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MAPPING THE DYNAMICS OF SCIENCE AND TECHNOLOGY

Sociology of Science in the Real World

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MICHEL CALLON

INTRODUCTION

If laboratories and research sites are to the twentieth century what monasteries were to the twelfth, then the sources of their power and efficacy remain a mystery. How is it that the ideas and writings that issue from these institutions are able to revolutionise, if only gradually, conditions of work in industry, the universe of consumer goods and lifestyles? How are the discoveries made in Stanford, Gif-sur-Yvette, and Cambridge diffused such that they become universally known and recognised? How are certain technical devices, shaped in research departments of French or English companies, able to conquer markets throughout the world? Anthropological studies of the laboratory have shown that nothing exceptional occurs within the walls of research centres themselves which could account for their influence. These studies have also shown that the force and generality of results obtained cannot be attributed to the existence of a specific scientific method (Latour and Woolgar, 1979; Knorr-Cetina, 1981; Lynch, 1985). Though scientists give certain activities a higher priority than others (see Chapter 3), the former do not possess greater rigour or a logic which enable an observer to distinguish them from the latter. In addition, the study of controversies has discredited the view that science and technology are free from any influence other than the intellectual (Collins and Pinch, 1982; Shapin, 1979; MacKenzie, 1978). Rather, they are impure and heterogeneous. If the hesitations, changes and evolutions that mark their development are to be understood, then interests,

strategies, and power relationships which do not stop at the laboratory door must also be brought within the scope of analysis. In sum, though science and technology develop in some measure apart from the rest of the world, they are neither detached nor fundamentally different in nature from other activities.

The power of science must thus be explained in another manner. Yet though sociology and anthropology have played a decisive role by describing the detailed content of scientific practices and have undermined a range of classical assumptions about science, they have unfortunately failed to account satisfactorily for its undeniable influence. This is because they have sought to explain its origins and success in terms of supporting political interests (MacKenzie, 1978), resources gathered by researchers (Latour and Woolgar, 1979; Knorr-Cetina, 1981), or pressures of economic demand (Hessen, 1971, Yoxen, 1981). In short, they have searched for the causes of scientific power not within science but rather within the surrounding society. Unfortunately, these explanations are inadequate for, as is shown by an increasing number of studies, the development of scientific knowledge and technical systems cannot be understood unless the simultaneous reconstruction of the social contexts of which they form a part is also studied (Latour, 1984; Callon, 1980b, 1981a; Law, 1985b; Pinch and Bijker, 1984).

In order to uncover the mechanisms of power of science and technology, it is therefore important to reveal the ways in which laboratories simultaneously rebuild and link the social and natural contexts upon which they act. In this chapter we present three concepts which make it possible to analyse this 'co-evolution' of 'society', technological artefacts and knowledge of nature. The three concepts are those of the actor-world, translation and the actor-network.

ACTOR-WORLDS

Let us start, then, with a short detour, by posing a question that is of perennial interest to sociologists: of what and of whom is society made up? Sociologists often believe that, as a profession, they are better able to answer this question than others. Are they not social specialists who know how to juggle groups, classes, orientations, habitus and power in order to explain and predict behaviour?

However, scientists and technologists constantly undermine the knowledge and competence of the sociologists. This is because they are

continuously rebuilding society by introducing unpredictable variations and new associations. Furthermore, it is from these variations and associations that they draw their power. More than any other kind of actor, technologists may be sometimes endowed with the capacity to construct a world, their world, to define its constituent elements, and to provide for it a time, a space, and a history. (Latour, 1984; Hughes, 1983). To illustrate this ability we will follow the development of a technological innovation that was thought to be of major importance in France during the early 1970s: that of the electric vehicle, the VEL (véhicule électrique).

In 1973, the EDF (Electricité de France) presented a plan for the VEL that not only determined the precise characteristics of the vehicle it wished to promote, but also the social universe in which the vehicle would function.

First, the EDF defines a certain history by depicting a society of urban, post-industrial consumers grappling with new social movements. The motor car occupies a highly exposed position, for it forms part of the world that is under attack. Thus it serves as a point of departure for the construction of far-reaching and radical demands which will lead to a future that may be discerned only with difficulty. The internal combustion engine is the offspring of an industrial civilisation that is behind us. The Carnot cycle and its deplorable by-products are stigmatised in order to demonstrate the necessity for other forms of energy conversion. On the one hand, the motor vehicle is considered responsible for the air pollution and noise that plague our cities. On the other hand, it is irretrievably linked to a consumer society in which the private car constitutes a primordial element of status. However, electric propulsion will render the car commonplace by decreasing its performance and reducing it to a simple, useful object. The electric car could lead to a new era in public transport in the hands of new social groups which are struggling to improve conditions in the city by means of science and technology. The goal would be to put science and technology at the service of the user, and to do away with social categories that attempt to distinguish themselves by their styles of consumption. The EDF has based this vision on an evaluation of the trajectories of development open to different types of electrochemical batteries.[1] Firstly, public transport could be equipped with improved lead accumulators. Then, accumulators and fuel cells could open up the larger market of private transport by enabling the VEL to reach speeds of up to 90 km/h.

By predicting the disappearance of the internal combustion engine due to the rise of electrochemical generators and by ignoring traditional

consumers so as to better satisfy users who have new demands, the EDF has not only defined a social and technological history but also identified the manufacturers that would be responsible for the construction of the new VEL. The CGE (Compagnie Générale d'Electricité) would be asked to develop the electric motor and the second generation of batteries, and to perfect the lead accumulators to be used in the first generation of the VEL. Renault would mobilise its expertise in the production of traditional automobiles in order to assemble the chassis and make the car bodies. The government would also be enlisted: this ministry would formulate regulations favourable to the VEL; that ministry would subsidise those municipalities interested in electric traction. The list goes on: companies that run urban transport systems would cooperate with research centres, scientists, etc. The EDF has defined the roles, and then attempts to enrol other entities into them.[2] It binds the functions of these roles together by building a world where everyone has his own place.

Up to this point, the entities are ones familiar to the sociologist. There are consumers, social movements and ministries. But it would be wrong to limit the inventory. There are also accumulators, fuel cells, electrodes, electrons, catalysts and electrolytes. For, if the electrons do not play their part or the catalysts become contaminated, the result would be no less disastrous than if the users rejected the new vehicle, the new regulations were not enforced, or Renault stubbornly decided to develop the R5. In the world defined and built by the EDF, at least three new and essential entities must be added: zinc/air accumulators, lead accumulators, and fuel cells with their cohort of associated elements (catalysts, electrons, etc.).

But just a moment. EDF is not an actor that is faced with new and unfamiliar technologies or knowledge located throughout society. Neither is it an imaginary construction that might be considered as unrealistic by an experienced sociologist. Nor is it a simple world. There is what we propose to call an actor-world, a world of which EDF, its prime mover, forms a part. EDF puts forward a list of entities and a list of what they do, think, want and experience. These entities are not human alone since electrons, catalysts, electrolytes and lead accumulators are included. These entities act, react and cancel each other out, in just the same way as any others. They may be either individual or collective. Actor-worlds have no favourites and are racialist only by omission.

The actor-world not only determines the repertoire of entities that it enlists and the histories in which they take part. It also determines their relative size. For the EDF actor-world, Renault is no longer a powerful company that seeks to be the largest European car manufacturer.

Indeed, it will never regain that status. Rather, it is reduced to the level of a modest entity that intervenes in the assembly of the VEL. The same is true of the status groups that give way to social movements and their new demands.

The notion of the actor-world makes it possible to describe the contents of technical objects and theoretical knowledge. The VEL is one of the results of the identification and interpretation of entities by the EDF actor-world. The ingredients of the VEL are the electrons that jump effortlessly between electrodes; the consumers who reject the symbol of the motor car and who are ready to invest in public transport; the Ministry of the Quality of Life which imposes regulations about the level of acceptable noise pollution; Renault which accepts the fact that it will be turned into a manufacturer of car bodies; lead accumulators whose performance has been improved; and post-industrial society which is on its way. None of these ingredients can be placed in a hierarchy, or be distinguished according to its nature. The activist in favour of public transport is just as important as lead accumulators which may be recharged several hundred times.

In the absence of one ingredient the whole would break down. If the user were removed this would be just as serious as a failure to ensure the durability of the fuel cells. In both cases the vehicle would stop dead. In other words, the existence of the VEL is bound up with the construction of the actor-world. This particular technical object cannot be understood without considering the fact of its concomitant actor-world. It does not matter whether it is the catalyst that gets contaminated, the consumer who becomes dissatisfied with poor performance, or Renault which refuses to fall into line; if any of these happen the VEL will cease to work and exist. Accordingly, technical objects must be seen as a result of the shaping of many associated and heterogeneous elements. They will be as durable as these associations, neither more nor less. Therefore, we cannot describe technical objects without describing the actor-worlds that shape them in all their diversity and scope. The VEL is just like the actor-world that both supports and is being supported by it. It is scientific, political, and economic throughout. This is because it is a combination of elements borrowed from these different registers which the sociologist claims to be able to distinguish from one another.

Once we accept that the VEL is constructed from this range of heterogeneous elements, the next question to ask is how we can describe its construction. As we have just seen, this is the same as asking how our actor-world is built, for without the actor-world, the technical object would not exist.

TRANSLATION

An actor-world associates heterogeneous entities. It defines their identity, the roles they should play, the nature of the bonds that unite them, their respective sizes and the history in which they participate. But actor worlds must not be represented as shoppers in a well-stocked supermarket choosing what they wish to buy from a pre-established list. Once an actor-world comes into being, it does not draw its entities from previously established stock. It is not constituted in the way a shopping cart is filled. In short, there is no world, or worlds, from which pre-existing elements can be extracted. Nor is there a world which guarantees that the combinations created by the actor-world are realistic. Actors may construct a plurality of different and incommensurate worlds.

Is the world of EDF in 1973 as real or true as any rival construction? Is the fuel cell a fiction? Are the new users who are ready to give up cars with internal combustion engines simply phantoms? Have the interests of the CGE been appropriately analysed? For almost three years everyone is uncertain. The EDF's answers to these questions go unchallenged. Even Renault remains silent, terrified by the possibility of a world that it does not have the power to unmake: a world in which it will have to undergo a difficult process of change. Is the VEL viable? This depends upon the capacity of the EDF to keep Renault in its role, prevent the contamination of catalysts, and render the new demands of consumers durable. But will Renault stay in its subsidiary role? Or will it fight back? In fact, as the story unfolds, Renault does indeed struggle with the EDF; it attempts to build its own and very different world. In short, like EDF before it, it tries what we propose to call translation (Callon, 1975, 1980b, 1985). Translation may be treated as falling into three components.

The Translator-Spokesman

EDF translates Renault, EDF translates fuel cells, and EDF translates consumers. All these expressions signify the same thing. EDF attributes to Renault an identity, interests, a role to play, a course of action to follow, and projects to carry out. EDF characterises fuel cells, the way they work, their performance, and their mode of use. The notion of translation is necessary because this enrolment (in the strict sense of occupying a role) is neither pre-given nor an external (if hidden) reality that a shrewd EDF attempts to understand and capture. Renault can be

something completely different. It might be seen as a car-maker whose future depends upon the development of the petrol-engined vehicle, the automation of the assembly line and the application of electronics to the automobile. But for several years this choice does not exist. Renault becomes a company whose interests and abilities relate to the construction of car bodies for the VEL. Thus EDF translates both the will and the projects of the powerful Billancourt firm just as it translates the needs, expectations, and demands of consumers and the characteristics and performance of accumulators and fuel cells.

The translator is thus the spokesman of the entities he constitutes. EDF speaks in the name of Renault, of consumers, and of fuel cells just as a politician or a political party speaks in the name of the constituents or the social classes he aims to represent. The translator expresses their desires, their secret thoughts, their interests, their mechanisms of operation. This is the most general way of expressing it, for what is true for human entities, whether they be collective or individual, is also true for the other elements that constitute an actor-world. EDF also speaks for accumulators, for cells, for electrons, and for catalysts. By establishing the characteristics of lead accumulators, by describing the behaviour of an electron upon a catalyst, by demonstrating that a cheaper catalyst might replace platinum, by projecting the future of fuel cells and so on, EDF determines the identity of these elements and regulates their behaviour and evolution.

Translation is at first an endeavour. Later, it may be achieved. Thus Renault can block the translation and define its future differently. This, as intimated above, is exactly what occurred a few years later when it published a book arguing against EDF and its VEL. Everything is challenged by Renault: EDF's version of the interests and projects of the car firm, the possibility of constructing high performance cells, the expectations of users, and the doubtful future of the internal combustion vehicle. The actor-world of the EDF, together with the VEL, begin to fall to pieces. Meanwhile, Renault has accumulated electrochemical expertise, made contacts with the administration and obtained evaluations of the reactions of consumers. It is thus able to stop being an onlooker and to counter-attack instead. The VEL existed in 1973. In 1976, it was attacked on all sides and now exists only in the limited form of a commercial vehicle equipped with lead accumulators. Translation becomes treason, *tradutore–traditore*, once an enrolled entity refuses to enter the actor-world in order to expand into others. Since entities are not easily translated, the destiny of most spokesmen is thus to be brutally contradicted.

Translation builds an actor-world from entities. It attaches character-

istics to them and establishes more or less stable relationships between them. Translation is a definition of roles, a distribution of roles and the delineation of a scenario. It speaks for others but in its own language. It is an initial definition. But, as the example of Renault shows, no translation can be taken for granted for it does not occur without resistance. Catalysts, Renault, users, and the CGE are not entities whose elasticity and 'good will' are limitless. The EDF must deal with them and test its strength against theirs. In theory, catalysts make the fuel cells work. In practice, the EDF must reckon with the fact that they may be too expensive or become contaminated (which is what scientists and economists of the Institut français du Pétrole (IFP) constantly tell EDF). In theory, Renault can be transformed and abandon the petrol-driven vehicle in order to be pulled into the actor-world of EDF. In practice, this modification proves to be negotiable only with difficulty. The same is true for the municipalities, the ministries and the users. Translation cannot always be taken for granted, and the strategies used depend upon the particular circumstances in which they develop. Certain municipalities are prepared to accept the role prepared for them and certain electrochemical generators are already available for the VEL. But Renault drags its feet, accumulates resources, and ends up challenging the EDF. Successful translation depends upon the capacity of the actor-world to define and enrol entities which might challenge these definitions and enrolments.

Translation: A Geography of Obligatory Points of Passage

If the success of translation can never be taken for granted, how is it that sometimes it is achieved? This question brings us to the second component of translation: the strategies by which an actor-world, in this case EDF, renders itself indispensable. Renault, the CGE, new users, fuel cells, and accumulators, none of these have any future outside this actor-world. The VEL thus becomes a passageway through which all the other entities that make up its world must pass. To translate, then, is to oblige an entitity to consent to detour.

This is done by choosing from a spectrum of methods that ranges from seduction to pure violence by way of simple bargaining. In the case of science and technology, one of the most generally used strategies may be called problematisation. EDF says to its users: if you want to solve your pollution and transport problems we must first create an electric vehicle. But if we are to solve the problem of how to build an electric

vehicle we must first solve the problem of the short life of the electrochemical power sources that will be needed to equip the electric vehicle. Research institutes can extend the translation further: to improve the performance of electrochemical sources of power, you must first pass through our laboratories and scientific teams which are studying hydrogen catalysis on platinum surfaces. The translation thus maps out a geography of necessary points of passage for those elements who wish to continue to exist and develop. In turn, the laboratory in the above example places itself at a strategic point through which the actor-world must pass. Users of the VEL may consider that their future, their values, and their projects all depend upon the wisdom of a researcher whose eyes are fixed upon the data produced by a nuclear magnetic resonance (NMR) machine. This, in part, explains the source of the power of the laboratory in its isolation: it may become an obligatory passageway.

Translation as Displacement

While translation determines where the points of obligatory passage will be located, this does not exhaust the action. The translator-spokesman and the translator-strategist who impose certain itineraries are bringing about movement. Thus the third component of translation is displacement, in a literal sense. Some link is necessary to make entities accept certain spokesmen and certain points of passage. Otherwise, the action at a distance involved in enrolling Renault, CGE, and the fuel cell into the EDF's projects will remain mysterious.

Let us start by listing some displacements. Entities are converted into inscriptions: reports, memoranda, documents, survey results, scientific papers. These are sent out and received back, acted upon and reacted to. EDF tries to orchestrate the circulation of inscriptions, as well as the movement of people. It organises meetings, symposia, study sessions at which different parties are bodily convened. There are also movements of materials and of money. Translation cannot be effective, i.e. lead to stable constructions, if it is not anchored to such movements, to physical and social displacements (Latour, 1985, Law, 1985d).

EDF is a centre of translation, not just because it attempts to organise and structure the movements, but also because it actually ensures that it has its own centres of communication and aggregation, such as research centres, meeting halls and construction facilities, that focus and control the displacements. In this way, it extends the future of its actor-world

through symposia, experiments, construction of prototypes, trial runs, investments. The actor-world accumulates materials that render it durable.

To appreciate the importance of durability, imagine that EDF had been successful and that the VEL had been finally marketed. Once built and in circulation, it would have constrained producers and consumers, central government and municipalities, within the roles created for them. The user would then have been trapped, independently of further action by EDF. He could either have accepted his fate and put himself behind the wheel of a VEL, or he could have chosen to walk.

In summary, to translate is to speak for, to be indispensable, and to displace. All translation works to solidify actor-worlds. Successful translation quickly makes us forget its history. If the VEL had been successful, the actor-world that shaped it would have lasted longer than the strategies, intrigues, power plays and trial runs that were used to build it. All that would have been left would have been producers, consumers, supply and demand, and a watchful government. The notion of translation recalls all the work and the consent that was granted, that was needed in order to achieve the seemingly natural order, where each element relates with the others.

THE CONCEPT OF THE ACTOR-NETWORK

In the preceding sections the heterogeneity of the elements that go to make up actor-worlds has been stressed, and we have considered the mechanisms by which these may be enrolled. This has made it possible to understand how both a society and the technical objects that make it up are simultaneously given shape. However, a number of additional questions have to be considered. In particular, little has been said of the structure of actor-worlds or the precise way in which they evolve. It is clear that an actor-world may be more, or less, extended, heterogeneous and complex. How shall we describe this range of possibilities, and the translations that occur between them? In order to answer this question, we introduce the notion of actor-network. This concept allows us to describe the dynamics and internal structure of actor-worlds.

Simplification is the first element necessary in the organisation of an actor-world: indeed it is an inevitable result of translation. In theory, reality is infinite. In practice, as a result of the translations that it brings about, an actor-world is limited to a series of discrete entities whose characteristics or attributes are well defined. The notion of simplification is used to account for the reduction of an infinitely complex world by means of translation.[3] For example, towns consist of more than public transport, the wish to preserve town centres and the town councils that constitute their spokesmen. They differ from one another with respect to population, history and geographical location. They conceal a hidden life whose anonymous destinies interact. However, so far as the EDF is concerned, they may be reduced to a transport system that must avoid adding to the level of pollution and a town council that seeks to advance towards this goal.

EDF does not need to know more. This definition will remain realistic so long as the simplification on which it is based is maintained. In other words, such simplifications will be maintained so long as other entities do not appear which render the world more complex by rejecting the reality represented by these simplifications as an impoverished betrayal: the town council is not representative; living conditions in different neighbourhoods cannot be reduced to those in the town centre; and the system of public transport is but one aspect of a larger urban structure. The same is true of fuel cells. If the catalysts and electrolytes that were trusted are contaminated or destabilised, the fuel cell that we hoped would power the VEL becomes appallingly complex. Instead of being easily mastered, fuel cells are transformed into an apparatus whose ever-increasing elements turn out to be beyond control. A 'black box' whose operation has been reduced to a few well-defined parameters gives way to a swarm of new actors: scientists and engineers who claim to hold the

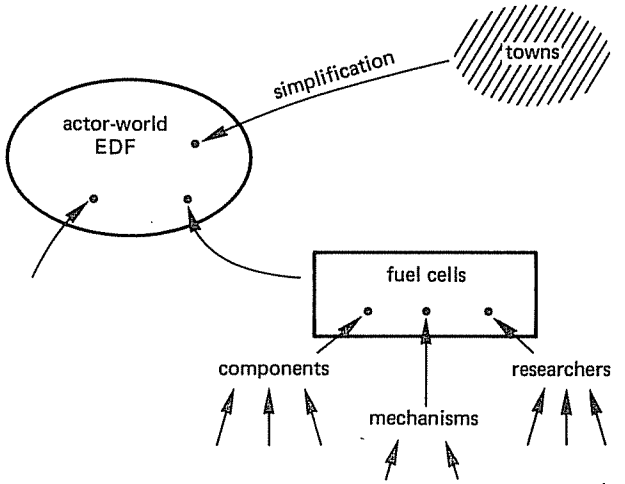

FIGURE 2.1 *The anatomy of the EDF actor-world*

key to the functioning of the fuel cell, hydrogen atoms that refuse to be trapped by the cheaper catalysts, Third World countries that raise the price of precious metals, etc.[4]

Behind each entity there hides a set of other entities which it more or less effectively draws together. We can see and know little of them before they are unmasked. Hydrogen fuel cells and zinc/air accumulators are two of the elements that make up the actor-world of EDF. However, the controversies that developed in their name rapidly divided them into a series of other elements (much as a watch is dismantled by a jeweller to find out what is wrong). Thus simplification, like translation, is never guaranteed. It must always be tested. The catalyst gives way and the fuel cell breaks down thus causing the downfall of the EDF. As for the catalysts, the electrolytes can be decomposed into a series of constituent elements: the electrons on the platinum and the migrating ions. Each of these elements will only be revealed if they are brought into a controversy: in other words, into a trial of strength in which the entity is suspected. Of course, what we have to say about fuel cells, catalysts, and the electrons is also true of city councils or administrations. In the actor-world of the EDF, the city is reduced to the city-council-that-wants-to-preserve-the-town-centre-at-all-costs. But to preserve its integrity, the city council must stabilise the elements which hold it together: the middle-class electorate that trusts it, the pedestrian precinct that pushes the flow of traffic to the edge of the town centre, the urban spread, and the system of public transport which enables the inhabitants of the suburbs to come and do their shopping in the town centre.

An entity in an actor-world (i.e. a simplified entity) only exists in context, that is in juxtaposition with other entities to which it is linked. Fuel cells, Renault as a car-body builder for the VEL, and users who no longer consider the car to be a status symbol, are all interrelated. Remove one of these elements and the whole structure shifts and changes. The actor-world is the context which gives each entity its significance and defines its limitations. It does this by associating the entity with others that exist within a network. There is thus a double process: that of simplification and juxtaposition. The simplifications are only possible if elements are juxtaposed in a network of relations; but the juxtaposition of elements conversely requires that they be simplified.

These juxtapositions define the conditions of operation for the actor-world. In fact, it is from these juxtapositions that the actor-world draws its coherence, its consistency, and the structure of relationships that exists between the components that go to make it up. Without placing them in a network, these elements would be doomed. These relationships, which define the contribution of each element as well as the solidity of the construction as a whole, are very varied. One must abandon the conventional sociological analysis that tries to adopt the easy solution of limiting relationships to a restricted range of sociological categories. Of course, there may be exchange relationships (the user exchanges his money for a VEL), subcontractual relationships (CGE works for EDF), power relationships (EDF brings Renault to its knees), or relationships of domination. But often the relationships between entities overflow simultaneously into all these categories, while some escape completely from the vocabulary of sociology or economics. How can one describe the relationships between fuel cells and the electric motor in terms other than those of electric currents or electromagnetic forces? Not only is the actor-world composed of heterogeneous elements, but their relationships are also heterogeneous. Whatever their nature, what counts is that they render a sequence of events predictable and stable. Hydrogen feeds the fuel cells which power the motor that ensures the performance of the VEL for which the users are willing to pay a certain price. Each element is part of a chain that guarantees the proper functioning of the object. It can be compared to a black box which contains a network of black boxes that depend upon one another both for their proper functioning as individuals and for the proper functioning of the whole. What would the battery be without hydrogen? What would become of the consumer without his VEL?

Therefore the operations that lead to changes in the composition and functioning of an actor-world are extremely complex. The extent to which an entity is susceptible to modification is a function of the way in which the entity in question summarises and simplifies one network on behalf of another. If we wish to construct a graphical representation of a network by using sequences of points and lines, we must view each point as a network which in turn is a series of points held in place by their own relationships. The networks lend each other their force. The simplifications which make up the actor-world are a powerful means of action because each entity summons or enlists a cascade of other entities. Fuel cells mobilise catalysts, electrons, and ions which all work for the fuel cell. This, in turn, works for the VEL and EDF actor-world. Through these successive simplifications (which are never as apparent as when they fail) electrons, specialists at Renault, the middle-class electorate and researchers at the CGE have all been enlisted, translated, and mobilised. EDF only sees and knows fuel cells, accumulators, city council spokesmen, and the public transport authorities. But each of these entities enrols a mass of silent others from which it draws its

strength and credibility. Entities are strong because each entity gathers others. The strength of EDF and the durability of the VEL are built by means of these simplified and mobilised entities. Thus a network is durable not only because of the durability of the bonds between the points (whether these bonds concern interests or electrolytic forces) but also because each of its points constitutes a durable and simplified network. It is this phenomenon that explains the conditions that lead to the transformation of actor-worlds. It is possible to modify the performance of fuel cells to account for the new demands of users only if the catalysts or electron spin states can be modified in order to increase, for example, the power and longevity of the fuel cell. Each modification thus affects not only the elements of the actor-world and their relationships, but also the networks simplified by each of these elements. An actor-world is a network of simplified entities which in turn are other networks.

Transformation thus depends on testing the resistance of the different elements that constitute the actor-world. Is it easier to change the expectations of the users, the demands of the municipalities, the interests of Renault, or the longevity of platinum? This is a practical question that is answered through the continual adjustments that are also negotiated changes. To adapt the VEL by changing this or that aspect of its performance is to act upon the actor-world, and its success thus depends upon the capacity to test certain resistances to their limits whether these spring from social groups, cash flows, or electrodes to be improved.

An actor-world, such as the one described in this chapter, can in turn be simplified. The solidity of the whole results from an architecture in which every point is at the intersection of two networks: one that it simplifies and another which simplifies it. It can be translated into other actor-worlds. For example, the VEL can be linked to the TGV (high-speed train) or the Airbus, thus forming a part of a new French transport policy. Although simplified into a point and displaced in this manner, it is still composed of associated entities. While these entities are susceptible to being moulded or shaped, they in turn may transform the actor-world of which they form a part. It thus deserves to be called an actor-network. However, it is distinguished from a simple network because its elements are both heterogeneous and are mutually defined in the course of their association. Entities may disappear in order to permit the networks that they simplify to expand and surface. This capacity of self-definition and self-transformation is underlined by the fact that the two words 'actor' and 'network' are linked together in a single term. However, an actor-network is distinguished from a simple actor by its

texture or structure which is an arrangement of constituent elements that has been translated. Remove all that the VEL translates and it becomes an entity without strength, society or future and it can no longer function. The actor is an association of heterogeneous elements each of which associates its own elements.

To summarise, the terms actor-world and actor-network draw attention to two different aspects of the same phenomenon. The term actor-world emphasises the way in which these worlds, built around the entities that create them, are both unified and self-sufficient. The term actor-network emphasises that they have a structure, and that this structure is susceptible to change. Accordingly, in later chapters the two are used interchangeably.

APPLICATION OF THE METHOD

In the introduction to this chapter it was asked how we might describe the 'co-evolution' of science and society in order to explain the effectiveness and the influence of the former. This chapter has put forward certain instruments of analysis which offer the elements of a response to this question.

We have suggested that the notion of translation makes it possible to describe the mechanisms by which actor-worlds are constructed. It also reveals that mechanisms cannot be taken for granted: whether they are fuel cells, catalysts, users, or industrial firms, translated entities could in theory follow other routes or be brought into other projects. They could in other words escape the logic of the actor-world into which they have been enlisted.

As we have noted, the functioning of actor-worlds and their translations are not adequately described by the usual frameworks of analysis. There are, in fact, two major obstacles that stand in the way of this: (a) the elements from Nature and Society are associated with one another in an entirely heterogeneous manner and cannot possibly be distinguished from one another (Law, 1985b); (b) the choice of entities and the way in which they are associated cannot normally be predicted because these result from operations of translation that are in progress. In short, not only does the repertoire of translated entities extend beyond that generally accepted in social science, but the composition of this repertoire does not obey any definitive rules. How can the social elements be isolated when an actor-world associates the spin of an electron directly with user satisfaction? How can any interpretation of

social interaction be established when actor-worlds constantly attempt to transform the identities and sizes of actors as well as their interrelationships? The fact that actor-worlds constantly create new combinations of entities renders this task even more difficult.

The notion of actor-network is developed in order to handle these questions. This notion makes it possible to abandon the constricting framework of sociological analysis with its pre-established social categories and its rigid social/natural divide. We have shown that by inserting the entities into a cluster of heterogeneous relationships, an actor-world places them into a network. Each entity is thus reduced to a few properties which are compatible with the relationships established between the entities: Renault, a company-that-builds-car-bodies, can cooperate with CGE, a firm-that-produces-engines-and-transmissions; electrons are elementary-particles-which-transport-electric-charges-from-one-electrode-to-another thus producing the electric-current-which-drives-the-motor-of-the-VEL. An entity, firm, technical device, or social group is assigned to a black box and the actor-world may thus be seen as a bundle of black boxes. We have seen that these simplifications may always be rejected: a social group enrolled and reduced to a few interests and/or a few needs can define itself differently; a fuel cell trimmed to a few elements whose characteristics are well known can suddenly become extremely complex. Actor-worlds are supported by all the elements which have been gathered and simplified within the translated and enlisted entities. It is by virtue of this fact that they obtain their force, and if disintegration occurs, they are, accordingly, weakened.

NOTES

1. In this chapter the term battery will be used as a generic term to cover all portable chemical devices for generating electricity.
2. For the notion of enrolment, see Callon and Law (1982).
3. There is an analogy here with scientific theory. As Hesse (1974) has so persuasively argued, description always entails loss of information and simplification. The latter is thus not necessarily a Machiavellian tactic.
4. On the notion of black-boxing as a form of simplification, see Callon (1981b) and Law (1984b).

3 Laboratories and Texts

JOHN LAW

ON LABORATORIES AND RATS

What is so special about a laboratory? Why is it the laboratory rather than the boardroom that counts as Touraine's strategic locus for the twentieth century? Why is the laboratory the most important centre of translation? What goes on behind its doors that gives it the power to influence events far beyond its walls? For certainly, if you stand outside those doors, it does not seem very remarkable. The laboratory that this author knows best is up six flights of stairs in some temporary rooms that appear to have been added as an afterthought to a more permanent structure.[1] The whole is in need of a new coat of paint. At the top of those stairs you come to a double door. Until recently this door stood open during working hours. Now there are anxieties about the activities of the animal liberation front, so it is necessary to be inspected by a technician inside. You enter the hallway, pass down a corridor and walk into the main laboratory. Here there are five or six benches, and a clutter of sinks and cupboards. One or two young people are working. They are shaking test tubes, or pouring out solutions of chemicals. There is occasional talk: when are the new copolymers expected? Will the water supply be cut off before midday? Who won the game of bridge last night?

I ask for Rose. She is the scientist that I know best. She appears from a back room off the laboratory. She is wearing a white coat and latex gloves. She beckons me and I follow her into what they call the operating theatre. Here the rats are sacrificed. Rats? Well yes, they arrive at the laboratory day by day in little cages. They come from a place called the 'animal house'. The more cynical call it 'the zoo' and refer to the fact (if it is a fact) that the Home Office requires higher standards for the housing of rats than of people.

Rose is learning a new technique. She is trying to inject a radio-