Technologies have social implications. Indeed we have argued that it is impossible to pry technical and social relations apart. The shaping of a technology is also the shaping of a society, a set of social and economic relations. This means that many—perhaps all—technologies are born in conflict or controversy. Different social groups have different concerns, or simply different practices, and hope for or expect different things from their technologies. How are conflicts resolved? How are new technical and social relations set in place? How is irreversibility achieved? The papers in the first section offer certain suggestions. In particular, they point to the importance of the strategies deployed by heterogeneous engineers—for instance, the ways in which system builders deploy organizational and legal resources as they attempt to stabilize a network of social and technical components. The papers in this section build on this theme.

Misa takes us to the history of steelmaking to describe the way in which two controversies were resolved. The first concerned pneumatic steelmaking and a conflict between two groups, each of which held patents crucial to the process. The result was that neither was able to build an advanced Bessemer converter. To have done so would have infringed the patents of the other group. In the geophysical case described by Bowker, Schlumberger defended its patents as a delaying tactic. Although it knew that these would probably turn out to be indefensible, the object was to maintain its strategic position close to the oil exploration companies long enough to build up a body of expertise and a set of practices in which its products were seen as indispensible. Patents thus took the form of a crucial resource. In the case described by Misa they were equally important, but were used quite differently. Instead of fighting in the courts, the two groups agreed to a legal and organizational innovation—the formation of a patent pool from which *both* would profit. The individual legal and technical resources of the two groups were thus combined.

Misa's second controversy concerns the distinction between "iron" and "steel"—one that was important to different protagonists in different ways. Thus, at least in the early stages of the controversy, "steel" carried a price premium. In addition, scientific and professional reputations were at stake: a distinction based on the percentage of carbon demanded the use of (professionally administered) chemical and physical measurements. Finally, there were issues of daily practice. Thus steelmen tended to talk of "steel" to describe metal that fused completely during the process of production, and saw little reason to change their practice. Unlike the patent pool, this controversy was not settled by legal or organizational innovation.

Rather, as the circumstances changed ("steel" ceased to command an economic premium), the inertia of the steelmen carried the day. As Misa puts it, stabilization owed "less to written authority than to the daily practice of thousands of steelmen."

Scientific and professional knowledge, daily practice, and organizational arrangements—all of these also play a role in the story about the technological handling of radioactive waste described by de la Bruhèze. Indeed, de la Bruhèze's account in many ways reads like an essay in technologically informed bureaucratic politics. The name of the deadly game he describes was the mobilization of bureaucratic and organizational resources in order to define the appropriate social and technical arrangements for the handling and treatment of radioactive waste.

Leaving aside its intrinsic importance, there are several striking features of this story. One has to do with the way in which boundaries are drawn. Thus de la Bruhèze illustrates the way in which so much of the bureaucratic maneuvering turned around questions about who or what should have the right to speak, and what they should be allowed to say. The right to speak was, of course, precisely what was at stake. Whoever could speak for the AEC—and make it stick—would define its policy. Accordingly, there were endless tussles about such matters as committee membership and the circumstances under which different individuals and agencies might make their views known. The processes of boundary negotiation described in de la Bruhèze's paper thus resonate with those found in the studies by Misa (who should have the right to speak about the proper character of steel?), Bowker (who should have the right to speak for geophysics, who should have the right to work alongside the oil companies?), Bijker (who should be allowed to define the proper character of fluorescent lighting?), and Law and Callon (who should be allowed to comment on, and make decisions about, the progress of an aircraft project?).

A second feature of de la Bruhèze's story concerns time. None of the protagonists, even in their own estimation, believed that they had a complete solution to the problem of radioactive waste at hand. At best, they believed that they had found methods that would, if properly developed, lead to such a technical solution. Their object, then, was to deploy and freeze organizational and bureaucratic arrangements that would generate technical solutions—and, at the same time, to use the *promise* of new technologies to fix current social relations.

We have encountered this form of bootstrap sociotechnical engineering in the case of the TSR.2 described by Law and Callon. But the geophysical case described by Bowker is also similar. Here Schlumberger believed that a workable new technology might evolve if the current legal challenges, however well founded they might be, could be held off for long enough. To be sure, there is nothing inherently obnoxious about this kind of circularity. But it does indicate that technological innovation may start neither with invention (technology push) nor with consumer demand (demand pull) but rather in an interactive, time-dependent, process of sociotechnical bootstrapping in which promises about technologies and social relations are played off against one another in the search for durable solutions.

If promises are a crucial resource in sociotechnical maneuvering, then the third paper in this section considers another type of resource—the simplifying cultural and cognitive models or strategies used by innovators. Carlson examines the moviemaking endeavors of Thomas A. Edison and his company—efforts that finally failed with the withdrawal of Edison from the moviemaking business. Carlson's argument is that Edison's style of invention and innovation was production-oriented. Thus he tended to create capital goods for business markets, rather than consumer goods for the general public. This worked well in such cases as the telegraph and business equipment, the electric light, and the phonograph. In the case of moviemaking, though, the business was in the end undermined by the development of a consumer culture. In this the hero was not the hard-working inventor but movie and sports stars. Furthermore—and this lay at the root of his business failure—a mass audience grew up that sought diversion, entertainmen, and glamour in its movies, rather than education, information, and "improvement."

In his paper Carlson draws on the sociology of scientific knowledge, and in particular on the notion of the "frame of meaning" developed by Collins and Pinch. This is close to Bijker's concept of "technological frame" except that it applies to engineers and managers alone, and not to other social groups. Nevertheless, like "technological frames," "frames of meaning" are a tool for making sense of the strategies of entrepreneurs. They include cultural commitments, class biases, business strategies, and methods of design. Accordingly, they bring a concern with "narrow" technical factors together with "broad" macrosocial and cultural considerations. Like patents and organizational arrangements, frames of meaning may thus be seen as a resource—a more or less satisfactory set of cultural and cognitive assumptions for making sense of and operating on the sociotechnical world.

4

Controversy and Closure in Technological Change: Constructing "Steel"

Thomas J. Misa

"A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk."

Alexander Holley (1873b, 117)

Controversies in science and technology are not new, but recent studies of their genesis and resolution have generated fresh insights into the making of "objective culture."[1] Empirical research now stands behind the view that nature does not determine the form of scientific facts or technological artifacts and that their shape is negotiated among actors. Indeed, the principle of "interpretive flexibility" forms the core of the social constructivist research program. Its advocates maintain there is nothing in principle that cannot be disputed, negotiated, or reinterpreted—in short, become the subject of a controversy. Yet if everything were endlessly negotiated, the effort might exhaust the time and resources of actors and render change impossible. To effect change, actors deploy strategies to hold in place otherwise wayward elements. Through these efforts actors ensure that controversies—if sometimes lengthy—are rarely interminable. In fact, a distinctive characteristic of scientists and technologists is their ability to resolve controversies and engineer consensus. This ability vests facts and artifacts with authority and permanence. What could be tractable or "soft," the topic of interminable controversy, becomes obdurate or "hard," a part of constructed reality. The concept of closure helps account for this remarkable shift.

Recent studies of closure have extended its meaning beyond the familiar one of the effective termination of a controversy.[2] Closure has come to mean the process by which facts or artifacts in a provisional state characterized by controversy are molded into a stable state characterized by consensus. At least four research programs use