Beyond Inevitability

Emphasizing the Role of Intention and Ethical Responsibility in Engineering Design

Kathryn A. Neeley and Heinz C. Luegenbiehl

Design is "the first signal of human intention."
– William McDonough (1993)

Abstract Much of how humans think about their world and their actions in relation to it is governed by the manner of their speaking. In this paper the authors argue that this has an especially significant impact on the work of engineers and their perception of ethical responsibility. A discourse framework governing the actions of engineers which focuses on the idea of technological development tends to lead toward perceptions of technological inevitability, whereas one focusing on the terminology of engineering design enhances perceptions of choice and, consequently, of individual responsibility. Perceptions of responsibility resulting from design focused discourse thus are not limited to narrow safety and production considerations, but include holistic considerations such as aesthetic and environmental factors, as well as considerations of societal implications of design choices. The authors propose that increased focus on design discourse, in both professional and public settings, will enhance a broader sense of ethical responsibility among engineers.

1 Introduction

Engineers usually find it relatively easy to identify issues of professional ethics as they arise in personal relationships and when making individual decisions. It is often more difficult, however, for them to feel responsible for, or even to recognize, the ethical issues associated with technology-based systems and large-scale technologies that are developed by groups and organizations.

These larger-scale forms of technological development, despite the tremendous impact they have *on* individuals, are typically seen as being out of the control *of* individuals. Part of the reason for this is that discourse, using technological development as a referent, tends to be dominated by the notion of inevitability and the assumption that the path of technological development is difficult, if not impossible, to control. Discourse about design is related to individuals and focused on the vocabulary of intention; it appears to be based on the assumption that we have

K. A. Neeley, University of Virginia

H. C. Luegenbiehl, Rose-Hulman Institute of Technology

P. E. Vermaas et al. (eds.), *Philosophy and Design*.

reasonable control over the shape of our designs and the consequences that will follow from their use; and it conceptualizes design as a process imbued with ethical considerations.

In this chapter we argue that the notions of openness and choice that are reflected in the discourse of design are much more conducive to ethical awareness, reflection, and responsibility than is the notion of inevitability that characterizes the discourse of technological development. It then follows that, if the discourse about technological development can be changed in the vocabulary of engineers to one focused on design, their ability to engage in ethical reflection will be enhanced.

Our analysis is aimed at suggesting ways to move beyond the discourse of inevitability and toward a framework that emphasizes an ideal of individual ethical responsibility in team-based and large-scale engineering design. Specifically, we argue that supplanting the discourse of inevitability will require:

1. recognizing that the robustness of the discourse of inevitability derives from many sources, including the way it resonates with lived experience and its pervasiveness in the popular media, which gives rise to its perceived simplicity and familiarity.
2. developing a compelling discourse of design that is, in turn, based on a sound philosophy of engineering and philosophy of technology.
3. demonstrating that as humans we have choices about the forms of discourse in which we engage and that those choices have significant societal consequences.

In what follows we take a discourse analysis approach, that is, we carefully examine exactly *how* the discourse of technological inevitability functions as a way of gaining insight into the sources of its power and how it might be supplanted.

2 Key Features of the Discourse of Inevitability

The discourse of inevitability regarding technological development pervades popular culture and public discourse about technology and appears in particularly vigorous form in discussions of information and communication technology. It is clearly reflected in the cover headlines of publications such as *Popular Science, PC Magazine, PC World*, and *Wired*, whose covers are replete with exclamation points, "The Super Power Issue: The Impossible Gets Real!" (*Wired*, August 2003), imperatives, "Go Wireless: It's Faster & Easier Than Ever" (*PC Magazine*, May 18, 2004), promises, "Live Forever: 7 Easy Steps to Engineered Immortality" (*Popular Science*, January 2005), and offers of competitive advantage or empowerment, "PC Secrets! 15 Easy Ways to Make Your System Do More" (*PC World*, March 2006) and "Build Your Perfect PC: Faster than Dell, Cooler than Apple, Cheaper than Sony" (*PC Magazine*, March 7, 2006). Kroker and Weinstein (1994) concisely summarize the discourse of inevitability in their book *Data Trash: The Theory of the Virtual Class* (1994): "adapt or you're toast."

Both the covers and the content of these publications make it clear that the discourse of inevitability is first and foremost a marketing strategy, a way of selling what is “new and next,” along with promises and visions of the future. To the extent that the theme of choice is raised at all in these discussions, the choices to be made are typically between various versions of a particular technology, for example, digital cameras, flat screen televisions, personal computers, or software packages, rather than about whether particular technologies should be used at all.

The discourse of inevitability is associated with several metaphors in which technology is conceptualized as a force of nature or an autonomous agent making demands and producing “powerful and inevitable change” (Sasseville, 2004, n.p.). It implies that technology is the primary or sole driver of social evolution and that control over designs and outcomes is either difficult or impossible. The current popular and engineering discourses using the vocabulary of technological development thus reflect a perspective that has been analyzed and critiqued by a number of recent commentators on technology such as Jacques Ellul (1964), Martin Heidegger (1977), Langdon Winner (1977), Arnold Pacey (1983), Thomas Hughes (1987), and Rosalind Williams (2002). Winner begins his discussion by writing: “One symptom of a profound stress that affects modern thought is the prevalence of the idea of autonomous technology – the belief that somehow technology has gotten out of control and follows its own course, independent of human direction. That this notion is (at least on the surface) patently bizarre has not prevented it from becoming a central obsession in nineteenth- and twentieth-century literature.” (Winner, 1977, 13) Given the central role of the requirement to make choices in ethics, it is thus not surprising that popular discourse discourages both ethical reflection and individual ethical responsibility by promoting the view that there is nothing an individual can do to affect the course of technological development meaningfully.

Challenging the discourse of inevitability has been one of the major projects of the STS community, an effort that most scholarly analysts see as both successful and largely complete. Having dismissed inevitability within our own professional communities, it is tempting to overlook the extent to which the concept of inevitability still resonates in popular and engineering discourse.

3 Understanding the Robustness of the Discourse of Inevitability

The robustness of the discourse of inevitability derives from many sources, including its simplicity and familiarity and the way in which it resonates with lived experience. Where the more complex narratives of professional historians may more fully capture the subtleties and intricacies of the processes by which technology and society shape each other, the discourse of inevitability appears to provide “an easy and uncomplicated explanation” (Selwyn and Gorard, 2003, 80). There is also a host of assumptions, myths, and predispositions that make people inclined to accept the narrative of inevitability (Pacey, 1983; Martin and Schinzinger, 1989; Frost, 1996).

Perhaps more importantly and persuasively, the discourse of inevitability resonates with lived experience. This point has been developed by several analysts of technology, including Arnold Pacey (1983) and Eric Schlosser (2002), but it is perhaps most clearly delineated by Rosalind Williams in *Retooling: A Historian Confronts Technological Change* (2002). Williams, herself a historian of technology, analyzes her experience as a university administrator involved in a "Reengineering Project" designed to improve management of her institution's existing resources.

Drawing on Thomas Hughes' concept of technological momentum, Williams concludes that "It is easy to refute the logic of technological determinism, but the everyday experience of having to conform to 'the technology,' 'the software,' or 'the computer' cannot be refuted by logic" (2002, 117). The process, Williams argues, begins with what she terms "technological drift," the tendency to address the aspects of a problem that are most susceptible to a technological solution and where visible results can be accomplished quickly. Once this happens, "The rules that govern the technology start to govern everything else. Technological drift becomes technological momentum, which begins to *feel* [emphasis added] very much like technological determinism" (2002, 116). What starts out as choice comes to be experienced as inevitability. This resonance with lived experience is one of many reasons why the narratives produced by historians and philosophers of technology and other professional analysts cannot compete with or dominate simpler narratives of inevitability. We believe that the community of professional analysts of technology-society interactions is not likely to disrupt the discourse of inevitability unless we can connect with broad social discourses about technology. We argue that the discourse of design and intention has the potential to make that connection and to elucidate the ethical dimensions of the development of technological systems more fully.

4 Contrasting the Language of Design with the Language of Technological Development

Given that we are locating much of the lack of ethical responsibility in the language that is often applied to technology, it is worthwhile to contrast the discourse tendencies that differentiate design and technological development. Table 1 gives a brief catalogue of terms associated with these perspectives.

Here we have space only to highlight several of these contrasting terms and how they influence the subjective feeling of choice. For example, as the word "design" is typically used in engineering, it is focused on something *specific*, either an individual project or part of a larger scale project, but still with a specific outcome. The terminology "technological development" usually refers to a *general* trend. Any specific development thus becomes part of a larger process. The notion of design thus makes it easier to think in terms of originality, whereas the notion of technological development shifts the question to how the new technology fits into a larger totality. Underlying technological development is therefore the idea of progress, the issue of building on something prior, which will be better than or

Table 1 Discourse tendencies

Design	Technological Development
Specific Innovation	General Trend
Originality	Process
Change	Progress
Imagination	Production
Aesthetic Considerations	Efficiency
Individual	Team
Credit	Anonymity
Inventor	Corporation
People	Technology
Iteration	Linear

improve on what already exists. This then restricts the possible range of choices for the engineer. For design, however, if originality is the criterion, while it is still possible to reference the notion of "better," the primary focus is on being different, on creating a rift with that which has come earlier.

The question of aesthetics also functions differently in the two discourses. In technological development, the production function is primary; that is, the idea of improvement is based on whether a given task will be performed more efficiently by a new device, a criterion often arising out of the nature of the technology. This further limits the scope of what constitutes appropriate development. In design, however, if the criterion is originality, then the device as a whole becomes the subject of concern, not simply one aspect or function of it. This, in turn, vastly increases the number of perceived choices and justifies the designer in bringing other elements into the equation, such as ethical considerations. A development is a part of a chain; a design implies the interruption of a chain.

In contemporary engineering, design and technological development are most typically characterized as team based, but design continues to be associated with the idea of individuality, so that the designer has the sense that she is placing her mark on something. For example, news magazines such as *Time* regularly publish lists of creative "design" activities that highlight particular individuals for their creative power and originality, while trends in technology are described in terms of industries or company initiatives. Thus, in technological development, what is absent is a focus on people. Instead, the focus is on the technology, on how well it performs its designated function, and because of this, there is a lack of ethical concern beyond the question of functionality. The idea of responsibility, which is at the core of ethics, is thus narrowed only to the technical; for example, in terms of durability or safe use. The wider issue of coherence with societal priorities is ignored, and, once the technology is developed, becomes difficult to raise. Yet asking how well a device performs its function is clearly different from raising the range of ethical questions that are relevant to the introduction of a new technology, for example, in terms of materials being used in the production process and its effects on human beings and the environment.

A further distinction between the two discourses is that the process of engineering design is generally seen as being iterative, while technological development is linear. Design, viewed in terms of a feedback loop, provides the opportunity for revision and rethinking, thus increasing the range of perceived choices. While modifications are also possible from the perspective of technological development, these are focused on the question of improved fit or other standards of progress. Further examination thus actually decreases the range of perceived choices to those that are “most appropriate,” rather than increasing them.

An example of the contrast between these two types of discourses can be found in the public’s image of the Apple I-Pod versus the manufacture of Dell computers. The I-Pod is sold to the public as a technology that integrates form and function, so that its aesthetic considerations appeal to the public just as much as what it does. Steve Jobs is hailed as a creative genius and receives much of the credit for creating public desire for a product that is sold based on its originality, independently of whether it actually fits with a previously existing trend of devices for listening to music. Each new version of the I-Pod is viewed in the popular literature as another revolutionary “must-have” device, although it only expands the capabilities of a previous version or miniaturizes the device further. By contrast, the Dell computer is seen by the public as a pure commodity. Progress here is not defined in terms of originality, but rather in terms of its opposite. Dell prides itself on relying on parts manufactured by others and on making the production process as efficient as possible. The attraction of the product is increased computer power with each new version of the computer, at a lower cost. Michael Dell is hailed as a genius, but one whose genius is reflected in developing innovative production processes rather than in design originality.

Another way of looking at the same contrast is in terms of the popular late twentieth-century contrast between American “innovation” and Japanese *kaizen*. Masaaki Imai (1986) characterized the distinction: “Innovation is dramatic, a real attention-getter. *Kaizen*, on the other hand, is often undramatic and subtle, and its results are seldom immediately visible. While *kaizen* is a continuous process, innovation is generally a one-shot phenomenon.” (1986, 23). Given the Japanese success in the marketplace during the 1970s and 1980s, American companies were urged to imitate the Japanese model, the implication of course being that it is building on the past in an incremental fashion that matters, not the originality of the product. Design considerations thus began to take a secondary role to manufacturing innovations, such as those developed by Dell, in the quest to duplicate Japanese success. The Japanese, who had been known as borrowers of foreign technology, which they then produced more efficiently and at less cost, became the model for processes such as just-in-time parts delivery and team-based manufacturing. We argue that the shift in emphasis that accompanies the move from design to technological development has embedded within it a potential for neglect of ethical considerations.

5 Ethical Implications of the Discourse We Employ

In their study of “Ethical Considerations in Engineering Design Processes” (2001), Van Gorp and Van de Poel point to two central features of the design process recognized by engineers. These are issues of trade-offs, for example between safety and economic considerations, and the generally ill-defined nature of design problems, such that there is no given optimal solution to the design problem. Both of these considerations explicitly provide the opportunity for ethical reflection, even if the position is taken in the end that ethical intervention by the engineers is not justified. Questions arising out of the process of making trade-offs might be: "How should one decide, for example, on the relative importance of safety versus costs? Who is to make this decision? The engineers, the manager or principle [sic] of the project, the portrayed users, the people possibly affected, the general public? And how is this decision to be made in an ethically acceptable way?" (2001, 19). In relation to the ill-defined nature of engineering design, Van Gorp and Van de Poel conclude in a preliminary fashion based on their study: "If requirements need to be further operationalized, which is regularly the case, or if requirements cannot all be met at once, which is also regularly the case, this seems to trigger off reflections on and discussions relating to requirements. Ethical aspects can, but do not necessarily, play a part in these discussions" (2001, 21).

Given the need for trade-offs and the ill-defined nature of engineering problems – especially when we consider the combination of social, ethical, and technical aspects – no one optimal solution exists for an engineering problem. Once this is recognized, then the issue of choice can come to the fore, along with a sense of responsibility for one's actions. In terms of traditional engineering ethics, this means that considerations of the impact of the design on the public and its safety, on the natural and human environment, and on the utilization of different types of natural resources can come to the foreground. Engineering ethics, conceived in this fashion, can be broadened to cover issues beyond traditional ones such as confidentiality and conflicts-of-interest. The focus on design as a process imbued with ethical considerations makes possible a wider perspective on the societal implications of technology than the technologically governed emphasis on production, progress, and efficiency.

The difference in emphasis between the two ways in which we can discuss the work of engineers can guide us in overcoming the barriers to ethical reflection by the creators of technology. How do we draw on our understanding of sociotechnical systems to identify fruitful ways of talking about the process and increase awareness of ethical choices? To begin with, we know that we need to be very careful about the kinds of sociotechnical systems that we put in place. As Hughes' (1987) concept of technological momentum reminds us, we generally experience a foreclosing of options once a choice has been made and a system put in place. This means that ethical reflection must be seen as being appropriate throughout the design process, especially at its earliest stages. Johnson, Gostelow, and King in *Engineering & Society* (2000) paraphrase Hughes saying, "Once the first step has been taken, it is difficult if not impossible to stop a development.…detailed discussion is essential *before* the technology proceeds" (2000, 542).

Johnson et al. describe the first step of the design process in familiar terms: "Review the problem area and select the need that is to be addressed" (2000, 293), and go on to comment, "Both the review of the problem area and the choice of the specific need that is to be addressed are relatively subjective processes. They set the design agenda and belong in a broadly political and commercial strategic domain. *Engineers should be encouraged to be much more involved in this key part of the design process*. [emphasis added] This is the point at which broad issues such as ecological sustainability of design outcomes are most effectively addressed. It is also where basic ethical choices are made about professional priorities, including what problems and issues will and will not be addressed" (2000, 291 and 292). This kind of framework redefines the engineer's sphere of appropriate analysis and decision-making in a way that is much more conducive to a sense of openness and choice – and, thus, to ethical responsibility.

If we can draw on what we do know about sociotechnical systems, we also need to realize what we do *not* know. A compelling discourse of design must be based on a sound philosophy of engineering, which is in turn based on a sound philosophy of technology, and poses three basic questions: How does technology evolve? How are the choices made as to which potential technologies will be developed and which ignored? Who makes these choices? (Ihde paraphrased by Johnston, Gostelow, and King, 2000, 542) Although we have made progress in answering these questions, we have yet to answer them in ways that engineering practitioners find easy to operationalize. Furthermore, a key task for the philosophy of engineering will be to reconcile the macro level of philosophy of technology with the micro level that Martin and Schinzinger describe as the "individual as the ultimate locus of action" (1989, 331). Broader responsibilities inherent in the process of design can be brought to the awareness of engineers involved in the design process; however, the question of the extent to which engineers as designers are justified in imposing their own values on the process of technological development remains a key issue (Luegenbiehl, 1985, 93). This last point highlights the importance of addressing the way both engineers and non-engineers think about and discuss the work of engineers.

6 Developing a Compelling and Accessible Narrative of Individual and Collective Empowerment

One way of overcoming the current dichotomy between discourses of individual responsibility and technological inevitability is to refocus the discussion of technological progress and individual determination around a common theme that captures a wider sense of responsibility within the framework of human intention. As an example, we will here use William McDonough's "Centennial Sermon on the 100th Anniversary of the Cathedral of St. John the Divine, New York City" (McDonough, 1993). He points us toward a process by which we can develop a compelling narrative in which engineers as responsible moral agents play a key role and where relevant decision-making junctures can be identified. It is notable that McDonough – an architect, not a minister or theologian – chose to cast his first formal public declaration of his perspective on the creation of technology in the form of a sermon and to deliver it in a cathedral. From the outset, his ideas are framed both literally and figuratively in contexts of traditional moral and ethical authority. He also uses biblical language and imagery to articulate his new definition of design: "If we understand that design leads to the manifestation of human intention, and if what we make with our hands is to be sacred and honor the earth that gives us life, then the things we make must not only rise from the ground but return to it, soil to soil, water to water, so everything that is received from the earth can be freely given back without causing harm to any living system" (McDonough, 1993, 3). Design – the making of things with our hands – goes beyond being pragmatic and becomes a sacred activity through which we either honor or dishonor the source that gives us life.

For readers to whom the spiritual dimensions of this framing are not persuasive, McDonough offers another level of imaginative transformation centered on "the concept of design itself as the first signal of human intention" (1993, 3). Through this concept, "design, ecology, ethics and the making of things" become inextricably intertwined. In this model, the things we make are representations and signals of "our longings and intentions." Our designs, in other words, communicate and announce our intentions even if we do not speak a word. The products of design express principles or ideas in visible form. They epitomize and embody and, in the process, speak volumes about our intentions even when we have not explicitly articulated those intentions. In this framework, artifacts, systems, and structures "speak." McDonough calls our attention to what we are essentially saying when we design and operate systems in a certain way: "Our culture has adopted a design stratagem that essentially says if brute force or massive amounts of energy don't work, you're not using enough of it" (1993, 3–4).

McDonough further develops the idea of products or designs as "speaking" about our aspirations and intentions by using the concept of "idiom," which carries meaning in both design and communication contexts. In place of the "industrial idiom of design" which we can associate with the concept of development, he proposes the idea – based on "natural design" – that "waste equals food," in other words, that all wastes produced serve as food for other systems. "All materials given to us by nature are constantly returned to the earth without even the concept of waste as we understand it. Everything is cycled constantly with all waste equaling food for other living systems" (1993, 4). This new model serves as an incentive to creativity, and evokes, and is compatible with, a very different ethical framework than the "idiom of industrial design."

In the domain of engineering design, especially engineering design sponsored in the context of capitalist organizations, the equivalent of McDonough's model may lie in the emerging concept of "doing well by doing good," that is, approaching business with the aim of balancing the financial bottom line with the bottom line of ethics and social concerns (Finkel, 2002, 2). The "doing well by doing good" approach leads researchers at Northwestern and the Wharton School of Business to address subjects in which ethics and issues of social responsibility "become a central focus of management thinking in general" (2002, 5). "Balancing the relationships between financial success and a progressive social agenda can prove extremely complicated for business" (2002, 5), but it can also be a great source of individual and collective empowerment, especially for engineers whose own professional history is rooted in an emphasis on "doing good."

7 Conclusion

We have argued in this chapter that disrupting the discourse of inevitability will require us to recognize and confront the sources of its robustness. To put it simply, we must find a way to connect with public discourse on a large scale and to develop accessible and persuasive narratives in which the individual engineer can make a difference. Developing an accessible discourse that will help people reinterpret their own experience is an essential step in this process. Another is to help both the community of engineering professionals and those outside it recognize that we have choices about the forms of discourse in which we engage, and that those choices matter. One key element in realizing these goals will be for STS scholars to engage with public discourse and offer accessible and persuasive narratives of design as a process imbued with ethical considerations.

The point of this chapter is not to make a claim about the nature of technological development. It is to focus on the impact of our way of speaking about the process of the introduction of technology in society. It is our argument that the mode of discourse in relation to technology, as well as elsewhere, is centrally relevant to how we perceive the thing itself. This is not a new thesis in its theoretical dimension, (see, for example, Heidegger, 1977) but one which has often been ignored in the dominant focus on the object (technology) itself. STS has done an admirable job of looking at the dual influence, i.e., feedback loop, between technologies and society, but in that very feedback loop has implicitly expressed a notion of inevitable progression. To give true voice to ethical concerns, however, it is important not to see technological development simply as a chain of developments, of which any human actors become simply another link, but instead as an opportunity for the expression of creative and original impulses (upsurges in Being). If we can focus the discourse of technology on this dimension, then the opportunity for ethical discourse and reflection arises for the central actors in the process. The how, why, and wherefore of technological innovation will be subject to interrogation without a predetermined answer based on a narrow conception of progress, for example, increased efficiency. The outcome of that process will be seen as the STS community already accepts: indeterminate.

References

Ellul, J., 1964, *The Technological Society*, J. Wilkinson, trans., Knopf, New York.

Finkel, E., 2002, Doing well by doing good: new Kellogg BASE major explores the social context of business, *Kellogg World* (Winter 2002); http://www.kellogg.northwestern.edu/kwo/win02/indepth/doingwell.htm

Frost, B., 1996, Historical dimensions of high tech: the politics and rhetoric of progress talk in twentieth-century France. *American Historical Association Meeting* (Atlanta, January, 1996).

Heidegger, M., 1977, *The Question Concerning Technology and Other Essays*, W. Lovitt, trans., Harper Torchbooks, New York.

Hughes, T. P., 1987, The evolution of large technological systems, in: *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, W. Bijker, T.P. Hughes, and T. Pinch, eds., MIT Press, Cambridge, MA, pp. 76–80.

Kroker, A., and Weinstein, M. A., 1994, *Data Trash: The Theory of the Virtual Class*, St. Martin's, New York.

Idhe, D., 1993, *Philosophy of Technology: An Introduction*, Paragon, New York.

Imai, M., 1986, *Kaizen: The Key to Japan's Competitive Success*, Random House, New York.

Johnston, S. F., Gostelow, J. P., and King, W. J., 2000, *Engineering & Society*, Prentice Hall, Upper Saddle River, NJ.

Luegenbiehl, H. C., 1985, The nature of engineering ethics: preliminary considerations, in: *Technology Studies Resource Center Working Papers Series*, Vol. 2, Feb. 1985, S. H. Cutcliffe, ed., Lehigh University, Bethlehem, PA, pp. 79–98.

Martin, M. W., and Schinzinger, R., 1989, *Ethics in Engineering*, 2nd ed., McGraw Hill, New York.

McDonough, W., 1993, Design, ecology, ethics and the making of things: centennial sermon on the 100th anniversary of the Cathedral of St. John the Divine, New York City, February 7, 1993; http://www.mcdonough.com

Pacey, A., 1983, *The Culture of Technology*, MIT Press, Cambridge, MA.

Sasseville, B., 2004, Integrating information and communication technology in the classroom: a comparative discourse analysis, *Can. J. of Learn. and Techn*. **30**(2); http://www.cjlt.ca/content/vol30.2/cjlt30-2-art-1.html

Schlosser, E., 2002, *Fast Food Nation: The Dark Side of the All-American Meal*, Perennial, New York. (2001, Houghton Mifflin).

Selwyn, N., and Gorard, S., 2003, Exploring the 'new' imperatives of technology-based lifelong learning, *Res. in Post-Compulsory Edu*. **8**(1):73–92.

Van Gorp, A., and Van de Poel, I., 2001, Ethical considerations in engineering design processes, *IEEE Technol. and Soc. Mag*. Fall 2001:15–22.

Williams, R., 2002, *Retooling: A Historian Confronts Technological Change*, MIT Press, Cambridge, MA.

Winner, L., 1977, *Autonomous Technology*, MIT Press, Cambridge, MA.