Acting in an Uncertain World

An Essay on Technical Democracy

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The MIT Press
Cambridge, Massachusetts
London, England

First published as *Agir dans un monde incertain: Essai sur la democratie technique* by Editions du Seuil.

Set in Stone Serif and Stone Sans on 3B2 by Asco Typesetters, Hong Kong. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Callon, Michel.
[Agir dans un monde incertain. English]
Acting in an uncertain world : an essay on technical democracy / Michel Callon, Pierre Lascoumes, Yannick Barthe.
p. cm.
Originally published in French as: Agir dans un monde incertain.
Includes bibliographical references and index.
ISBN 978-0-262-03382-4 (hardcover : alk. paper)
1. Democracy. 2. Political leadership. 3. Technology—Political aspects. 4. Science—Political aspects. I. Lascoumes, Pierre, 1948–. II. Barthe, Yannick. III. Title.
JC423.C245413 2009
321.8—dc22 2008021376

10 9 8 7 6 5 4 3 2 1

1 Hybrid Forums

In March 1987, at intervals of a few days, the same scene takes place in the rooms of the prefectures of four French departments. Dozens of local councilors, mayors, and departmental councilors attend a ''briefing.'' The prefect who has called them together has not clarified the purpose of the meeting, but their presence seems to be of the greatest importance. Proof of this is the diligence shown by the prefecture services. The summons was sent the previous day by telegram, and police cars have been sent to facilitate the councilors' movement.

During the meeting, the prefect quickly hands over to officials from ANDRA. ANDRA? The participants, who have never heard this strange acronym, learn that it is a national agency created within the Commissariat à l'énergie atomique (Atomic Energy Commission) with responsibility for radioactive waste.[1] It is this task that explains their presence in the various departments. ''To eliminate certain nuclear waste that will have significant radioactivity for several thousands of years, burying it in deep geological strata has been considered,'' one of the experts from Paris explains. In a slightly professorial tone, he adds: ''Inasmuch as some of these geological formations have been stable for millions of years, we assume that they will continue to be so for the period of decrease in radioactive elements. The geological structure will constitute then a 'trap' more than 400 meters deep. This trap should enable the waste to be isolated from the environment when the containers have been destroyed by erosion and the memory of the site has been lost. This 'geological safe' offers an immense advantage: it makes all the always uncertain conjectures on the evolution of society pointless.'' The audience can only be reassured. Never mind the schemes of future generations that everyone has been talking about for some months. It matters little whether or not they take care of this difficult inheritance. What matters now is not the behavior of changeable human beings, but the long-term behavior of geological formations that are *a priori*

favorable. Precise and technical questions take the place of vague and general preoccupations. In order to answer these questions it is enough to ascertain the quality of the accommodating rock and to develop the soundest possible predictive models. ''A series of geological explorations will be undertaken on four sites chosen for their subsoil. At the end of these explorations, a single site, one meeting all the requirements, will be selected for the installation of an underground laboratory. It goes without saying,'' the scientists conclude, ''that a project like this would be a source of jobs and of not inconsiderable earnings for the department in which it is situated.''

The news spreads in a few hours. It has the effect of a thunderbolt in the four departments concerned. Residents, whom it had no doubt been forgotten to invite to the briefing, quickly form associations. They are opposed to what they see as a fait accompli, and they demand information on the project. Is it reasonable to bury nuclear waste irreversibly? Can we trust the studies of the geological explorations? Are there other solutions? In the villages of the Ain, the Maine-et-Loire, the Deux-Sèvres, and the Aisne, the four departments affected by these geological drillings, ANDRA organizes dozens of briefings and distributes hundreds of leaflets presenting the project. Communication specialists explain, popularize, and reassure. Thinking that these populations are in the grip of irrepressible fears and terrors, they proclaim *urbi et orbi* that there really is no risk. Or, they admit reluctantly, it can involve only a very small risk, in the distant future, at a time beyond our imagination. In any case, they add, there is no other solution. We really have to get rid of nuclear waste once and for all! We cannot pass on this heavy burden to our descendants! Burial is a technical necessity. It is also a moral duty with regard to future generations.

But ordinary citizens have learned to mistrust information provided by nuclear agencies, even when they seem to be above suspicion technically and morally. Ordinary citizens still remember the Chernobyl cloud, which the established experts dared to maintain would halt at France's borders. This is why they prefer to turn to other sources of information. Some figures of nuclear counter-expertise are invited to give their point of view on the ANDRA project. Discussion points gradually emerge. These specialists qualify the idea that geological storage is the only conceivable technical solution. In the heat of the controversy, the residents realize that there are many uncertainties and that the burial of radioactive waste is only one line of research, requiring lengthy and complex scientific studies. They also discover that, in the past, other solutions had been considered which, for reasons that are far from clear, were quickly abandoned without thorough investigation. There is the technique of transmutation, for example,

which, by ensuring the destruction of radionuclides with a long life, would have the advantage of considerably reducing the uncertainties inherent in geological storage.

Awareness of the existence of these scientific and technical uncertainties leads to the reformulation of the terms of the problem and the emergence of new questions and new scenarios. What if future generations were to find more satisfactory methods for dealing with these burdensome residues? What if the technical capabilities of our distant descendants were to make it possible one day to develop this waste? And what if the irreversibility of storage was contrary to the scientific approach? And . . . ?

Questions that were thought to have been settled definitively are reopened. Arguments multiply and the project constantly overflows the smooth framework outlined by its promoters. In the course of the controversy, unexpected connections are established between what should have been a simple technical project and a plurality of stakes that are anything but technical. Thus we see new actors taking up the problem, imposing unexpected themes for discussion, and redefining the possible consequences of the project. The Bresse poultry farmers, for example, point out a danger that the technicians, obsessed with the seismic and hydro-geological data concerning the department's subsoil, clearly could not imagine. This is the threat posed to the economic health of the regions concerned by the introduction of a center for storing nuclear waste. The relationship established in the consumer's mind between the quality of certain agricultural products and the presence of radioactive waste makes the farmers fear that the image of these products will be damaged. Seen by its promoters as a source of local economic development, the storage of nuclear waste becomes a potential threat to some commercial interests. Local councilors leap to the defense, anxious to defend the interests of their electors and restive at the imposition of a definition of the general interest that disregards local realities. They call for a national debate, for a pluralistic expertise, and for a better consideration of the social and economic aspects of the problem.

The conflict grows acrimonious and turns into a pitched battle. No one talks now of the risks associated with storage strictly speaking, but of the risk of riots on the part of what are deemed to be uncontrollable minorities. Soon, squads of the riot police are sent to protect the ANDRA technicians so that they can continue their work. At the same time, demonstrations increase, attracting more and more people. The inhabitants of the departments are intent on resisting, with violence if necessary, the arrogance of the technicians and the arbitrary decisions of the central power that deny the identity of their territory. To put an end to this climate of civil war, in

1990 the government decides to backpedal and declares a moratorium on the research being conducted by the ANDRA. The time has come for a complete re-examination of the case. Space is made for consultation with all the interested parties. Caught unawares, the government discovers the existence of institutions that could be useful to it. It seeks help from the College for the Prevention of Technological Risks and from the Parliamentary Office for the evaluation of scientific and technological choices. The first real French law concerning the nuclear domain, the law of 30 December 1991, called the ''Bataille law'' after the name of its rapporteur, arises from these consultations and discussions. This text, and the apparatuses it sets up, strives to open up the ''black box'' of science in order to promote a program of research justified by an uncertainty that is now acknowledged and accepted. The dominant feature is the refusal of a definitive choice, which is put back and will require a new law to be passed. In the meantime, it is envisaged that three major lines of research will be explored and regularly evaluated by a commission of independent experts and the Parliamentary Office for the evaluation of scientific and technological options. The political dimension of the issue is recognized. It is no longer a matter of identifying and negotiating risks, as in a contract between insurer and insured, but of establishing constraining procedures for managing the apparent contradiction between minority points of view and what some consider to be the general interest. Furthermore, the law introduces a new conception of the mode of political decision making. It is no longer a matter of deciding on the basis of indisputable scientific facts. The law outlines the framework of a gradual approach that favors adjustments and corrections. In a word, it is decided not to decide, but to take time to explore conceivable options before deciding.[2]

Let us change the scene, or the department rather. Let us leave the Bresse region and move to Sarthe, following in the footsteps of the sociologist Élisabeth Rémy.[3] The problem here is not the burial of nuclear waste but a high-voltage line installed by Électricité de France, or more precisely the effects of the electromagnetic fields produced by this line. For some time, in fact, strange phenomena have been occurring in a small rural commune, to the extent that its inhabitants feel like they are involuntary actors in a science fiction film. Sometimes it is the siren of the commune's fire truck that goes off on its own. At other times, despite many visits from the people who installed it, an automatic gate pleases itself and opens without being given the order. The inhabitants complain of frequent headaches and insomnia. Those who prided themselves on their iron constitution are frequently ill. There is said to be a child who is constantly pulling his hair out

. . . except when he goes on holiday—that is, when he moves away from the accursed village. It is also said that the suicide, leukemia, and cancer rates are increasing in the area, following, as if by chance, the track of the high-voltage lines. Faced with what they see as threats, the inhabitants organize, try to make a list of all these cases, and aggregate the multiple isolated facts produced over the whole of the territory in order to give consistency to the hypothesis of the harmful effects of electromagnetic fields on health. Others appeal to experts whom they judge to be independent in order to make measurements in their property and prove the danger. Their suspicion is encouraged by the ambiguous discourse of Électricité de France officials, who, while refusing to state publicly that there is no danger, consider that if there is a risk it can only be slight and, in any case, the problem is being studied.

Actually, the problem is being studied. The question of harmful effects of low frequency electromagnetic fields is keenly debated by specialists. Despite much epidemiological and biological research on the subject over 20 years, there are still many uncertainties. The hypothesis of a danger linked to exposure to low frequency electromagnetic fields from electric lines was raised seriously for the first time in 1979. That year, in the very official *American Journal of Epidemiology*, an American researcher published the results of a study showing a statistical relationship between cancers in children and exposure to electromagnetic fields. Since then investigations have been carried out aiming either to support or refute this hypothesis. But no certainty succeeds in settling the debate, and the experts are practiced in evasive answers. We cannot completely exclude the existence of a danger, they say; on the other hand, nothing permits proof of the contrary.

It has to be acknowledged that the problem posed is not an easy one to solve. Research aiming to identify possible danger comes up against difficulties that are confronted by every epidemiological study of effects produced by weak exposure to a substance deemed to be harmful. In these tricky cases several conditions have to be met before a sound diagnosis can be given. First, we must be able to identify precisely the populations affected and, consequently, we must be able to define a level of exposure above which given individuals are considered to have been exposed. Second, given that what is being researched are long-term effects, in order to get reliable results there should be an epidemiological follow-up of the population over several years. The third condition concerns the characterization of effects produced by low doses. Since it is difficult to apprehend these effects directly, hypotheses have to be formulated and widely discussed. A fourth uncertainty concerns the way in which what is called a

dose of electromagnetic field is calculated: Should we accept the average accrued intensity of the exposure, the peak of exposure, its temporal variation, or its frequency? As can be seen, the experts and the groups concerned are faced with what may be described as radical scientific uncertainties. They are especially uncertain since there are some who have an interest that they are and ... that they remain uncertain. Imagine the predicament of Électricité de France if the danger were to be proven!

There are striking similarities between the two cases just set out. In the example of radioactive waste as in that of high-voltage lines, the uncertainties concerning the dangers incurred (whether long-term or short-term) are patent. In both cases, despite these uncertainties, indeed because of them, decisions nevertheless have to be made, or, as we say, ''something must be done.'' In the two cases, the controversies bear at the same time on the characterization of the dangers and on the procedure to be established so as to arrive at what may be considered a credible and legitimate characterization. In both cases, the controversies take place in public spaces that we propose to call *hybrid forums*[4]—forums because they are open spaces where groups can come together to discuss technical options involving the collective, hybrid because the groups involved and the spokespersons claiming to represent them are heterogeneous, including experts, politicians, technicians, and laypersons who consider themselves involved. They are also hybrid because the questions and problems taken up are addressed at different levels in a variety of domains, from ethics to economic and including physiology, nuclear physics, and electromagnetism.

This kind of socio-technical controversy is on the increase. In this book we will visit some of the many hybrid forums that the unpredictable and often chaotic development of science and technology has created: the Mad Cow forum, that of genetically modified organisms or of avian influenza, the AIDS forum, and that of neuromuscular diseases or nanotechnologies. But before going further into the analysis of these controversies and their organization, dynamic, and possible closure, we propose to show that they are an appropriate response to the increasing uncertainties engendered by the technosciences—a response based on collective experimentation and learning.

Uncertain Times

Contrary to what we might have thought some decades ago, scientific and technological development has not brought greater certainty. On the contrary, in a way that might seem paradoxical, it has engendered more and

more uncertainty and the feeling that our ignorance is more important than what we know. The resulting public controversies increase the visibility of these uncertainties. They underscore the extent of these uncertainties and their apparently irreducible character, thereby giving credit to the idea that they are difficult or even impossible to master. These uncertainties are most striking in the domains of the environment and health, undoubtedly the most fertile terrains for socio-technical controversies. In view of their role in the constitution of hybrid forums and their capacity to render the future opaque and threatening, is it not advisable to ask "What exactly are we talking about when we evoke the notion 'uncertain'?"

From Risk to Uncertainty

Let us be careful not to confuse the notion of uncertainty with that of risk, which is its false friend. The two notions tend to be used interchangeably in current language, but they cover very different realities.

The term 'risk' designates a well-identified danger associated with a perfectly describable event or series of events. We do not know if this event or series of events will in fact take place, but we know that it *may* take place. In some cases, statistical instruments applied to series of systematic observations performed in the past make it possible to calculate the event's probable occurrence, which will then be described as objective probability. In the absence of such observations, the probabilities assigned depend on the points of view, feelings, or convictions of the actors; these are called *subjective* probabilities. Whether objective or subjective, these probabilities have in common their application to known, identified events that can be precisely described and whose conditions of production can be explained.

The notion of risk is closely associated with that of rational decision. In fact, in order for such a decision to be made, three conditions must be met. First, we must be able to establish an exhaustive list of the options open to us. In the case of the management of nuclear waste, this implies that we can guarantee that the three strategies of deep burial, transmutation, and surface storage are the only strategies worth considering. Second, for each of the options under consideration, the decision maker must be able to describe the entities constituting the world presupposed by that option. In the case of deep burial, for example, we will consider a world made up of clay strata or granitic massifs, of groundwater, of heedless human beings, and of a terrestrial atmosphere that is inexorably warming. Finally, the assessment of the significant interactions that are likely to take place between these different entities must be feasible. Human beings may decide to sink mines, penetrating the geological safe unawares; equally, predicting a tidal

wave linked to global warming, they may decide to bury their dwellings, which will then be exposed to water containing radioactive substances. If these three conditions are satisfied, then the decision maker can make comparisons between the options on offer. To account for this truly exceptional situation, decision theorists introduce a notion that will be very useful for us: that of possible states of the world. A state of the world is defined first by the list of human and non-human entities that make it up, and then by the interactions between these entities. In choosing a state of the world, we choose not only the entities with which we decide to live but also the type of history we are prepared to share with them. We refer to *possible* states of the world because we know of causal chains that could produce them. Another way of talking about these states of the world is to employ the notion of scenario, a notion dear to futurologists.

The notion of risk is indispensable for understanding the choices made by a decision maker. For a moment, let us entertain the evidently implausible hypothesis that the management of nuclear waste can be reduced to this analytical framework. If we follow this procedure, we will be led to distinguish a state of the world (or a scenario) in which the waste is buried deep, another in which it is transmuted, and a third in which it is stored on the surface. On the basis of the knowledge available to us, we will try to describe the significant interactions that may occur in each of these scenarios, especially those between the social world and the waste. In this way we will identify potentially dangerous events for certain social groups. Being able to predict developments and identify effects, the decision maker will thus be in a position to make a rational choice. Obviously this will depend upon his preferences and those of the actors he thinks must be taken into account. It will also depend, and this is the important point, on how the decision maker assesses the possible dangers associated with each scenario, and, in particular, on his calculation of the probability of their occurrence. The notion of risk plays a crucial role, therefore, in rational decision theory and in the choice between several possible states of the world that it presupposes. That is why, to avoid ambiguities, it is sensible to reserve use of the notion to these completely codified situations.

Let us agree to speak of risk only in those quite specific cases where the exploration of possible worlds (or, if you prefer, the establishment of conceivable scenarios) has been completed, revealing the possibility of harmful events for certain groups. We are completely familiar with these events and know the conditions necessary for them to take place, even if we do not know whether they will in fact occur, and even if all we know is the probability of their occurrence.

It is easy to see why the notion of risk, thus defined, does not enable us to describe situations of uncertainty or to account for the modes of decision making in such contexts. In actual fact, science often proves to be incapable of establishing the list of possible worlds and of describing each of them exactly. This amounts to saying that we cannot anticipate the consequences of the decisions that are likely to be made; we do not have a sufficiently precise knowledge of the conceivable options, the description of the constitution of the possible worlds comes up against resistant cores of ignorance, and the behavior and interactions of the entities making them up remain enigmatic. The conditions required for it to be relevant to talk of risk are not met. We know that we do not know, but that is almost all that we know: there is no better definition of uncertainty. In such situations the only option is questioning and debate, notably on the investigations to be launched. What do we know? What do we want to know? Hybrid forums help to bring some elements of an answer to these pressing questions.

Uncertainty is a useful concept because it prevents us from confusing hybrid forums with situations of risk. It is nevertheless a fuzzy concept covering diverse configurations. Obviously, uncertainties may be more or less radical. There is a vast space between dismal ignorance and an impeccable knowledge of the states of possible worlds. It is worthwhile plotting its contours, for that is where the hybrid forums install themselves. One way of realizing this cartographic work is to review the different forms of uncertainty and note the particular controversies to which each of them may give rise.

Radical Uncertainties

The most revealing examples of the situation of radical uncertainty correspond to what are called *development risks*. These are situations linked to the commercialization of substances whose dangers must be unknown to the producer when he puts them on the market. This case is all the more striking as these problems often concern products, like drugs, requiring authorization to be put on the market, which presupposes prior and public checking of their harmlessness. If harmful effects become apparent, it is only after several years, and their explanation will necessitate further delays. The most famous example is distilben, a drug that was widely prescribed in the 1950s for woman likely to miscarry. Not until much later was it realized that, if the product had no direct harmful effect on the mothers, it nonetheless triggered serious disorders in the children. These effects only became apparent at puberty (malformations of the reproductive apparatus, sterility, cancer). There was, therefore, a gap of 15–20 years

between absorption of the product by mothers and the first clinical signs for their daughters. It took a long time to identify the latter. And it took even longer to establish that they had a common source in the treatment prescribed to the mother. The set of processes was reconstructed only at the end of the 1970s.

Another recent example is that of infected blood. Until 1983, when the first hypotheses of exposure to danger were formulated, hemophiliacs and people having blood transfusions were given dangerous, indeed mortal health-care products, the dangerousness of which, and how serious the danger was, no one had been able to predict.

In these kinds of situation, uncertainties can only be lessened *a posteriori*. That is why they deserve to be called radical. The question that arises in these conditions is clearly whether the dangerous nature of the substance could and should have been seen earlier. The answer is undoubtedly positive. Being able to anticipate and track down potential overflows, establishing a system of supervision, and systematically collecting data in order to sound the alarm as soon as bizarre events occur entail a long list of measures. This suggests that ignorance is not inevitable, and that to think in terms of uncertainty is already to provide oneself with the means to take its measure. Moreover, the courts share this conviction when they try to find those responsible. Justifications that ''it is just bad luck'' are less and less admissible. Hence the importance of emergent controversies, even and especially if they are aroused by prophets of calamity. History has taught us that Cassandra was not always wrong.

The Era of Suspicion

Opacity dissolves gradually, and situations of uncertainty in which the hypothesis of a danger emerges are distinguished from each other by the precision of observations and explanations.

We will talk of ''plausible potential danger'' when persons or life environments suffer damage that is perfectly describable but whose causes and precise nature remain unknown. Such situations often lead to the drawing up of inventories. Some actors embark, individually or collectively, on the collection of cases that may confirm the existence of a new threat. The uncertainties surrounding them encourage the informal and sometimes wild development of hypotheses that are not yet verified and are often not immediately verifiable. Controversy focuses on plausible but fictional scenarios that provide acceptable interpretations of the observed facts. Those who sound the alarm, whether laypersons or experts, are at the center of the debates.

The publication in the *British Medical Journal* of a study by the French epidemiologist J.-F. Viel on cases of leukemia in young children living near the French nuclear reprocessing plant at La Hague sparked a controversy that illustrates perfectly this entry into the era of suspicion. According to Viel, there are convincing arguments that allow the supposition that the observed connection between certain customs of the inhabitants (swimming, eating shellfish) and an atypical level of cases of leukemia (four observed cases rather than the expected 1.4) could be due to the presence of radioactive substances in the environment. It will take two successive expert commissions to pacify the public controversy and provide data acceptable to all the parties involved.

Suspicions do not ineluctably lead to studies concluding that there is no danger. In the case of the possible carcinogenic effects of mobile telephones, we see an impressive spread of works based on very different methodologies. In May 2000, one of the most respected scientific journals, *Nature*, published an article by De Pomerai et al. demonstrating the effects on worms of prolonged exposure to radiation weaker than that emitted by mobile phones. Biological changes (the appearance of specific proteins) are observed that are analogous to those usually triggered by thermal stress. In view of the constant character of this type of response to heat, the authors consider that comparable phenomena are conceivable in the human being. These results conflict with others, which are more reassuring, but based on studies financed, at least partly, by the manufacturers. As a ''precaution,'' the British government recommends a maximum restriction of the use of mobile phones by children, in view of the consideration that their developing nervous system is likely to make them highly vulnerable. These preliminary works led to the launch in the summer of 2000 of a major epidemiological campaign by the International Agency for Research on Cancer (IARC). Its aim is to identify several thousands of cancer cases (brain tumors, cancers of the acoustic nerve and of the parotid gland) and to retrospectively evaluate the possible risks to users of mobile phones.

Suspicions feed the debates that focus on the materiality of the observed effects, their description, and the causal chains responsible for them. Only through systematic investigations can these suspicions be invalidated or confirmed. As the exploration of possible states of the world progresses, the controversy may evolve; suspicions may gradually give way to presumptions.

From Suspicion to Presumption

Suspicion leads to the contemplation of states of the world which are considered to be plausible in the light of bizarre, fragile phenomena that are

difficult to describe. With presumption we move on to a new stage. In law, the term 'presumption' designates induction from a known to a disputed fact. The corpse exists, and conjectures lead us to think that we have found the murderer, but we do not have the proof that assures us that he or she is the real culprit. In the controversies corresponding to this case, the phenomena are firmly established and no one challenges their existence. Sound observations enable one to back up the facts and qualify them by showing, for example, that thresholds have been crossed and developments confirm the observations: the number of deaths cannot be explained by random phenomena, and their number exceeds levels beyond which the tendency is irreversible. The uncertainties focus essentially on the causal chain, although we have the beginnings of an explanation. Such was the case with Bovine Spongiform Encephalopathy (BSE) in 1988. The threat was certain. We knew that cows were affected by it; we knew what the agent was, but its existence raised some doubts; we did not know exactly how it spread, but some hypotheses seemed likely; we did not know if the disease could affect humans, but nothing could be ruled out. In such situations, controversy essentially focuses on two points. First, as in cases of suspicion, the reliability of the information and the data collected may be disputed. Do they merely reflect the anxieties of those involved in publicizing the problem, or are they the firm basis of a scientific evaluation of the dangers incurred? The confrontation may also, and especially, focus on the action to be taken. Do we know enough to make decisions? Should we undertake further investigation in order to stick with indisputable proofs? If so, what tracks should be followed? Should we wait before taking measures, or should we take them right away? If we opt for the latter, what measures is it appropriate to adopt?

The issue of nuclear waste corresponds quite closely to this scenario. No one denies the dangers of storage; the debate concerns how to deal with them. Should we put up with irreversible storage that some specialists say presents only a low risk? Or should we pursue new lines of research in the hope that they will result in methods that will enable us to eliminate the danger associated with nuclear waste? In the meanwhile, what measures should we take?

Social and Technical Uncertainties

At first sight, the uncertainties we have so far considered could be described as scientific or technical. The strategy that is essential for lessening them could come from laboratories or research departments.

However, the controversies engendered by these uncertainties go far beyond solely technical questions. One of the central things at issue in these

controversies is precisely establishing a clear and widely accepted border between what is considered to be unquestionably technical and what is recognized as unquestionably social. The line describing this border constantly fluctuates throughout the controversy. To declare that an issue is technical is effectively to remove it from the influence of public debate; on the other hand, to recognize its social dimension restores its chance of being discussed in political arenas.

Nuclear energy provides, at least in France, good examples of these fluctuations. In the 1960s the issue of nuclear energy was seen as being essentially a technical matter and therefore as having to be dealt with by the relevant specialists; the social was defined in a residual way as rallying a public that was more or less favorable, more or less prey to irrational fears and anxieties. Twenty years later the division had undergone profound change. The anonymous public constituted by the individuals of crude psychology gave way to differentiated groups capable of speaking outside of opinion polls and of developing constructed arguments. It was enriched by genuine political movements that challenged the democratic character of certain decisions. After another ten years, the stage was crowded with unexpected actors: residents' associations, local groups, chicken farmers, viticulturists, professional associations. What the anthropologist Marilyn Strathern calls the ''proliferation of the social''[5] was accompanied by a continual enrichment of the technical issue itself. In truth, the two histories are closely interwoven. That is why the initial distinction becomes blurred. To the question ''Is deep burial a technical solution?'' everyone agreed in giving an affirmative answer. To the question ''What is the social component of the nuclear issue?'' the specialists answered with a single voice: ''It arises from the public's irrational fears.'' Thirty years later, this response seems out of date. This society without consistency has vanished before the disenchanted eyes of nostalgic technocrats. Multiple groups have appeared whose existence no one suspected, defending their interests and projects, and adding their two cents to the so-called technical discussions. There are, of course, many people who contest the solutions envisaged or who demand their modification. But life is not that simple. Security and surveillance services are also summoned and questioned as to their long-term ability to fulfill their mission; there are even the ''future generations'' about whom everyone is suddenly concerned, in whose name all believe they are authorized to speak, and who are thus invited to all the meetings at which storage, fast breeder reactors, and transmutation are discussed. As a result, the solution of deep burial is only secondarily seen as technical problem. To the great displeasure of the specialists, it becomes an eminently social and political problem. The border between the

two spheres has been completely scrambled in the space of two or three decades.

As the foregoing example shows, the controversies that unfold in hybrid forums are fostered not only by scientific and technical uncertainties but also by social uncertainties. In discussing the border between what is technical and what is social, the protagonists, whose identities vary over time, introduce an indeterminacy that will not be settled until the end of the controversy. Moreover, it is the entry of new actors on the scene that causes the border to be called into question. Society may indeed be as uncertain and unpredictable as the nonhuman entities with which it has chosen to share its destiny.

Dynamic

Socio-technical controversies unfold in time and space. Their trajectory is largely unpredictable because it depends on the nature and degree of the uncertainties and also on the way in which some of them end up being lessened or disappearing. What social groups will arrive on the scene? What alliances will they forge? What technological options will be revealed, or ruled out, by the research undertaken? What new lines of research will be explored? These questions are continuously formulated and reformulated as the socio-technical controversy develops. They are both the consequence and the motor of its dynamic. To understand this point, it is useful to return to the notion of a possible state of the world.

We have said that in a situation of uncertainty the states of the world that are likely to be realized are to a great extent unknown. There is reliable evidence that permits us to think that the list of conceivable scenarios is not exhaustive, that each scenario is only described schematically and very incompletely, and that the causal chains that allow us to predict the conditions under which a scenario can or cannot be realized are only identified approximately. Controversy focuses on these zones of ignorance. It explores them and occasionally helps to reduce them through the game of confrontations to which it gives rise and through the information it generates and circulates. In short, it organizes the more complete investigation of possible states of the world. Thus we pass from radical uncertainty to suspicion, and then from suspicion to presumption and sometimes proof. But this is not the only possible trajectory. Uncertainties may increase with the emergence of increasing numbers of diverse groups and the discovery of vast continents of ignorance.

BSE is a good example of a situation of uncertainty that took a long time to reduce and which is present to some extent even today. Although the

epizooty now seems to be under control (1,646 cases in the world in 2003, 878 in 2004, and only 474 in 2005), for many years the course of this ''crisis'' was characterized by a real proliferation of uncertainties. In the mid 1980s, for example, two main means of transmission of prions were identified: feeding animals with contaminated meal and transmission by affected cows to their calves during gestation. Yet despite culling and strict control of the animal feed sector, the number of cases of cattle with BSE born after the ban remained stable albeit low (16 in France for the first half of 2000). Because the origin of this type of contamination could not be explained via the two known routes, complex hypotheses were put forward. Some of them had already been formulated in 1999 by expert committees, and used by the French government to oppose the lifting of the British beef embargo, despite the European Commission's demand. In particular, the existence of a third contamination route was suspected, but none of the observations made nor the measures taken during the heat of the controversy were able to reduce the uncertainties. Nothing pointed to the outcome of this turbulent controversy, which was constantly fueled by new questions. Rather than reducing uncertainties, the investigations tended to amplify them, especially at first.

One of the powerful motors of this dynamic is found in the dialectic established between scientific and technical research on one side and social reconfiguration on the other: it is decided to undertake investigations that result in the identification of new possible states of the world, mere reference to which brings out unforeseen actors, who, in turn, launch themselves into the debate and propose new lines of exploration. The socio-technical spiral is up and running and has no reason to halt. Given its fruitfulness—it produces knowledge and fosters learning—the only reasons for halting it are bad ones, despite the fears aroused by its development.

Explorations and Collective Learning

Sociologists of social movements have shown how easy it is for social conflicts to be assimilated to pathological forms of behavior that can be explained either by the irrationality of those who are mobilized or by the clumsiness of the dominant actors. Socio-technical controversies are not exceptions to the rule. They are often seen as the result of a lack of communication and information: the scientist or politician did not want (or failed) to be understood by the ordinary citizen. At best, controversies are often seen as a waste of time that could be dispensed with; at worst they are

seen as the hardly avoidable consequence of the intellectual backwardness of people in need of continuous guidance.

The position we take in this book is at variance with these two conceptions. It is that controversies enrich democracy.[6] When scientific expertise and political voluntarism adopt the form of an authoritative discourse, they fail to respond to the questions of concerned citizens.

We propose to shift the gaze cast on controversies by passing from the time of contempt or indifference to one in which they are taken into consideration. This is not out of an indiscriminate love of exchanges and communication; as we will show, controversies are not just a useful means for circulating information. Nor are they reducible to simple ideological battles. With the hybrid forums in which they develop, they are powerful apparatuses for exploring and learning about possible worlds.

Controversy as a Mode of Exploration

Controversies make possible the exploration of what we propose to call *overflows* engendered by the development of science and techniques. Overflows are inseparably technical and social, and they give rise to unexpected problems by giving prominence to unforeseen effects. All, specialists included, think they have clearly defined the parameters of the proposed solutions, reckon they have established sound knowledge and know-how, and are convinced they have clearly identified the groups concerned and their expectations. And then disconcerting events occur.

To start with, controversies help to reveal events that were initially isolated and difficult to see, because they bring forward groups that consider themselves involved by the overflows that they help to identify. As investigations go on, links from cause to effect are brought to the fore. The controversy carries out an inventory of the situation that aims less at establishing the truth of the facts than at making the situation intelligible. This inventory focuses first on the groups concerned, on their interests and identities. It is not the result of a cold, distant, and abstract analysis. It is carried out at the same time as the actors arrive on the scene. The distribution is not known in advance but is revealed as the controversy develops, and it is precisely for this reason that the latter is an apparatus of exploration that makes possible the discovery of what and who make up society.

The sudden appearance of new actors (residents living along a polluted river, consumers of beef, pregnant women in the canton of La Hague, future generations who will inherit irreversible stocks of nuclear waste) corresponds to more or less radical reconfigurations of the social landscape. In the first scenario it may be a case of new actors who are not really new. Pre-

viously kept in the wings, they take advantage of the controversy to enter the scene in a legitimate role. The second scenario is that of really emergent concerned groups created by the controversy.

The example of the protest in France against the TGV Sud-Est (South-East High-Speed Train) illustrates this dual process perfectly, as in many other countries. To begin with, when the first studies are completed, in July 1989, the Société Nationale des Chemins de fer Français (French National Railways) initiates institutional yet discreet consultation, with the leading politicians only. Subsequently, at the beginning of the 1990s, after leaks about the route and the revelation of the existence of these contacts, there is an outburst of mobilization. Elected representatives from the communes and departments, associations for the protection of the environment, representatives of wine growers and market gardeners, and, in some areas, a number of residents associations, all come together in a heterogeneous coalition. This proliferation of actors and demands halts the project and results in the postponement of the start of work. An arbitration mission is appointed in August 1991 to offer the threatened populations "a bunch of new negotiators."[7] But this remedial operation, which lasts until the start of 1991, is not enough to reduce the conflict. In parallel, actors from local politics and associations form a structure. A local association mixing farmers and residents is formed at the start of 1990 and leads protests that produce a more entrenched situation. Shortly thereafter, a more extensive coordination is created and brings together very diverse groups on the theme of the defense of Provence's landscape. It initiates a new representation of associations that rivals the older regional organization, which is not very involved in the protest, and it plays a decisive role in the third stage, in the course of which a pluralist "college of experts," appointed in May 1992, conducts the negotiations that lead to the resolution of the crisis two years later. We can see how, in this case, the controversy brings to light actors who previously were distant from the public space or did not exist.

Socio-technical controversies contribute to the realization of a second inventory: an inventory of the possible connections between the problems under discussion and other problems with which some committed groups strive to establish links. The effort to make links is not just a matter of simple exposure. It needs the appearance of new actors and their activity of reflection and investigation to establish unexpected connections. Decision makers think that the parameters of the questions to be dealt with have been suitably and properly defined, from both a technical and a political point of view, and now overflows identified by the actors demonstrate the opposite: that controversy allows an inventory to be made of the different

dimensions of what is at stake in a project. Controversy brings about the discovery, for example, that the mobilizations provoked by the introduction of major facilities (motorways, high-speed trains, airports, or the storage of dangerous waste) is not explained simply by the fear of pollution experienced by the resident populations, but also by their relationships with the territory, its history, and its elites.

We can say that the controversy enriches the meaning of a situation. In fact, all big projects of development or social reform pursue precise but partial objectives. They generally respond to needs or demands which are deemed to be legitimate and which come from a public agency or body seeking to extend or renew its field of action (modernization of the means transport, resolution of the problem of nuclear waste, or even broadening anti-drug policies); they may also arise from political parties seeking to deal with problems encountered by the population (new epidemics, lack of security, the lack of status for civil partnership, etc.). The initial delimitation and formulation of these needs is generally carried out within closed circles (political offices, central administrations, directors of public enterprises, and so on). But such containment cannot last. Every decision-making process requires a work of opening out, of diffusion, if only because of the need to mobilize the actors who will enable the project to be brought to a successful conclusion (or, at least, will guarantee that it is not violently rejected). Deciding is opening Pandora's Box by permitting actors previously held at arm's length to take part in a dynamic to which they quickly contribute.

The development of mobile telephony perfectly illustrates this open process of exploration of issues and matters of concern. When the first relay antennas were set up, nobody took any notice. But information soon began to circulate. Researchers claimed that the electromagnetic waves emitted by the antennas could affect the health of people living nearby. Local organizations were set up and demanded that the plan to install the antennas be shelved. International epidemiological investigations were launched and produced results that were reassuring but left many doubts. The health issue continued to be a subject of mobilization, and many measures were taken, at European and national level, to set emission levels. The experts kept on working and writing reports. At their suggestion, the French government, inspired by the precautionary principle, decided to go further and demanded that antennas not be installed near nurseries or schools. But soon things became complicated. The health issue became only one among other controversial issues. People who lived near antennas and who had started by questioning their placement in the name of health

often switched to other subjects of preoccupation. For instance, they denounced the conditions under which the local authorities had decided to install the antennas, or they criticized its poor environmental integration. On a site on which unexplained cases of leukemia appeared, families started by implicating the antenna, placed on a school building. One thing led to the next, as official and unofficial inquiries proliferated. It was discovered that the ground had been polluted by a military camp situated nearby, and by industrial waste. Thus, the history of an entire area was examined by the population, and health concerns were soon forgotten. The people living in the area laid charges against the municipality, which it accused of having chosen the site without any public consultation, and against the mobile phone operators who devalued public property by installing antennas that defaced the buildings. In short, at national and local level we witnessed an ongoing exploration of matters of concern. These proliferated and ended up weaving a dense web of unexpected issues and groups expressing and exploring them.

These stories and other examples in this book illustrate the power of socio-technical controversies to reveal the multiplicity of stakes associated with one issue, but also to make the network of problems it raises both visible and debatable.

Controversies also allow the exploration of conceivable options by going beyond the list established by the official actors. Thus the public debates provoked by certain bullet train projects succeeded in reopening the ''black box'' of technical solutions. While the TGV no longer gave rise to discussion after the success of the Paris-Lyon link, which was thought to be not only the best solution possible but the only conceivable solution, on the occasion of the TGV Sud-Est project it was possible to reintroduce another option: that of the tilting technique, which had initially been rejected. In a situation of a lack of public funds, the mobilization of new political actors (local communities, groups defending the environment, and residents associations), and the development of controversies over all TGV projects, this alternative solution was re-launched and even became popular. Certainly, the tilting train is defended only by minority groups and is firmly criticized by the Société Nationale des Chemins de fer Français. But it becomes an obligatory subject of debate in public exchanges. Everyone taking part in the debate is now required to make their position public and to argue for it.

A controversy reveals uncertainties and, as a consequence, new lines of research to be explored. It provides the opportunity to return to abandoned tracks, for one of the strategies for re-opening a debate or for changing its terms is to mobilize solutions that have greater credibility, having already

been tested in other places and other circumstances. Faced with realistic options that they did not think they would have to consider, those promoting a project have to justify themselves, explain why they do not want to, and thereby make explicit the criteria for their choices and decisions. By situating a policy in its history, or by redefining its context, controversies bring to light possibilities that were not taken up and suggest the recycling of solutions envisaged in the past. In addition, they lead to the identification of constraints that were not taken into account during the development of technological projects. Once identified, these new constraints will reorient research and open up the elaboration of new projects and new solutions.

Because they formulate a triple inventory of actors, problems, and solutions, controversies are a highly effective apparatus for the exploration of possible states of the world when these states are unknown, owing to uncertainties. They encourage the enrichment and transformation of the initial projects and stakes, simultaneously permitting the reformulation of problems, the discussion of technical options, and, more broadly, the redefinition of the objectives pursued. This exploration, which aims to take the measure of overflows not yet framed within definite parameters, equally constitutes a process of collective learning.

Controversy as Learning

Once the overflows are brought out and made explicit, the question is no longer whether or not a solution is good; it is a question of how to integrate the different dimensions of the debate in order to arrive at a ''robust'' solution. The opposition between experts and laypersons, between science and politics, is replaced by socio-technical arguments, by scenarios that articulate different kinds of considerations. Conflict is not extinguished, but shifted. Controversy allows the design and testing of projects and solutions that integrate a plurality of points of view, demands, and expectations. This ''taking into account,'' which takes place through negotiations and successive compromises, unleashes a process of learning. This learning is not limited to redrafting the proposals of experts, who could then be content with integrating non-technical considerations so as to take them over. In some extreme cases, such redrafting takes the form of a simple modification of vocabulary in order to avoid words that frighten the population. Since the 1991 French law on nuclear waste, we no longer talk of ''burial,'' but of ''deep storage.'' Talk of creating an ''underground laboratory'' defers the debate on the creation of storage centers. The learning pro-

voked by socio-technical controversies goes further. It is collective. As the following chapters will show, it allows laypersons to enter into the scientific and technical content of projects in order to propose solutions, and it leads the promoters to redefine their projects and to explore new lines of research able to integrate demands they had never considered.

To what are these effects of learning due? First, to the constraints that every organized debate in a public space brings to bear on the actors involved. In the dynamic of controversy, everyone is asked to listen to other people, to respond clearly to their arguments, and to formulate counter-proposals. A ''besieged fortress'' type of strategy (defending one's initial point of view at any cost), or one of ''sitting on the fence'' (saying as little as possible to avoid committing oneself), is especially unproductive, and generally such strategies go against those who adopt them. In a public arena, the actors must express themselves and listen. This double requirement results in real exchanges taking place.

But exchanges alone are not enough, however courteous and civilized. A gain must be produced. New knowledge must be acquired and shared, and new ways of thinking, seeing, and acting must be developed, pooled, and made available. Two fundamental mechanisms account for the production of this gain.

The first mechanism is linked to the unusual confrontation that socio-technical controversies organize between specialists and laypersons. Controversy establishes a brutal short circuit between these two poles, which are usually separated by an almost unbridgeable gulf. In fact, relations between specialists and non-specialists usually bear the stamp of asymmetry. The former, imagining that they are faced with an ignorant or even obtuse public, take on the mission of enlightening and instructing the latter. The discussion established in hybrid forums wrong foots this model. It demonstrates that both categories of actors possess specific forms of knowledge (a capacity for diagnosis, an interpretation of the facts, a range of solutions) that mutually enrich each other. In the case of the TGV Sud-Est, the residents unfavorable to the project give prominence to new local problems (the construction of massive embankments, the environmental impact on sensitive natural milieus, unawareness of local transport networks) which were not considered in the initial studies and with which the experts have to make themselves familiar and which they will have to learn to take into account. In the Rhine-Rhone TGV project, the laypersons also help to put the experts in a learning situation. The arguments of the opponents marshal facts that had already been collected by groups opposed to a previous

project for a canal with the same course, and which the promoters had not explicitly taken into account (in particular regarding the impact on the hydrological network).

The second mechanism of learning is linked to the perceptions that different groups have of each other. Instead of confronting each other and debating through interposed spokespersons and official representatives (members of parliament, local councilors, union leaders, et al.), the actors involved in the controversy do not hesitate to provide themselves with new representatives closer to their way of thinking and demands. The latter, having no guarantees that they will keep their position (they can be disowned at any moment), take better account, in the positions they adopt, of the evolution of changing and developing identities. The actors involved find themselves more directly in tune with each other, which improves mutual understanding. A socio-technical controversy makes it tangible that planners are not just developers, that opponents of nuclear power are not just nostalgic for candlelight, that the councilors of small communes are not just simple spokespersons for their electors, and that scientific experts are not just monsters of abstraction indifferent to any social cause. Controversy makes it possible to go beyond a simple opposition setting defenders of the general interest against defenders of selfish interests, or representatives of progress against the standard bearers of a backward-looking mode of life. For a time, the relative equalization of ''rights to speak,'' the opportunity for everyone to argue on his or her own account and to question the justifications of others, transforms for a time the usual hierarchies and their underlying conceptions. This mutual discovery obviously affects each actor, whose identity is modified in turn. Becoming aware that one's sworn enemy is not the person one thought he was facilitates the revision of one's own positions.

The redefinition of identities opens the way to compromises and alliances that would be unthinkable without the existence of controversies. The latter thus contributes to the formation of networks of actors sharing a collective project, to the emergence of ''project'' or ''cause'' coalitions that otherwise would not have existed. These reconfigurations of identities, proximities, alliances, and commitments result in a veritable mutual learning process that is all the more fruitful as the traditional representative institutions are powerfully short-circuited. Controversies make it possible to overcome the gap separating laypersons and specialists, but also to go beyond the sterile roles of the ordinary citizen and his legitimate representatives that tend to prevail.

The Dialogical Space of Hybrid Forums

The examination of the functioning of hybrid forums leads us to see the controversies that develop within them as powerful and original apparatuses for exploration and learning:

- exploration of the identity of the actors who are concerned about the projects under discussion; exploration of the problems raised as well as all those that the concerned actors consider to be associated problems; exploration of the universe of conceivable options and the solutions to which they lead
- learning that results in alternate exchanges between the forms of knowledge of specialists and the knowledge of laypersons; learning that, beyond institutionalized representations, leads to the discovery of mutual, developing, and malleable identities that are led to take each other into account and thereby transform themselves.

Controversies are not summed up in the simple addition and aggregation of individual points of view; their content is not mechanically determined by the context in which they unfold; they are not confined to friendly discussions or by debates intended to conclude with an agreement. By trial and error and progressive reconfigurations of problems and identities, socio-technical controversies tend to bring about a common world that is not just habitable but also livable and living, not closed on itself but open to new explorations and learning processes. What is at stake for the actors is not just expressing oneself or exchanging ideas, or even making compromises; it is not only reacting, but constructing.

By fostering the unfolding of these explorations and learning processes, hybrid forums take part in a challenge, a partial challenge at least, to the two great typical divisions of our Western societies: the division that separates specialists and laypersons and the division that distances ordinary citizens from their institutional representatives. These distinctions, and the asymmetries they entail, are scrambled in hybrid forums. Laypersons dare to intervene in technical questions; citizens regroup in order to work out and express new identities, abandoning their usual spokespersons. Thanks to this double transgression, as yet unidentified overflows are revealed and made manageable. The hybrid forums could thus become an apparatus of elucidation. The cost of accepting their use is acceptance of the challenge to the two great divisions. Actors involved in socio-technical controversies are not mistaken. When they establish a new hybrid form,

they lay their cards on the table: ''We do not accept the monopoly of experts! We want to be directly involved in the political debate on questions that our representatives either ignore or deal with without speaking with us!''

Every hybrid forum is a new work site. It is a site for testing out forms of organization and procedure intended to facilitate cooperation between specialists and laypersons, but also for giving visibility and audibility to emergent groups that lack official spokespersons. The task of the actors is all the more difficult as it comes up against two monopolies: that of the production of scientific knowledge and technology and that of political representation. Without a minimum of formalism and guarantees, hybrid forums would be doomed to failure, a protest soon to be forgotten. By designating the great double division as that which they are struggling against, the actors express this clearly. They identify the possible adversaries; they get ready for a confrontation. This would quickly redound to their disadvantage if there were not procedures that the actors had invented and tried out, forum after forum. Chapters 4 and 5 present these procedures and put forward a balance sheet of the experience so far. But before doing this we must examine the question at the heart of technical democracy: In what circumstances, under what conditions, according to what modalities, and with what effectiveness is collaboration between laypersons and specialists conceivable? Is it not, perhaps, just a case of occasional and superficial exchanges? Alternatively, can we conceive of a lasting cooperation? This is the theme of the next two chapters.