complex and indeterminate matter of labour responsibility, or what Fox (1974) terms power/trust relations. It is on this axis that the relative success or failure of the two more material dimensions will depend.

Specific points linking production processes and strategies will point to specific modes of rationality structuring organization around the technical core. In the model as illustrated three distinct modes are represented: the Fordist, the neo-Fordist and the post-Fordist, each associated respectively with consistently low, medium and high positions on the three dimensions. With this model in mind, much of the dispute which has occurred in the literature falls into place. Those theorists such as Pollert (1988) who regard flexible manufacturing systems as simply another instrument of worker control, de-skilling and labour degradation, may well be accurately characterizing their use when implemented under a neo-Fordist mode of rationality, as Badham and Matthews (1989: 208) suggest:

> Aware of the flexible potential of new technologies, and of the need for limited forms of worker responsibility, managerial strategies in this area will be focused on further developing

technology in a direction that overcomes short term needs for increased worker skills and responsibility.

The interest of a labour movement, one would anticipate, would be in moving as much of national enterprise as possible towards the post-Fordist axis. Research evidence suggests that the dice may be loaded against this move – but to know how the dice are loaded is a first step in seeking to develop ways of playing the game despite the handicap. If we are moving into a period of flexible specialisation it is still in an early period and the implications for jobs, work organization and skills are still uncertain. Research evidence showed how managerial intentions towards deskilling were limited. Shaiken *et al.* (1986), Buchanan (1986) and Wilson (1987) have all outlined different ways in which new demands were made on the workforce – programs needed to be debugged and the production process monitored. Workers' knowledge was essential to all this. Their knowledge was not somehow 'outside' the circuits of power which framed work but was institutionally integral to it. Perrow (1984) had previously offered several entertaining and frightening illustrations of the disastrous implications of ignoring the workforce role in automated control systems in power generation, aircraft and ship navigation systems. Management intentions are often unrealistic (Towill 1984), impractical, unrealistic, resisted and not always fulfilled (Noble 1979; Buchanan 1982; Wilkinson 1983; Burnes 1984).

Wilson and Buchanan (1988) argue that there will be a general tendency towards deskilling where products and processes make this possible. This is too deterministic: what is crucial is the configuration of power framing particular settings. Where deskilling does occur their research suggests that the experience will be similar for workforces from different plants. Introducing new technology gives managers an opportunity to redesign work and deskill where they find it possible or advisable to do so. The worker may only be trained to the point where he/she can carry out the revised operations. As the neo-Fordists argue, the new skills may not be transferable between companies. Hyman (1988) notes 'Delegated management does not equal self management nor does an expected portfolio of competences equal enhanced skill'.

Delegated management depends upon workforce commitment. The old adversarial relations, bred in the great legends of the industrial class struggle, are not likely to provide an appropriate

basis for (post?) modern times. Workforce commitment has become a central concern because of the need to involve employees not only in developing the skills needed to operate technology effectively but also to participate in quality circles. These add to workers' list of responsibilities that of quality control, as part of planning to bring about Total Quality Management and place new demands on them. Rather than perceive these quality initiatives as an example of power sharing, as one might from a zero-sum power perspective, it might well be more appropriate to regard them as another potential circuit for more power to flow through, for new disciplinary practices to develop and through which empowerment may possibly occur. Quality circles can be empowering or disempowering: the usefulness may be only in as much as they allow management to make use of the detailed knowledge held by the workforce, in the diagnosis and solution of production or quality problems. However, by contrast, Watanabe (1990) has argued that quality circles can be introduced to counteract the simplification of jobs and the alienation of workers. For quality initiatives workers have to give more in the employment relationship. Workers are unlikely to invest time and effort if the only reward is psychological (Jones 1983). Where will the incentive to participate be if the reward is negative, if, for example, job times or rates are revised thereby cutting the wage effort ratio (Wilson 1989)?

It is important to parcel out changes in work techniques and not treat them all as a package. With just-in-time production methods (JIT), for example, it can be argued that the philosophy represents the intensification of Taylorist methods of work organization (Schonberger 1983: 193). Management are more able to pinpoint areas of slack production and as Shaiken *et al.* (1986) argue JIT offers the opportunity to introduce assembly line pacing into batch production areas which were previously subject to a degree of operator control. Evidence collected by Bramble (1988) from the Australian Metal Industry shows how JIT allowed management to increase their surveillance and intensify control. The outcome for the production workers was the steady intensification of work, the widening of routine operations performed by each person and a reduction in manning levels.

The upsurge of interest in participative schemes in the 1980s could be seen as a response by management to economic and industrial decline paraphrased crudely as 'let's all pull together or we'll pull apart' (Marchington 1982). Ramsay (1977) has argued

that when management face a crisis, usually as a result of external economic threats, participation schemes have been developed in order to secure the compliance of workers. A decline in the threat usually coincides with a waning of interest in participation. Any 'lifeboat democracy' is extremely fragile and will come to grief on the rocks of managerial prerogative (Cressey and McInnes 1985).

Perhaps the same could be said of some quality initiatives? The increase in autonomy that these bring about may foster the belief in the workforce that they are participating in a process which reflects their needs, abilities and choices when this is clearly not the intention of the management. How important are these objectives, however? If the objective of senior managers is to make steady and high profits, to mobilise consent for increased productivity, not to attend to workers' needs, does this matter if in the process they create new conduits of power which can be utilized productively by the workforce?

Conclusions

The locus of control cannot always be moved from workers to managers during technical change nor from managers to workers. Control ultimately does lie with management and is a prime managerial objective but not because managers are necessarily tyrants seeking to dominate workers. (Some may be! – often with disastrous results for their organizations.) It is managers who are held responsible for organizational control in its various forms, at its various levels, in its various disciplines. Thus, they are implicated in circuits of power whether they intend it or not. It is this which makes them the conduits through which accountability flows for various organizational actions: for instance, increases in productivity and the reduction of uncertainty in the production process (Thompson 1967). Job design researchers have demonstrated that increased skill and discretion of the workforce in general are not incompatible with effective organizational control of production. If these forms of organizational empowerment can bring about greater productivity why is it that managers have not utilised this line of reasoning more often?

There is no system of managerial control that can completely eliminate the discretion of the employee (Clegg 1981) and there are no authority relations which can fully command obedience. All depends on the subordinates' preparedness to bend to managerial

control and management's success in securing the kind of power-circuitry which enables them to do so. The argument of this paper has been that it may well be a conceptual error and handicap to see these as necessitating a zero-sum power relation. Postive-sum outcomes which are not simply a result of manipulation but which offer potentially fruitful contingencies and real politics are possible if we can only see them. To see them means abandoning deep-grained analytical prejudices about power. Correlatively, it means that we have to re-think organizations as well.

Organizations will not necessarily become neo-romantic utopias, as proposed by some perspectives occluded by their interpretation of what turning Japanese entails. It is not like that there and its misinterpretation is not going to create the myth as reality elsewhere. Nor are organizations necessarily perfectable neutral vessels through which can flow like manna the pure reason of efficiency and effectiveness, couched wholly in technical terms. Organizations are always composed of social relations. Nor are organizations to be necessarily conceived as anvils designed as forms upon which the working class can be endlessly hammered into submission by the blows of managerial power and prerogative. Power is not wholly equivalent to structurally given opportunities for brute force. On the contrary the contingencies of both power and organizations are complex, interdependent and, to a point, potentially capable of change. Of course, they will be more so in some institutional frameworks than they are in others but that remains another story (Clegg 1990).

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