The idea that technologies have natural trajectories is deeply built into the way we talk. Almost as deep is the notion that any *individual* technology moves through a natural life cycle: from pure through applied research, it moves to development, and then to production, marketing, and maturity. As we have indicated in the introduction, many recent studies in the social history and sociology of technology suggest that these models of innovation are quite inadequate. This message is pressed home in this volume, but particularly in the three papers in this first section. These are all concerned in one way or another with the character of technological trajectories. And they are all concerned to show that there is nothing inevitable about the way in which these evolve. Rather, they are the product of heterogeneous contingency. In addition, the three papers suggest possible vocabularies for sociotechnical analysis—for making sense of the heterogeneity and contingency of technical change.

Law and Callon take the case of the TSR.2—a British military aircraft somewhat like the F111. After various vicissitudes the TSR.2 flew—in fact quite successfully—and was then cancelled. There are various ways of reading this story. It could, for instance, be treated as another example of profligate military waste, or as an example of the way in which politics can undermine decent technology. In fact, Law and Callon choose to examine the development of the project in an evenhanded manner. Yes, they say, it *is* possible to discern a trajectory for this project. But they go on to argue that there was nothing natural or inevitable about that trajectory. It was not a consequence of a naturally unfolding process of technological development; at all points it should be seen rather as a product of contingency. The result is that it twists and turns as social and technical circumstances change. Law and Callon use a network vocabulary to document the way in which the trajectory of the TSR.2 project was affected by the heterogeneous strategies of those involved. In particular, they describe the way in which the protagonists sought to give the project a degree of autonomy from its environment—a degree of insulation from some, though only some, of its contingencies.

The importance of this process of building a boundary between inside and outside—a boundary that eventually ruptured in the case of the TSR.2, with the collapse of the project—is also emphasized by Bowker. Here again, the concern is with a technological trajectory—that of the development of geophysical methods by Schlumberger. But if the development of these methods was not inevitable, then how was this achieved? Bowker argues that the company successfully mobilized a series of resources to build a version of natural

and social reality within which its methods secured success. As a part of this strategy, the company Whiggishly *claimed* that its geophysical techniques were, indeed, the product of an unfolding scientific and technical logic. With this claim the company successfully fought a series of legal delaying actions, which gave it time to mobilize the messy and heterogeneous resources needed to generate a content and a context for success. In short, the *pretense* of a natural trajectory and the concealment of contingency behind legal and organizational barriers were central ploys in the process of *creating* a successful technology.

Bowker's story suggests that the *idea* that technology may be seen as the appliance of science is a powerful form of rhetoric but, at least in the case of Schlumberger, rather far from the truth. Bijker's chapter takes us to the very different history of the fluorescent lamp to make a similar point. Here the issue has to do with the relationship between invention, development, production, and diffusion. Bijker shows that the design of a high-intensity fluorescent lamp took place in what orthodox economic theory would call its diffusion stage. This lamp was not designed by engineers in research and development, but rather through the joint efforts of the executives of the electric light manufacturers and the utilities. In this case, then, the conference table became the drawing board!

Here again, heterogeneous economic, organizational, and technical contingencies were at work. When General Electric and Westinghouse launched their original version of the fluorescent lamp, they were clear that one of its attractions was its efficiency. But this meant that the new fluorescent lights might reduce the sales of power—a matter of deep concern to the utilities. The invention of the high-intensity fluorescent lamp met the concerns of both the manufacturers and the utilities.

These three chapters thus press home the message that technical change is contingent and heterogeneous. They also, however, show that it is possible to tackle the character of that change using a variety of different vocabularies and theoretical perspectives. Law and Callon make use of the actor-network approach, which rests on the idea that innovation and the strategies that shape it may be described in a network vocabulary that emphasizes the interrelated and heterogeneous character of all of its components, whether social or technical. It also puts forth the view that the social and the technical are established simultaneously—indeed that they mutually constitute one another.

Bowker is also influenced by the actor-network approach, and in particular its concern with dealing evenhandedly with both the technical and its institutional context. However, his piece also draws on a range of other resources. In particular, his background as an historian is revealed in the analogy he draws between textual, contextual, and self-validating features of geophysical accounting and invention on the one hand, and the debate between Tawney and Trevor-Roper on the origins of the English revolution on the other. One consequence of this is the way in which he displays a concern with the products of historiography and the fact that they are ultimately open to question. Another is his interest in the way in which historical accounts may work to influence history and so generate the conditions for their own validity.

If Bowker brings the nuanced eye of the historian to his subject matter, Bijker's piece applies and extends a particular sociological tool to the analysis of technological change. The term "technological frame" refers to the concepts, techniques, and resources adopted by technologists and others. It is thus a way of talking of the set of theories, expertises, values, methods of testing, and physical tools and devices available to communities as they negotiate about the putative character of innovation. Here again, the stress is on heterogeneity. Bijker presses the view that both social groups *and* technologies are generated in the contingent arrangement of the concepts, techniques, and resources brought together in the relevant technological frames. Society itself is being built along with objects and artifacts.

1

The Life and Death of an Aircraft: A Network Analysis of Technical Change

John Law and Michel Callon

Imagine a technological project that lasts for a number of years, involves the mobilization of tens or hundreds of thousands of workers, designers, managers, and a plethora of heterogeneous bits and pieces including designs, parts, machine tools, and all the rest. Imagine that this project is developed in a constantly changing environment—that requirements, interests, and even the actors themselves change during the course of its lifetime. Imagine that not hundreds but hundreds of thousands of decisions are made. And imagine that in the end it is cancelled amid a welter of acrimony. How can we describe such a project in a way that is more than "simple" history? How can we describe it in a way relevant for the analysis of other projects and technological innovations? How can we explain the decision to close the project? How can we explain its failure? And how can we do this in a way that lets us avoid taking sides?

Despite the recent growth in interest in the social analysis of technology, few tools currently available are really useful. Our problem is that it is too simple (though it contains an element of truth) to say that context influences, and is simultaneously influenced by, content. What we require is a tool that makes it possible to describe and explain the coevolution of what are usually distinguished as sociotechnical context and sociotechnical content. In recent work we have used a network metaphor to try to understand this kind of process (Callon and Law 1989). We have considered the way in which an actor attempts to mobilize and stabilize what we call a *global network* in order to obtain resources with which to build a project. In our language, then, a global network is a set of relations between an actor and its neighbors on the one hand, and between those neighbors on the other. It is a network that is built up, deliberately or otherwise, and that generates a space, a period of time, and a set of resources in which innovation may take place. Within this space—we call it a *negotiation space*—the process of building a project