Marx and the Machine

DONALD MAC KENZIE

As an aside in a discussion of the status of the concepts of economics, Karl Marx wrote "The handmill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist."[1] The aphorism has stuck; as a succinct précis of technological determinism it has few rivals. Apt and memorable (even if historically inaccurate)[2] as it is, it is nevertheless misleading. There is much in Marx's writings on technology that cannot be captured by any simple technological determinism. Indeed, his major discussion of the subject—occupying a large part of volume 1 of *Capital*—suggests a quite different perspective. Marx argued that in the most significant complex of technical changes of his time, the coming of large-scale mechanized production, social relations molded technology, rather than vice versa. His account is not without its shortcomings, both empirical and theoretical. Yet interest in it is beginning to revive, and deservedly so. It resonates excitingly with some of the best modern work in the history of technology. Even where these studies force us to revise some of Marx's conclusions, they show the continuing historical relevance of his account of the machine. Its possible political relevance is shown by an interesting connection between the practice of the "alternative technology" movement and an important way of studying the social shaping of technology.

Marx as Technological Determinist

Not so long ago Alvin Hansen's conclusion in 1921 that Marxism is a "Technological Interpretation of History" was still widely accepted. Robert Heilbroner's celebrated 1967 paper "Do Machines Make His-

DR. MACKENZIE lectures in sociology at the University of Edinburgh. He is the author of *Statistics in Britain, 1865–1930: The Social Construction of Scientific Knowledge* (Edinburgh, 1981) and is currently studying the development of nuclear weaponry, particularly strategic missiles and their guidance systems.

[1]Karl Marx, *The Poverty of Philosophy* (New York, 1971), p. 109.

[2]Marc Bloch's work suggests that feudal lords actually tried to suppress hand mills, preferring centralized water milling with its greater potential for the exacting of feudal dues. See Bloch, "Advent and Triumph of the Water Mill," in his *Land and Work in Mediaeval Europe* (London, 1967), pp. 136–68.

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tory?" was headed by the famous "handmill" quotation, and Heilbroner clearly identified "the Marxian paradigm" as technological determinism. Tom Burns's 1969 reader, *Industrial Man*, headed its section on Marx: "Technology as the Prime Mover of Industrialization and Social Change."[3]

More recently, things have seemed not quite so clear. Many Marxists—and some non-Marxists—have been profoundly unhappy with the characterization of Marxism as technological determinism.[4] "All the friends of old Marx, it seems, have entered into a holy alliance to exorcise this specter [technological determinism]."[5] Yet the book that is in many ways the best product of recent academic theorizing about technology, Langdon Winner's *Autonomous Technology*, still throws its weight (though not without some reservations) behind a technological-determinist interpretation of Marx: in technology, Marx believed he had "isolated *the* primary independent variable active in all of history."[6]

To be a technological determinist is obviously to believe that in some sense technical change *causes* social change, indeed that it is the most important cause of social change. But to give full weight to the first term in expressions such as "*prime* mover" and "*independent* variable," it would also have to be believed that technical change is itself uncaused, at least by social factors. The first of these theses we can describe, following Heilbroner,[7] as the thesis that machines make history. The second we might call the thesis of the autonomy of technical change.

The thesis that machines make history is certainly to be found in Marxist writing. Perhaps its most unequivocal statement is in Bukharin's *Historical Materialism*, where we find assertions like the following:

[3]Alvin H. Hansen, "The Technological Interpretation of History," *Quarterly Journal of Economics* 36 (November 1921): 72–83; Robert L. Heilbroner, "Do Machines Make History?" *Technology and Culture* 8 (July 1967): 335–45; Tom Burns, *Industrial Man* (Harmondsworth, 1969), p. 35.

[4]Of the many pieces of work that could be cited, three stand out: David Dickson, *Alternative Technology and the Politics of Technical Change* (Glasgow, 1974); Nathan Rosenberg, "Marx as a Student of Technology," *Monthly Review* 28 (1976): 56–77; Raniero Panzieri, "The Capitalist Use of Machinery: Marx versus the 'Objectivists,' " in *Outlines of a Critique of Technology*, ed. Phil Slater (London, 1980), pp. 44–68. My debt to each of these is clear. Monika Reinfelder's survey article, "Introduction: Breaking the Spell of Technicism," in Slater, pp. 9–37, provides a useful overall sketch of "technicism" and "antitechnicism" in 20th-century Marxism, although her judgments sometimes seem unduly harsh.

[5]William H. Shaw, " 'The Handmill Gives You the Feudal Lord': Marx's Technological Determinism," *History and Theory* 18 (1979): 155–176, quote on p. 155.

[6]Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Mass., and London, 1977), p. 79. But see also, e.g., p. 39: "one should not go too far in attributing a theory of autonomous technology to Karl Marx."

[7]Heilbroner (n. 3 above).

"the historic mode of production, i.e. the form of society, is determined by the development of the productive forces, i.e. the development of technology."[8] Bukharin was far from alone in this claim,[9] and there are indeed passages from Marx's own writings that can be read in this way. The best known is the sentence from the *Poverty of Philosophy* quoted above. More weighty, though not so crisp, is the "1859 Preface":

> In the social production of their existence, men inevitably enter into definite relations, which are independent of their will, namely relations of production appropriate to a given stage in the development of their material forces of production. The totality of these relations of production constitutes the economic structure of society, the real foundation, on which arises a legal and political superstructure and to which correspond definite forms of social consciousness. The mode of production of material life conditions the general process of social, political and intellectual life. It is not the consciousness of men that determines their existence, but their social existence that determines their consciousness. At a certain stage of development, the material productive forces of society come into conflict with the existing relations of production or—this merely expresses the same thing in legal terms—with the property relations within the framework of which they have operated hitherto. From forms of development of the productive forces these relations turn into their fetters. Then begins an era of social revolution. . . .[10]

And there are several other statements, chiefly from the 1840s and 1850s, which can be read as claims that machines make history.[11]

[8]Nikolai Bukharin, *Historical Materialism: A System of Sociology* (Ann Arbor, Mich., 1969), p. 124 (first published in Russian in 1921). Before his fall from power in the 1930s, Bukharin was one of the leading Bolshevik theorists.

[9]Reinfelder (n. 4 above).

[10]Karl Marx, *A Contribution to the Critique of Political Economy* (London, 1971), pp. 20–21 (first published in German in 1859).

[11]For example, Marx's 1846 letter to P. V. Annenkov, in Burns (n. 3 above), pp. 35–36. There is also an interesting passage, seldom cited, at the end of vol. 3 of *Capital*: "To the extent that the labour-process is solely a process between man and Nature, its simple elements remain common to all social forms of development. But each specific historical form of this process further develops its material foundations and social forms. Whenever a certain stage of maturity has been reached, the specific historical form is discarded and makes way for a higher one. The moment of arrival of such a crisis is disclosed by the depth and breadth attained by the contradictions and antagonisms between the distribution relations, and thus the specific historical form of their corresponding production relations, on the one hand, and the productive forces, the production powers and the development of their agencies, on the other hand. A conflict then ensues between the material development of production and its social form" (Karl Marx, *Capital: A Critique of*

Alternative readings of at least some of these are possible. Rosenberg, for example, takes the "handmill" quotation and suggests that by placing it in context it can be seen as not necessarily implying a technological determinism.[12] The "1859 Preface" is, however, where debate has centered. It was explicitly presented by Marx as "the general conclusion at which I arrived and which, once reached, became the guiding principle of my studies."[13] Echoes of it reappear throughout Marx's later works, and it has often been taken as *the* definitive statement of historical materialism.

Anything approaching a careful reading of it quickly reveals two things. First, to make it into a statement that machines make history, the "forces of production" would have to be interpreted as equivalent to technology. Second, to make it into a strong technological determinism in the sense outlined above, the development of the forces of production would have to be taken as autonomous, or at least independent of the relations of production.

Langdon Winner signals his ambivalence about the first point when he writes that "although there is some variation in the manner in which Marx uses these terms, *for our purposes* 'forces of production' can be understood to comprise all of physical technology."[14] In fact, even within orthodox Marxism that interpretation is questioned. Stalin's "Dialectical and Historical Materialism" employed a broader definition: "The *instruments of production* wherewith material values are produced, the *people* who operate the instruments of production and carry on the production of material values thanks to a certain *production experience* and *labour skill*—all these elements jointly constitute the *productive forces* of society." The opponents of orthodox Marxism put it more sharply than that. Lukács, criticizing Bukharin's *Historical Materialism*, wrote: "Technique is a *part*, a moment, naturally of great importance, of the social productive forces, but it is neither simply identical with them, nor . . . the final or absolute moment of the changes in these forces."[15]

Political Economy [London, 1974], 3:883–84). Shaw (n. 5 above), p. 159, cites this passage as evidence of Marx's technological determinism, but shortens "The moment of arrival of such a crisis is disclosed by the depth and breadth attained by" simply to ". . . [because of]."

[12]Rosenberg (n. 4 above), p. 74.

[13]Marx, *Contribution to the Critique of Political Economy* (n. 10 above), p. 20.

[14]Winner (n. 6 above), p. 78; my emphasis. Winner does include "labor" as a force of production, but apparently primarily as a "source of energy."

[15]Joseph Stalin, "Dialectical and Historical Materialism," in *The Essential Stalin: Major Theoretical Writings, 1905–52*, ed. Bruce Franklin (London, 1973), p. 318; George Lukács, "Technology and Social Relations," *New Left Review*, no. 39 (September/October

Interpretations of Marxism as technological determinism thus rest, in effect, on the equation "forces of production = technology." Yet even defenders of the proposition that Marx was a technological determinist, such as William Shaw, find it difficult to impute this equation to Marx: ". . . for Marx the productive forces include more than machines or technology in a narrow sense. In fact, labor-power, the skills, knowledge, experience, and so on which enable labor to produce, would seem to be the most important of the productive forces." So Shaw is forced to concede that "technological determinism is a slight misnomer since Marx speaks, in effect, of productive-force determinism."[16] But much more is at stake than a "slight misnomer." For if the forces of production include human labor power, then a productive-force determinism will look very different from a technological determinism as ordinarily understood. From his earliest writings on, Marx emphasized that what was specific about human work was that it was *conscious*:

> . . . free conscious activity is man's species character. . . . In *his work upon* inorganic nature, man proves himself a conscious species being. . . .
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> A spider conducts operations which resemble those of the weaver, and a bee would put many a human architect to shame by the construction of its honeycomb cells. But what distinguishes the worst architect from the best of bees is that the architect builds the cell in his mind before he constructs it in wax. . . . Man not only effects a change of form in the materials of nature; he also realizes his own purpose in those materials.[17]

The inclusion of labor power as a force of production thus admits conscious human agency as a determinant of history: it is people, as much as or more than the machine, that make history.

The autonomy of technical change is likewise a proposition attributable to Marx only questionably, even if the productive forces = technology equation is accepted. The "orthodox" position is that the productive forces have a tendency to advance but can be encouraged or

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1966), pp. 27–34, quote on p. 29 (first published in German in 1925). Lukács, most famous as a literary critic, was in the early 1920s one of the leading opponents of technicist and mechanical approaches to Marxism.

[16]Shaw (n. 5 above), p. 158.

[17]Karl Marx, *Economic and Philosophic Manuscripts of 1844* (London, 1973), p. 113; Karl Marx, *Capital: A Critique of Political Economy* (Harmondsworth, 1976), 1:284. This latter work (the Penguin/New Left Review translation of vol. 1 of *Capital*) is cited below simply as *Capital* 1.

held back by the relations of production. Stalin, for example, admitted that the relations of production "influence" the development of the forces of production, but he restricted that influence to "accelerating or retarding" that development. But not all Marxist writers have seen it like this. There is a change of terrain in the way the modern French Marxist Etienne Balibar shifts the metaphor away from "accelerate/decelerate": ". . . the most interesting aspect of the 'productive forces' is . . . the *rhythm* and *pattern* of their development, for this rhythm is directly linked to the nature of the relations of production, and the structure of the mode of production." Lukács disagreed with the orthodox interpretation even more sharply: ". . . it is altogether incorrect and unmarxist to separate technique from the other ideological forms and to propose for it a self-sufficiency from the economic structure of society . . . the remarkable changes in the course of [technique's] development are [then] completely unexplained."[18]

The Difficulties of Determinism

In addition to the unclear meaning and questionable autonomy of the "forces of production," a further difficulty arises in reading the "1859 Preface" as technological determinism. That is the nature of the middle terms in the propositions it implies. Just what is the "determination" (or conditioning, or being the foundation of) exercised by the "totality of [the] relations of production"? What concept of determination is implied when it is said that the relations of production themselves are "appropriate" to "a given stage in the development of [the] material forces of production"?

On few topics has more ink been spilled. As Raymond Williams has pointed out, the verb "to determine" (or the German *bestimmen*, which is what the English translations of Marx are generally rendering when they write "determine") is linguistically complex. The sense that has developed into our notion of "determinism," powerlessness in the face of compelling external agency, derives, Williams suggests, from the idea of determination by an authority (as in "the court sat to determine the matter"). But there is another, related but different, sense of "to determine"—to set bounds or limits (as, for example, in "the determination of a lease").[19]

If the determinative effect of the forces of production over the relations of production, or of the relations of production over the

[18]Stalin (n. 15 above), p. 321; Louis Althusser and Etienne Balibar, *Reading Capital* (London, 1970), p. 235; Lukács (n. 15 above), p. 30.

[19]Raymond Williams, *Marxism and Literature* (Oxford, 1977), pp. 83–89.

"superstructure," can be read in this latter way, then our image of determination changes radically. It suggests not compelling causes but a set of limits within which human agency can act, and against which it can push. It is an image fully compatible with another of Marx's great aphorisms, that people "make their own history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past."[20]

This is not an issue, however, that semantic debate alone can settle. Dealing with such topics, after all, we approach the conceptual core of a social science (*any* social science, not just Marxism). Variant readings of "determination" *are* possible, from simple cause-effect notions to G. A. Cohen's recent sophisticated defense of the thesis that the explanations suggested by the "1859 Preface" are functional explanations ("to say that an economic structure *corresponds* to the achieved level of the productive forces means: the structure provides maximum scope for the fruitful use and development of the forces, and obtains *because* it provides such scope"). Erik Olin Wright argues, indeed, for making a positive virtue of diversity, and incorporating different "modes of determination" into Marxist theory. Furthermore, debate on this issue can seldom be innocent. Profound political and philosophical differences entangle rapidly with matters of theory and methodology, as an essay such as E. P. Thompson's "The Poverty of Theory" quickly reveals.[21]

Here we have reached the limits of the usefulness for our purposes of the exegesis of Marx's programmatic statements. The "1859 Preface" and similar passages will no doubt remain a mine, perhaps even a productive mine, for students of Marx's general theory and method. Students of technology, however, can turn their attention to a deposit that is both larger and closer to the surface—Marx's one extended and concrete discussion of technology.[22] Apart from its intrinsic interest

[20]Karl Marx, "The Eighteenth Brumaire of Louis Bonaparte," in Marx and Engels, *Selected Works in One Volume* (London, 1968), pp. 95–180, quote on p. 97.

[21]G. A. Cohen, *Karl Marx's Theory of History: A Defence* (Oxford, 1978), quote on pp. 278–79; Erik Olin Wright, *Class, Crisis and the State* (London, 1978), chap. 1; E. P. Thompson, *The Poverty of Theory and Other Essays* (London, 1978). See also Perry Anderson, *Arguments within English Marxism* (London, 1980).

[22]*Capital* 1, parts 3 and 4, especially chap. 15, "Machinery and Large-Scale Industry." Nathan Rosenberg has done most to bring this part of Marx's work to the attention of scholars within the English-language history of technology: see "Marx as a Student of Technology" (n. 4 above); also Rosenberg, "Karl Marx on the Economic Role of Science," in his *Perspectives on Technology* (Cambridge, 1976), pp. 126–38. But as Rosenberg writes in his most recent book, *Inside the Black Box: Technology and Economics* (Cambridge, 1982), p. viii, until quite recently "hardly anyone has . . . passed" through the "doors to the study

(the main focus of what follows), this discussion throws interesting retrospective light on the more summary passages. In particular, it makes the thesis that Marx was a technological determinist in any strong sense extremely difficult to sustain, at least without invoking a peculiar and marked inconsistency between his general statements and particular analyses.

The Labor Process and the Valorization Process

At the core of volume 1 of *Capital* is a chapter entitled "The Labour Process and the Valorization Process."[23] It is the pivot of the book. Marx, who up to that point had been analyzing chiefly the phenomena of the commodity, exchange and money, employed the full power of his skill as a writer to set the scene for the chapter: "Let us therefore . . . leave this noisy sphere, where everything takes place on the surface and in full view of everyone, and [enter] into the hidden abode of production, on whose threshold there hangs the notice 'No admittance except on business.' Here we shall see, not only how capital produces, but how capital is itself produced. . . ."[24] After the chapter, his argument built architectonically to the crescendo of "The General Law of Capitalist Accumulation" some 500 pages further on. While we will not follow him that far, this little chapter is central to an understanding of his discussion of machinery.

First, said Marx, we "have to consider the labour process independently of any specific social formation." He listed the "simple elements" of the labor process: "(1) purposeful activity, that is work itself, (2) the objects on which that work is performed, and (3) the instruments of that work." The labor process is a cultural universal, "an appropriation of what exists in nature for the requirements of man"; it is "common to all forms of society in which human beings live."[25] But it develops and changes through history.

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of the technological realm" that Marx opened. Marxist theory itself tended to neglect this part of *Capital* until interest in it was revived by Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (New York, 1974). A noteworthy exception to that neglect is Panzieri (n. 4 above), first published in the Italian journal *Quaderni Rossi* in 1961.

[23]*Capital* 1:283–306. This section of my paper owes a great deal to Iain Campbell. His manuscript, "Marxist Perspectives on the Transformation of the Labour Process under Capitalism," and his comments on an earlier draft of this paper, were extremely helpful to me in developing my understanding of the structure of Marx's theory. Copies of his manuscript can be obtained from him at 91 Pearson St., West Brunswick, Victoria 3055, Australia.

[24]*Capital* 1:279–80.

[25]Ibid., pp. 283, 284, 290.

Marx did not, as the technological-determinist reading would lead us to expect, turn now to the development of "the instruments of work." (It is interesting, indeed, that he subsumed technology in the narrower meaning of "instruments" under the broader head of "the labour process.") Instead, he moved from discussion of the labor process in general to the labor process under capitalism, and from it as a material process of production to it as a social process. The process of production under capitalism is not just a labor process, it is also a valorization process, a process of adding value. The capitalist "wants to produce a commodity greater in value than the sum of the values of the commodities used to produce it, namely the means of production and the labour power he purchased with his good money on the open market."[26] He wants to produce a commodity embodying surplus value.

The distinction between the labor process and the valorization process is not a distinction between two different types of process, but between two different aspects of the same process of production. Take a simple example, the production of cotton yarn. Looking at that as a *labor process* means looking at the particular, concrete ways in which people work, using particular technical instruments, to transform a given raw material into a product with given properties. In all societies that produce yarn it would be meaningful to examine in this way how they do it. But that is not all there is to the production of yarn under capitalism. The production of yarn as a *valorization process* is a process whereby inputs of certain value give rise to a product of greater value. The concrete particularities of the inputs and product, and the particular technologies and forms of work used to turn the inputs into the product, are here relevant only to the extent that they affect the quantitative outcome of the process.[27] Capitalist production processes, but not all production processes in all types of society, are valorization processes. The valorization process is the "social form" of the production process specific to capitalism.

Were Marx's theory technological determinism, one would now expect an argument that the labor process—the technology-including "material substratum"—in some sense dominated the "social form." Quite the opposite. In his general statements on the matter (which are mainly to be found in the unpublished chapter of *Capital*, "Results of the Immediate Process of Production"), he repeatedly argued that "the labour process itself is no more than the instrument of the valorization process."[28] And in *Capital* itself he presented an extended historical and

[26]Ibid., p. 293.

[27]See, particularly, ibid., pp. 302–3.

[28]The unpublished chapter is now to be found in *Capital* 1:941–1084; the quoted

theoretical account of the development of the capitalist production process, an account in which the social form, valorization, explains changes in the material content, the labor process. From this account let us select one central thread—Marx's history of the machine.

The Prehistory of the Machine

The history begins strangely, in that its central character is absent. The origins of capitalism, for Marx, lay not in a change in technology, but in a change in social relations, the emergence of a class of propertyless wage laborers.[29] "At first capital subordinates labour on the basis of the technical conditions within which labour has been carried on up to that point in history."[30] Archetypally, this took place when independent artisans (say textile workers), who previously produced goods on their own account, were forced through impoverishment to become employees. So instead of owning their spinning wheels or looms and buying their own raw materials, they worked (often in their own homes, under the "putting out" system) on wheels or looms belonging to a merchant, spinning or weaving raw materials belonging to him into a product that would be his property and which would embody surplus value. The social relations within which they worked had thus changed drastically; the technical content of their work was unaltered. This Marx described as the "formal subordination" of labor to capital.[31] It was formal in that it involved a change in social form (the imposition of the valorization process) without a valorization-inspired qualitative alteration in the content of the labor process: without "real subordination."

Inherited labor processes were indeed severely deficient vehicles for the valorization process. Within their bounds, capitalists could increase surplus value primarily by the route Marx called "absolute surplus

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passage is on p. 990 (emphasis in the original deleted), and the phrase "material substratum" on p. 981. For discussion of this point and further citations, see Campbell, "Marxist Perspectives" (n. 23 above), p. 19 and n. 50. See also Brighton Labour Process Group, "The Capitalist Labour Process," *Capital and Class*, no. 1 (Spring 1977), pp. 3–26.

[29]*Capital* 1:873–940. See also the three fascinating historical chapters of *Capital* 3 (n. 11 above): "Historical Facts about Merchant's Capital," "Pre-Capitalist Relationships," and "Genesis of Capitalist Ground-Rent," pp. 323–37, 593–613, and 782–813. The section of the *Grundrisse* on "Original Accumulation of Capital," which includes Marx's famous discussion of precapitalist economic formations, shows the development of Marx's thought on the topic. See Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy (Rough Draft)* (Harmondsworth, 1973), pp. 459–515.

[30]*Capital* 1:425.

[31]Ibid., p. 645; although the Penguin translation of *Capital* here prefers the more literal expression "formal subsumption."

value"—lengthening the working day. But that was not easily achieved. As Marx pointed out, the earliest statutes in Britain regulating the working day extend it, rather than limit it. But they were largely ineffective. It was often difficult to get workers to turn up for work at all at the beginning of the week (the tradition of "Saint Monday"). The intense, regular work required for valorization was a habit hard to impose. And outworkers working without direct supervision had an effective form of disvalorization available in the form of embezzlement of raw materials, as historians more recent than Marx have emphasized.[32]

The ways capitalists sought to overcome these deficiencies in the labor process from the point of view of valorization are the subject of part 4 of volume 1 of *Capital*. The first that Marx discussed is "simple co-operation." This occurs when capital brings individual workers together "in accordance with a plan."[33] There is nothing specific to capitalism about simple cooperation: in all societies it will, for example, offer advantages in the performance of simple physical tasks, two people working together being able to lift a weight each individually could not. Nevertheless, simple cooperation offers definite advantages from the point of view of valorization.

The nature of these advantages highlights an important feature of valorization: that valorization is not simply an economic process but involves the creation and maintenance of a social relation. Certainly, productivity is increased ("[t]he combined working day produces a greater quantity of use-values than an equal sum of isolated working days")[34] and the centralization of work can lead to savings in fixed capital. But, equally important, the authority of the capitalist is strengthened. For cooperation necessitates coordination. If you are lifting a weight, someone has to say "one, two, three . . . hup." Because the individual workers who are brought together by capital are subordinate to capital, that role of coordination becomes, in principle, filled by capitalist command—by capitalist *management*, to use an anachronism. The consequence Marx describes as follows: "Hence the interconnection between their [the workers'] various labours confronts

[32]Ibid., pp. 383–89; E. P. Thompson, "Time, Work-Discipline and Industrial Capitalism," *Past and Present*, no. 38 (1967), pp. 56–97; N. S. B. Gras, *Industrial Evolution* (London, 1930), p. 77; Sidney Pollard, *The Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain* (London, 1965), pp. 33–34; Stephen A. Marglin, "What Do Bosses Do? The Origins and Function of Hierarchy in Capitalist Production," in *The Division of Labour: The Labour Process and Class Struggle in Modern Capitalism*, ed. André Gorz (Hassocks, Sussex, 1978), pp. 13–54.

[33]*Capital* 1:443.

[34]Ibid., p. 447.

them, in the realm of ideas, as a plan drawn up by the capitalist, and, in practice, as his authority, as the powerful will of a being outside them, who subjects their activity to his purpose."[35] A form of alienation is involved here—not psychological alienation, nor alienation from a human essence, but the literal alienation of the collective nature of work. For that collective nature is here seen as becoming the power of another, of the capitalist. In addition, the physical concentration of workers under the one roof greatly facilitates the down-to-earth tasks of supervision: enforcing timekeeping and preventing embezzlement.[36]

Marx intended "simple co-operation" as an analytic category rather than as a description of a historical period in the development of the labor process (although recent writers have specified a historical phase in which it was crucial).[37] The form of cooperation typical of the period immediately prior to mechanization Marx describes as "manufacture."[38] (Marx, of course, uses the term in its literal sense of making by hand.) Crucially, manufacture, unlike the most elementary forms of cooperation, involves the differentiation of tasks, the division of labor. It arises in two ways. One is the bringing together of separate trades, as in the manufacture of carriages, where wheelwrights, harness makers, etc., are brought together under the same roof, and their work specialized and routinized. The other, and perhaps more significant, is where the production of an item which used to be produced in its entirety by a single handicraft worker is broken down into separate operations, as in the manufacture of paper, type, or (classically) pins and needles.

The division of labor involved in manufacture was often extreme. Marx spent nearly a page listing a selection of the trades involved in the manufacture of watches, and pointed out that a wire on its way to becoming a needle passed "through the hands of seventy-two, and sometimes even ninety-two, different specialized workers." The advantages from the point of view of valorization of this division of labor are clear. Labor is cheapened, according to the principle enunciated by Babbage in 1832: ". . . the master manufacturer, by dividing the work to be executed into different processes, each requiring differ-

[35]Ibid., p. 450.

[36]See the works of Gras, Pollard, and Marglin cited in n. 32.

[37]That is the 18th-century creation of "central workshops" in the British textile industry without any change in technique from that prevalent in putting-out. See Marglin, "What Do Bosses Do?" (n. 32 above); also, Jennifer Tann, *The Development of the Factory* (London, 1972). Even this is not a pure example, for there were elements of a "manufacturing" division of labor involved. There is a short but useful discussion in Maxine Berg, ed., *Technology and Toil in Nineteenth Century Britain* (London, 1979), p. 7.

[38]*Capital* 1:455–91.

ent degrees of skill or of force, can purchase exactly that precise quantity of both which is necessary for each process; whereas, if the whole work were executed by one workman, that person must possess sufficient skill to perform the most difficult and sufficient strength to execute the most laborious, of the operations into which the art is divided." Productivity is increased through specialization and the increased continuity and intensity of work, although at the cost of "job satisfaction": "constant labour of one uniform kind disturbs the intensity and flow of a man's vital forces, which find recreation and delight in the change of activity itself."[39]

In addition, the division of labor in manufacture reinforces the subordination of the worker to the capitalist. Craft workers able to produce an entire watch might hope to set up independently; the *finisseurs de charnière*, "who put the brass hinges in the cover," could hardly hope to do so. Even more strikingly than in simple cooperation, under manufacturing the collective nature of work, the interdependence of the different labor processes involved, confronts workers as the capitalist's power. The manufacturing worker, unable to perform or even understand the process of production as a whole, loses the intellectual command over production that the handicraft worker possessed. "What is lost by the specialized workers is concentrated in the capital which confronts them. It is a result of the division of labour in manufacture that the worker is brought face to face with the intellectual potentialities of the material process of production as the property of another and as a power which rules over him." The alienation of the collective nature of work has advanced one stage further and the division of head and hand, typical of modern capitalism, has begun to open up decisively. Marx quotes from a book written in 1824 a lament that today's radical science movement, or the participants in China's Cultural Revolution, would easily recognize: "The man of knowledge and the productive labourer come to be widely divided from each other, and knowledge, instead of remaining the handmaid of labour in the hand of the labourer to increase his productive powers . . . has almost everywhere arrayed itself against labour. . . . Knowledge [becomes] an instrument, capable of being detached from labour and opposed to it."[40]

And yet . . . manufacture was not a fully adequate vehicle for valorization. The basis of the manufacturing labor process remained hand-

[39]Ibid., pp. 461–62, 463; Babbage as cited by Braverman (n. 22 above), pp. 79–80; *Capital* 1:460.

[40]Ibid., pp. 462 and 482; W. Thompson, *An Inquiry into the Principles of the Distribution of Wealth* (London, 1824), p. 274, cited by Marx, *Capital* 1:482–83, n. 44.

icraft skill, however fragmented and specialized, and that skill was a resource that could be, and was, used in struggle against capital. So "capital is constantly compelled to wrestle with the insubordination of the workers" and "the complaint that the workers lack discipline runs through the whole of the period of manufacture."[41] But, by one of the ironies of the dialectic, the most advanced manufacturing workshops were already beginning to produce . . . the machine.

Enter the Machine

Up to this point in his discussion, Marx made effectively no mention of technical change, instead focusing exclusively on the social organization of work. It was not that he was ignorant of the technical changes of the period of manufacture. Rather, his discussion is laid out in the way it is to argue a theoretical point—that preceding organizational changes created the "social space," as it were, for the machine; and that the limitations of those changes created the *necessity* for it.

But what is a machine? Marx's chapter on "Machinery and Large-Scale Industry" opens with what appears to be a rather pedantic discussion of the definition of "machine." Yet this little passage is highly significant because of the nature of the definition that Marx chose.

He rejected definitions which saw a continuity between the "tool" and the "machine," definitions typical of "mathematicians and experts on mechanics." While it is true that any machine is analyzable as a complex of more basic parts "such as the lever, the inclined plane, the screw, the wedge, etc." that "explanation is worth nothing, *because the historical element is missing from it.*" Nor does it suffice to differentiate the tool from the machine on the basis of the power source (human in the case of the former, nonhuman in the case of the latter): "According to this, a plough drawn by oxen, which is common to the most diverse modes of production, would be a machine, while Claussen's circular loom, which weaves 96,000 picks a minute, though it is set in motion by the hand of one single worker, would be a mere tool."[42]

Instead, Marx offers the following definition: "The machine . . . is a mechanism that, after being set in motion, performs with its tools the same operations as the worker formerly did with similar tools." This *is* a historical definition in two senses. First, Marx argued that of the three different parts of "fully developed machinery"—"the motor mechanism, the transmitting mechanism and finally the tool or working

[41] *Capital* 1:490.

[42] Ibid., pp. 492–93 (emphasis added), p. 493.

machine"—it was with innovations in the third that "the industrial revolution of the eighteenth century began." Changes in the source of motive power were historically secondary and derivative. Second, and more important, it is a historical definition in that it points up the place of the machine in the process that Marx was analyzing. The machine undermined the basis on which manufacturing workers had resisted the encroachments of capital: "In manufacture the organization of the social labour process is purely subjective: it is a combination of specialized workers. Large-scale industry, on the other hand, possesses in the machine system an entirely objective organization of production, which confronts the worker as a pre-existing material condition of production."[43]

Essentially, in machinery capital attempts to achieve by technological means what in manufacture it attempted to achieve by social organization alone. Labor power is cheapened, most notoriously by the employment of women and children. This is not merely a technical matter of the simplification of labor or of "machinery dispens[ing] with muscular power." Under manufacture, the division of labor had already created a wealth of jobs requiring neither particular skill nor particular strength; and in any case it is clear that these attributes are not naturally the exclusive preserve of adult males. Rather, the tendency to the employment of women and children had been "largely defeated by the habits and the resistance of the male workers."[44]

In the long run, the machine contributes to valorization crucially through the medium of "relative surplus value": the reduction in the labor time required to produce the equivalent of the worker's wage, with consequent increase in the surplus value accruing to the capitalist. In the short run, however, the machine also sets capital free to accrue absolute surplus value. By undermining the position of key groups of skilled workers, by making possible the drawing of new sectors into the labor market, by threatening and generating unemployment, the machine "is able to break all resistance" to a lengthening of the working day.[45] And because work can now be paced by the machine, its intensity can be increased.

Most important, the alienation of the collective and intellectual aspects of work, already diagnosed by Marx in simple cooperation and manufacture, achieves technical embodiment in the machine. For "along with the tool, the skill of the worker in handling it passes over to the machine." The machine, increasingly a mere part of an automated

[43]Ibid., pp. 495, 494, 496–97, 508.
[44]Ibid., pp. 517, 489.
[45]Ibid., p. 531.

factory, embodies the power of the capitalist: "The special skill of each individual machine-operator, who has now been deprived of all significance, vanishes as an infinitesimal quantity in the face of the science, the gigantic natural forces, and the mass of social labour embodied in the system of machinery, which, together with these three forces, constitutes the power of the 'master.' "[46]

In the labor process of machino-facture, capitalist social relations thus achieve technical embodiment. It is characteristic of capitalism in all its stages that "the conditions of work," the means of production in their social form as capital, employ the worker, instead of the worker employing the means of production. "However, it is only with the coming of machinery that this inversion first acquires a technical and palpable reality." For prior to the machine, the worker still commanded the tool—and used this command as a source of countervailing power. From the point of view of the worker, the machine is thus a direct threat. It is "capital's material mode of existence."[47]

So class struggle within capitalism can take the form of "a struggle between worker and machine." Workers of course directly attacked machines (and still do, even if organized machine breaking has given way to less overt forms of "sabotage").[48] But the struggle, Marx emphasized, is two-sided. Capital uses machinery not only strategically, as outlined above, but also for precise tactical purposes. Where workers' (especially skilled workers') militancy poses a threat to valorization, capital can counter by promoting the invention and employment of machinery to undermine workers' power.

The theorist of this waging of class struggle by technical means was Andrew Ure. His 1835 *Philosophy of Manufactures* concluded that "when capital enlists science into her service, the refractory hand of labour will always be taught docility." Marx cited inventions discussed by Ure as means of doing this—coloring machines in calico printing, a device for dressing warps, and the self-acting spinning mule—and referred to inventors such as James Nasmyth and Peter Fairbairn whose work had apparently been motivated by the exigencies of defeating strikers. "It would be possible," Marx judged, "to write a whole history of the

[46]Ibid., pp. 545, 549.

[47]Ibid., pp. 548, 442.

[48]Within Marxism theoretical attention to sabotage as an important topic has come mainly from Italian "autonomists." See the collection, *Working Class Autonomy and the Crisis: Italian Marxist Texts of the Theory and Practice of a Class Movement* (London, 1979). Panzieri (see n. 4 above) was one of the intellectual founders of the "autonomist" tendency.

inventions made since 1830 for the sole purpose of providing capital with weapons against working-class revolt."[49]

Marx's Account and the Historical Record

Capital was published in 1867. How well does Marx's account stand up in the light of over a century of historical scholarship? There is considerable agreement with his characterization of the overall process of the mechanization of production, even from those who would not regard themselves as standing in any Marxist tradition. Thus David Landes:

> For many [workers]—though by no means for all—the introduction of machinery implied for the first time a complete separation from the means of production; the worker became a "hand." On almost all, however, the machine imposed a new discipline. No longer could the spinner turn her wheel and the weaver throw his shuttle at home, free of supervision, both in their own good time. Now the work had to be done in a factory, at a pace set by tireless, inanimate equipment. . . .[50]

The close connection of class conflict and technical innovation in 19th-century Britain has been noted moderately often in more recent historical writing. Landes writes that "textile manufacturers introduced automatic spinning equipment and the power loom spasmodically, responding in large part to strikes, threats of strikes, and other threats to managerial authority."[51] Nathan Rosenberg argues that "[t]he apparent recalcitrance of nineteenth-century English labor, especially skilled labor, in accepting the discipline and the terms of factory employment provided an inducement to technical change," and gives a list of particular innovations in which this process can be identified. His list largely follows that of Marx, but he adds additional items such as the Fourdrinier paper-making machine.[52] While denying

[49]Ure, *The Philosophy of Manufactures* (London, 1835), p. 370, as quoted in *Capital* 1:564; ibid., p. 563.

[50]David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present* (Cambridge, 1969), p. 43.

[51]Ibid., pp. 115–16.

[52]Nathan Rosenberg, "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," in his *Perspectives on Technology* (n. 22 above), pp. 108–25, particularly pp. 119–20; quote on p. 117. For the Fourdrinier machine, his sources are D. C. Coleman, *The British Paper Industry, 1495–1860: A Study in Industrial Growth* (Oxford, 1958), pp. 258–59; and H. J. Habakkuk, *American and British Technology in the Nineteenth*

that the spread of the self-acting mule to America can be accounted for in this way, Anthony F. C. Wallace echoes Ure and Marx on its technical development: "The goal of inventors, from Crompton's time on, was to make the mule completely automatic so as to reduce to a minimum the manufacturer's dependence on the highly skilled, highly paid, and often independent-minded adult male spinners."[53] Most recently, Tine Bruland has reexamined the issue and argues that, in the case of the mule (and also in those of calico-printing machinery and devices for wool combing), it was indeed true that "industrial conflict can generate or focus technical change in production processes which are prone to such conflict."[54]

For a different historical context (Chicago in the 1880s), Langdon Winner draws on the work of Robert Ozanne to provide another example. Newly developed pneumatic molding machines were introduced by Cyrus McCormick II into his agricultural machinery plant to break the power of the National Union of Iron Molders. "The new machines, manned by unskilled labor, actually produced inferior castings at a higher cost than the earlier process. After three years of use the machines were, in fact, abandoned, but by that time they had served their purpose—the destruction of the union."[55]

The obverse of the capitalists' use of machinery in class struggle, workers' resistance to the machine, is too well known in the case of Britain to require special documentation. Interestingly, though, historians have begun to interpret that resistance differently. Luddism, it has been argued, was neither mindless, nor completely irrational, nor even completely unsuccessful.[56] The working-class critique of machinery, of which machine breaking was the most dramatic concrete expression, left a major mark on British thought. Maxine Berg has shown

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Century: The Search for Labour-saving Inventions (Cambridge, 1962), p. 153. While Habakkuk, of course, argues that the desire to replace skilled labor was less potent in Britain than in the United States, he does admit that "[t]here are several instances where the desire to diminish the bargaining power of skilled craft labour provided a strong incentive to install machines" (ibid., pp. 152–53).

[53]Anthony F. C. Wallace, *Rockdale: The Growth of an American Village in the Early Industrial Revolution . . .* (New York, 1978), p. 193; see also p. 382.

[54]Tine Bruland, "Industrial Conflict as a Source of Technical Innovation: Three Cases," *Economy and Society* 11 (May 1982): 91–121, quote on p. 91.

[55]Langdon Winner, "Do Artifacts Have Politics?" *Daedalus* 109 (Winter 1980): 121–36, quote on p. 125. See Robert Ozanne, *A Century of Labor-Management Relations at McCormick and International Harvester* (Madison, Wis., 1967).

[56]E. J. Hobsbawm's classic 1952 "revisionist" essay, "The Machine Breakers," is to be found in his collection, *Labouring Men: Studies in the History of Labour* (London, 1968), pp. 5–22. See also E. P. Thompson, *The Making of the English Working Class* (Harmondsworth, 1968), esp. pp. 515–659.

the extent to which the science of political economy was formed in Britain by debate between the bourgeois proponents of machinery and its working-class—and also landed, Tory—opponents.[57]

Historians are also beginning to find resistance to the machine where it was assumed none existed. Merritt Roe Smith's justly celebrated *Harpers Ferry Armory and the New Technology* shows that the "American system of manufactures"—the distinctive contribution of 19th-century America to the development of mechanized mass production—*was* resisted. The highly skilled armorers, and many of the institutions of the still essentially rural society in which they lived, opposed, often bitterly and on occasion violently, changes which meant that "Men who formerly wielded hammers, cold chisels, and files now stood by animated mechanical devices monotonously putting in and taking out work, measuring dimensions with precision gauges, and occasionally making necessary adjustments."[58] The struggle documented by Smith between "the world of the craftsman" and "the world of the machine" at Harpers Ferry significantly modifies the assumption that "American workmen welcomed the American system."[59]

Marx's views on one particular key technology—the steam engine—have also found confirmation in G. N. von Tunzelmann's recent work. Marx's analysis, writes Tunzelmann, "is spare and succinct, encapsulating what emerge in my study as the truly significant links between steam-power and cotton." Von Tunzelmann finds himself in extensive agreement with Marx's argument that technical changes in the steam engine resulted from changing capital-labor relations in mid-19th-century Britain. It may not have simply been the Ten Hours Act, restricting the length of the working day, that induced employers and designers to increase boiler pressures and running speed, but the need "for squeezing out more labour in a given time" was certainly important.[60]

[57]Maxine Berg, *The Machinery Question and the Making of Political Economy, 1815–1848* (Cambridge, 1980). This book provides valuable background to the development of Marx's thought on machinery, particularly in the way Berg locates in its context Engels's book, *The Condition of the Working Class in England* (Oxford, 1958), first published in 1845, whose discussion of machinery (pp. 12–15 and 150–60, in particular) was an important precursor of Marx's.

[58]Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca, N.Y., 1977), p. 292.

[59]The significance of Smith's work in this respect is pointed out by Carroll W. Pursell, Jr., in "History of Technology," chap. 2 of *A Guide to the Culture of Science, Technology, and Medicine*, ed. Paul T. Durbin (New York, 1980), quote on p. 84. Cf. John E. Sawyer, "The Social Basis of the American System of Manufacturing," *Journal of Economic History* 14 (1954): 361–79.

[60]G. N. von Tunzelmann, *Steam Power and British Industrialization to 1860* (Oxford, 1978), p. 8 (see also pp. 217–25); *Capital* 1:536.

This way of proceeding—comparing Marx's theory with more recent historical accounts—can, however, too easily become an exercise in legitimation, or an argument that, to quote Paul Mantoux, Marx's "great dogmatic treatise contains pages of historical value."[61] It also ignores real problems of evidence concerning the origins of certain innovations. It is indeed a fact, as Rosenberg notes, that in early 19th-century Britain it was widely agreed that "strikes were a major reason for innovations."[62] But the extent of that agreement is a different matter from whether it described the actual state of affairs. Neither the "discovery accounts" of inventors[63] such as Nasmyth, nor the anecdotes and inferences of contemporaries such as Andrew Ure or Samuel Smiles, are necessarily to be taken at face value. Yet, in the still-common absence of historical research addressing such questions for particular innovations, more recent writers are often no better placed than Marx himself in the sources open to them. Studies such as *Harpers Ferry Armory*, alive equally to the detail development of particular technologies and to the social relations of production, are still too rare to allow confident generalization.

Further, it would be quite mistaken to see Marx's theory as *completed*. The theory contains difficulties and ambiguities, and these need to be clarified in parallel with, and in relation to, its testing against "actual history."

First of all, it needs to be realized that it is actually a theory, not a putative description of events. It is not a history of the Industrial Revolution, nor even of the Industrial Revolution in Britain, but an attempt to develop a theory of the social causes of organizational and technical changes in the labor process. Uniform, unilinear developmental paths cannot properly be deduced from its premises. Actual history will inevitably be more complicated. Thus Marx himself had to turn, immediately after his discussion of machine production, to the very considerable continuing areas of domestic outwork and manufacture. Raphael Samuel's major survey of the balance between "steam power" and "hand technology" in Marx's time shows the slowness of the process of mechanization. Indeed, Marx was arguably wrong to assume that outwork and small-scale manufacture were necessarily

[61]Paul Mantoux, *The Industrial Revolution in the Eighteenth Century: An Outline of the Beginnings of the Modern Factory System in England* (London, 1928), p. 36. Mantoux's reliance on Marx was perhaps greater than he acknowledged. Thus his discussion of the difference between a "tool" and a "machine" (pp. 193–94) followed that of Marx very closely.

[62]Rosenberg, "The Direction of Technological Change" (n. 52 above), p. 118.

[63]On "discovery accounts" in science, see S. W. Woolgar, "Writing an Intellectual History of Scientific Development: The Use of Discovery Accounts," *Social Studies of Science* 6 (September 1976): 395–422.

forms "transitional" to "the factory system proper."[64] A century after his death outwork still flourishes, even in some technologically advanced industries.[65] On occasion, valorization may be better served by decentralized rather than centralized labor processes.[66]

This example illustrates a general issue that has become important as interest in Marx's theory has revived during the past decade. In the rush of theoretical reflection and empirical research about the labor process, writers have sometimes conflated particular strategies that capital employs to further valorization with the goal of valorization itself. Capitalists have been seen as *always* pursuing the deskilling of labor, or as *always* seeking maximum direct control over the labor process. But neither assertion is even roughly correct empirically, nor is either goal properly deducible from the imperative of valorization alone. "Skill" is not always a barrier to valorization; only under certain (common but not universal) circumstances does it become one. Direct control over the labor process is not always the best means of valorization.

Marx himself seems on occasion to postulate something close to a thesis of continual deskilling and of the creation of a homogeneous work force: ". . . in place of the hierarchy of specialized workers that characterizes manufacture, there appears, in the automatic factory, a tendency to equalize and reduce to an identical level every kind of work that has to be done by the minders of the machines."[67] The outcome of the extensive research and debate occasioned by Harry Braverman's influential elaboration of the "deskilling" thesis can in part be summarized by saying that deskilling and homogenization are precisely "a tendency"—no more.[68] The imperative of valorization does bring about changes in the labor process that do away with capital's dependence on many human competences previously necessary; these changes do undermine the position of groups of workers who owe their relatively high wages or ability to resist capital to their possession of these competences; technology is crucial to this process. But these changes in the labor process also create the need for new competences;

[64]*Capital* 1:588–610, quote on p. 603; Raphael Samuel, "Workshop of the World: Steam Power and Hand Technology in Mid-Victorian Britain," *History Workshop*, no. 3 (Spring 1977), pp. 6–72.

[65]Thus the London *Financial Times* in August 1982 carried articles discussing outwork (renamed "networking") for Rank Xerox.

[66]This is argued cogently, from a management point of view, in Sir Frederick Catherwood, "Shop Floor Power," *Production Engineer* (June 1976), pp. 297–301.

[67]*Capital* 1:545.

[68]Braverman, *Labor and Monopoly Capital* (n. 22 above). A recent contribution to the debate, which provides a useful summary of criticisms of the deskilling thesis, is Stephen Wood, ed., *The Degradation of Work? Skill, Deskilling and the Labour Process* (London, 1982).

create new groups of "skilled" workers; and create types of work that are far from exemplifying the real subordination of labor to capital.[69] The very creation of these is often the obverse of the process of deskilling other occupations: computer programming is a contemporary example.[70]

Similarly with control. From a 20th-century perspective, too much weight is placed in *Capital* on what Andrew Friedman calls a "Direct Control" strategy on capital's behalf. This strategy, of which Taylorism is the obvious example for the period after Marx's death, "tries to limit the scope for labour power to vary by coercive threats, close supervision and minimising individual worker responsibility . . . [it] treats workers as though they were machines." But "Direct Control" hardly captures the range of strategies for the management of labor power. Thus management can also involve a "Responsible Autonomy" strategy, trying "to harness the adaptability of labour power by giving workers leeway and encouraging them to adapt to changing situations in a manner beneficial to the firm . . . [giving] workers status, authority and responsibility . . . [trying] to win their loyalty, and co-opt their organisations to the firm's ideals."[71]

Again, there is nothing in Marx's theory to suggest that capital will seek maximum control over the labor process as a goal *in itself*, or that capitalists will necessarily prefer direct over indirect forms of control. A degree of control over the labor process is clearly a prerequisite for valorization. But the theory does not lay down how that control can best be achieved, nor does it imply that control should be pursued regardless of its costs. Supervisors, after all, cost money; and techniques of production that maximize direct control over labor power may be fatally flawed in other respects.

To present Marx's theory as hinging around valorization, rather than deskilling or control as such, points to the relevance to it of the traditional concerns of those economic historians who have made

[69]See, e.g., Raphael Samuel's comment in "Workshop of the World," p. 59, that "nineteenth century capitalism created many more skills than it destroyed, though they were different in kind from those of the all-round craftsmen." See also Habakkuk's comments on skill requirements in 19th-century British industry: *American and British Technology in the Nineteenth Century* (n. 52 above), pp. 153–56. For a balanced judgment, see Tony Elger, "Valorisation and 'Deskilling': A Critique of Braverman," *Capital and Class*, no. 7 (Spring 1979), pp. 58–99, esp. pp. 72–78. This article, which is very pertinent to several of the issues discussed in the text, has now been reprinted in Wood (n. 68 above).

[70]For an interesting, if schematic, account, see Joan Greenbaum, *In the Name of Efficiency: Management Theory and Shopfloor Practice in Data-processing Work* (Philadelphia, 1979).

[71]Andrew L. Friedman, *Industry and Labour: Class Struggle at Work and Monopoly Capitalism* (London, 1977), p. 78.

technology a central focus of their work.[72] The level of wages, the rate of interest, the level of rent, the extent of markets—all these would be expected to influence choice of technique, and there are passages in Marx where he shows his awareness of this clearly.[73]

Where the Marxist and the "neo-classical" economic historian would diverge, however, is in the Marxist's insistence that "factor costs" ought not to be treated in abstraction from the social relations within which production takes place. This is a persistent theme throughout *Capital.* Capital, Marx wrote, is not a thing, it is not a sum of money or commodities, it is "a social relation between persons which is mediated through things."[74] The relation between capitalist and worker is not simply a matter of wages and hours of work, but also a matter of law and the state (in, for example, the worker's legal status as "free citizen" or otherwise), of supervision, discipline, culture, and custom, of collective forms of organization, power, and conflict.[75]

Thus William Lazonick, in his study of the choice of technique in British and U.S. cotton spinning, argues that, while factor prices mattered, their effect was conditioned by the very different nature of production relations in such spinning centers as Oldham in Lancashire and Fall River in Massachusetts. Such facts as the preference of Lancashire mill owners for spinning mules, and of their New England counterparts for ring spinning, have to be understood in the context of the different historical evolution of relations within the work forces and between work forces and capitalists.[76]

Lazonick's work, though, is far from an uncritical confirmation of

[72]For a useful survey, see Paul Uselding, "Studies of Technology in Economic History," *Research in Economic History*, suppl. 1 (1977), pp. 159–219.

[73]For example, *Capital* 1:513–17, which focuses on the level of wages as a determinant of choice of technique.

[74]Ibid., p. 932.

[75]Two very different articles that make this point are: Thompson, "Time, Work-Discipline and Industrial Capitalism" (n. 32 above), and John Holloway and Sol Picciotto, "Capital, Crisis and the State," *Capital and Class*, no. 2 (Summer 1977), pp. 76–101. The latter article's attack on the notion that the "capital relation" should be seen as simply a matter of "economics" has been particularly influential within recent British Marxist thinking.

[76]William H. Lazonick, "Production Relations, Labor Productivity, and Choice of Technique: British and U.S. Cotton Spinning," *Journal of Economic History* 41 (September 1981): 491–516. Cf. Lars G. Sandberg, "American Rings and English Mules: The Role of Economic Rationality," *Quarterly Journal of Economics* 83 (1969): 25–43. Closely related work by Lazonick includes: "Industrial Relations and Technical Change: The Case of the Self-acting Mule," *Cambridge Journal of Economics* 3 (1979): 213–62; "Factor Costs and the Diffusion of Ring Spinning in Britain prior to World War 1," *Quarterly Journal of Economics* 96 (February 1981): 89–109; and "Competition, Specialization, and Industrial Decline," *Journal of Economic History* 41 (March 1981): 31–38.

Marx. Indeed, it points up a major inadequacy in Marx's account, one that ties in closely with the problem of evidence mentioned above. Marx's reliance on sources such as the writings of Ure meant that he had quite plausible evidence for what class-conscious capitalists hoped to achieve from the introduction of the machine. But what they hoped for was not necessarily what happened. Marx quoted Ure's judgment on the self-acting mule: "A creation destined to restore order among the industrious classes." Lazonick's work shows that the mule had no such dramatic effect. In Lancashire, "adult male spinners (now also known as 'minders') retained their positions as the chief spinning operatives on the self-actors," developed a strong union, achieved standardized wage lists that protected their wage levels, and kept a fair degree of control over their conditions of work. Such was the failure of the self-acting mule in increasing capital's control that when ring spinning was introduced in New England it was talked about in precisely the same terms as the self-actor had once been, as a curb on "obstreperous" workers—only this time these were the minders of self-acting mules![77]

In large part, the failure of capitalists to achieve their goals can be put down to workers' resistance, and thus offers no fundamental challenge to Marx's account. Workers are not passive clay in capital's hands; quite the opposite. Even highly automated factories with close, harsh labor supervision offer major opportunities for both individual acts of noncompliance and collective action to change conditions.[78] Further, the very fact that the labor process, however much it is affected by the valorization process, remains a material process of production constrains what capital can achieve. Thus in his work on automatically controlled machine tools, David Noble found that despite all their efforts managements were unable totally to do without skilled machinists. As one machinist put it:

> Cutting metals to critical tolerances means maintaining constant control of a continually changing set of stubborn, elusive details. Drills run. End mills walk. Machines creep. Seemingly rigid metal castings become elastic when clamped to be cut, and spring back when released so that a flat cut becomes curved, and holes bored precisely on location move somewhere else. Tungsten carbide cutters imperceptibly wear down, making the size of a critical slot half a thousandth too small. . . .

[77]*Capital* 1:563; Lazonick, "Production Relations, Labor Productivity and Choice of Technique" and "Industrial Relations and Technical Change," quote from latter on p. 232; Sandberg, p. 33.

[78]See, e.g., Huw Beynon, *Working for Ford* (Wakefield, Yorks., 1975).

Experienced machinists were needed to make sure that "automatic" machines did not produce junk parts or have expensive "smashups."[79]

The intractability of both workers and the material world is, however, not fully sufficient to explain the type of development described by Lazonick. Here we come to an area where Marx's account clearly requires modification. The social relations of production within which technology develops are not simply between worker and capitalist, but between worker and worker. Crucially, they include relations between men workers and women workers, between older workers and younger workers, and, sometimes at least, between workers divided by ethnicity.

Marx was of course aware of the division of labor by age and sex, but he slid far too easily into a facile description of it as "natural."[80] Lazonick's account of the history of the self-acting mule, for example, shows that adult male minders in Britain retained their position not through any "natural" attributes, nor because of their power to resist capital, but because British employers found useful, indeed indispensable, the hierarchical division in the work force between minders and "piecers," whose job it was to join the inevitable broken threads. And this relation within the work force conditioned technical change. It made it rational for capitalists to work with slightly less automated mules than were technically possible, so that failures of attention by operatives led not to "snarls" that could be hidden in the middle of spun "cops," but to the obvious disaster of "sawney," where all the several hundred threads being spun broke simultaneously, with consequent loss of piecework earnings for the minder.[81]

Of the divisions *within* the work force that affect the development of technology, that between women and men is perhaps the most pervasively important. Marx's account captures only one of the (at least) three ways in which this division interacts with change in the technology of production. He focuses on the very common use of machinery plus low-paid, less unionized women workers to replace skilled men. Ruth Schwartz Cowan, in her review of "women and technology in American life," shows this process at work in American cigar making. But she also points to the very different situation of the garment industry, arguing that there the sewing process had not been automated (beyond the use of the sewing machine) in large part because of

[79]David F. Noble, "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools," in *Case Studies on the Labor Process*, ed. Andrew Zimbalist (New York, 1979), pp. 18–50, quote on p. 41.

[80]*Capital* 1:545.

[81]See Lazonick, "Industrial Relations and Technical Change" (n. 76 above), esp. pp. 240–46 and 256–57.

the availability of "successive waves" of immigrant women. Their undoubted skills cost employers nothing extra. Those skills were learned largely in the home, rather than at the employers' expense. And because sewing is "women's work," it is defined as unskilled (Phillips and Taylor argue that this, not the opposite as commonly assumed, is the real direction of causation) and thus is poorly paid.[82]

A third form of the interaction between gender divisions and workplace technology is that identified by Cynthia Cockburn in her study of the history of typesetting technology in Britain. Up to a point, the process was exactly parallel to that described by Marx. Employers "sought to invent a machine that could bypass the labour-intensive process of hand typesetting," so undermining the well-paid, well-unionized male hand compositors. By the end of the 19th century several such mechanized typesetters had become available, and struggle took place between the men and their employers over their introduction. But here the story diverges from Marx's archetype. The male compositors (like the mule spinners) were able to retain a degree of control over the new technology, and the machine that became the dominant means of mechanizing typesetting, the Linotype, was the one that offered least threat to their position. Unlike its less successful predecessor, the Hattersley typesetter, the Linotype did not split the process of typesetting into separate parts. As the men's union, the London Society of Compositors, put it, by not splitting up the process "the Linotype answers to one of the essential conditions of trade unionism, in that it does not depend for its success on the employment of boy or girl labour." The choice of the Linotype, backed up by vigorous campaigning by the union to exclude women, eventually left the composing room still "an all-male preserve." Technology, according to Cockburn, can thus reflect male power as well as capitalist power.[83]

The Politics of Design and the History of Technology

Perhaps the most intriguing question of all those that are raised by Marx's account of the machine is one that he himself neither very

[82]Ruth Schwartz Cowan, "From Virginia Dare to Virginia Slims: Women and Technology in American Life," *Technology and Culture* 20 (January 1979): 51–63; Anne Phillips and Barbara Taylor, "Sex and Skill: Notes towards a Feminist Economics," *Feminist Review* 6 (1980): 79–88. On the relations between gender and technological change, see Martha Moore Trescott, ed., *Dynamos and Virgins Revisited: Women and Technological Change in History* (Metuchen, N.J., 1979), and Judith A. McGaw, "Women and the History of American Technology," *Signs: Journal of Women in Culture and Society* 7 (1982): 798–828.

[83]Cynthia Cockburn, "The Material of Male Power," *Feminist Review* 9 (Autumn 1981):

clearly put nor unequivocally answered. Does the design of machinery reflect the social relations within which it develops? Do capitalists (or men) merely abuse machinery for their own purposes, or do those purposes somehow shape the machine itself?

At this point, of course, the issues raised by Marx's theory converge with a central question—perhaps *the* central question—of the history of technology. George Daniels posed it when he organized his essay on "The Big Questions in the History of American Technology" around the "nature and the direction of causation" in the relationship between technology and society, himself asserting his belief that "the direction of the society determines the nature of its technological innovations." "The influence of economics, politics, and social structure on technology" is among the topics mentioned by Thomas Hughes in his survey of "Emerging Themes in the History of Technology." According to Carroll Pursell, arguments about the neutrality of technology—whether "the purposes (ethics and values) of our society are built into the very form and fabric of our technology"—"have grave implications . . . for the way in which the history of technology is studied and taught." If the history of technology needs to be rescued, as David Hounshell believes, from becoming "increasingly internalistic" in its approach, then pursuit of this question offers a way of combining attention to technical detail with concern for broader issues of social history.[84]

Replying to Hounshell, Darwin Stapleton notes that Karl Marx "has always been in the background" of the history of technology.[85] Unfortunately, Marx himself equivocated on this crucial question. Sometimes he appears to treat machines as subject to abuse by capital but not in their design inherently capitalist. "It took both time and experience

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41–58; quotes on pp. 46 and 52; see also Cynthia Cockburn, *Brothers: Male Dominance and Technological Change* (London, 1983).

[84]George H. Daniels, "The Big Questions in the History of American Technology," in *The State of American History*, ed. Herbert J. Bass (Chicago, 1970), pp. 196–219, quotes on pp. 200 and 199; Thomas P. Hughes, "Emerging Themes in the History of Technology," *Technology and Culture* 20 (October 1979): 697–711, quote on p. 710; Carroll W. Pursell, Jr., "History of Technology" (n. 59 above), p. 98; David A. Hounshell, "On the Discipline of the History of American Technology," *Journal of American History* 67 (March 1981): 854–65, quote on p. 863. Lest I be misunderstood, let me emphasize that I am saying only that Marx's approach converges with the question raised by this literature, not that it is identical with it. For Marx studied in detail only one form of technology, that of production, and not, e.g., the equally important areas of domestic technology or military technology. And there are clearly non-Marxist ways of approaching the question of the influence of society on technical development.

[85]Darwin Stapleton, "The Discipline of the History of American Technology: An Exchange," *Journal of American History* 68 (March 1982): 897–900, quote on p. 899. For Marx's own remarks on the history of technology, see *Capital* 1:493–94, n. 4.

before the workers learnt to distinguish between machinery and its employment by capital, and therefore to transfer their attacks from the material instruments of production to the form of society which utilizes those instruments." He also writes, however, that a "specifically capitalist form of production comes into being (at the technological level too)."[86] While it seems to me that extension of his theory to the level of detailed technical design would be a natural step to take, we have no unequivocal evidence that Marx took it. A priori, it would not be unreasonable (indeed, as outlined above, it would be orthodox) to accept that the *pace* of technical change was affected by social relations—that mechanization was hastened by valorization-imposed needs to undermine the power of skilled workers, for example—while denying that those relations affected the actual design of technical artifacts. Without clear information about what Marx believed, we can but turn to the (in any case more important!) question of what actually is the case.

Fortunately, historians have found it possible to obtain at least partial, tentative answers to the question of the effect of social relations on technical design. Perhaps the most straightforward way of doing this hinges round documenting the *contingency* of design, identifying instances where "things could have been different," where, for example, the same artifact could have been made in different ways, or differently designed artifacts could have been constructed. Having identified contingency, the historian can then ask why one way, or one design, was chosen rather than another. In that way the question of the effect of social relations becomes a matter for empirical inquiry as well as for theory.[87]

Langdon Winner's stimulating essay "Do Artifacts Have Politics?" provides a rudimentary but clear example. Designing the bridges over Long Island parkways, builder Robert Moses could have had them constructed with a wide range of clearances. He chose to build them low, with "as little as nine feet of clearance at the curb." The reason was that the buses which might otherwise take poor people and blacks along the parkways to Moses's "widely acclaimed public park" at Jones Beach were 12 feet high![88] (Why contingency is important is obvious here. If it had not been clearly possible for Moses to choose to build higher overpasses, we would have no way of assessing the relevance of his social prejudices to his bridge design.)

[86]*Capital* 1:554–55 and 1024 (parentheses in original, emphasis deleted).

[87]For the relevance of contingency in the history of *science*, see Steven Shapin, "History of Science and Its Sociological Reconstructions," *History of Science* 20 (1982): 157–211.

[88]Winner, "Do Artifacts Have Politics?" (n. 55 above), pp. 123–24. See Robert A. Caro, *The Power Broker: Robert Moses and the Fall of New York* (New York, 1974).

There is of course nothing new about the approach of identifying contingency,[89] nor is identifying contingency in itself enough.[90] An explanation of the causes of the choices actually made is necessary too. But here Marx's theory *is* useful, because it does suggest where to look for such an explanation—in the area of the technology of production, at least. In any society, the design of production technology will reflect the need for that technology to be part of a labor process that is a functioning whole. This implies obvious physical constraints: thus the instruments of production must be compatible with the raw material available. But it also implies social constraints. The labor process in a capitalist society must function effectively not simply as a material process of production, but as a valorization process. Production technology will thus be designed with a view to ensuring successful valorization, and valorization will typically not simply be a matter of "profit maximizing" but will involve the creation and maintenance of desired social relations.

One piece of work that can be seen as attempting to apply this perspective to technical design is David Noble's analysis of the automation of machine tools. Noble identifies contingency in that development. There were *two* ways to automate—record-playback and numerical control—and it is far from clear that only numerical control was a priori viable. He also identifies a problem of valorization: the capacity of skilled machinists to control the pace of production, or indeed to disrupt it completely. He suggests that the choice of numerical control reflected its perceived superiority as a solution to this problem of valorization. As one engineer central to the development of both systems put it: "Look, with record-playback, the control of the machine remains with the machinist—control of feeds, speeds, number of cuts, output; with N[umerical] C[ontrol] there is a shift of control to management. Management is no longer dependent upon the operator and can thus optimize the use of their machines. With N.C., control over the process is placed firmly in the hands of management—and why shouldn't we have it?"[91]

Contingency and the Politics of Technology

There is of course one major objection to making contingency the way into the study of the social relations embodied in the actual design

[89]See, e.g., Habakkuk (n. 52 above), where the geographical comparison serves this function.

[90]Once again, I have found Iain Campbell's ideas on this point very helpful.

[91]David F. Noble, "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools, and a Challenge for Labor," *Politics and Society* 8 (1978): 313–47, quote on p. 337; see also Noble (n. 79 above).

of artifacts and of the technologies of production. That is, simply, that we may not be able to identify contingency. The most obvious way to legitimate any particular design decision or choice of technique is to say it is "technically necessary." A vested interest thus typically arises in disguising the actual extent of contingency. Even more seriously, particular ways of designing things and making things can become so routine and habitual that our minds may be closed to the very possibility of doing things otherwise. While Seymour Melman may be right that both choice in production techniques, and the consciousness of choice among engineers and designers, are pervasive, the parameters within which that choice operates may well be much narrower than those within which it potentially could operate.[92]

There are many people now working to reveal the extent of contingency by designing "alternative technologies." Best known are the attempts to embody in technology the virtues of small scale, decentralization, and ecological awareness. But there are also attempts from within high-technology industry to alter in fundamental ways both what is produced and how it is produced. In Britain, this is best exemplified by the "alternative plans" put forward by the work force at Lucas Aerospace. These involve attempts to shift production from military to "socially useful" products, and also to change the nature of production, to reverse in practice deskilling and the separation of head and hand. Interestingly, their work in this latter sphere seems to have been informed explicitly by Marx's analysis of the machine.[93]

Whatever the eventual success or failure of these efforts to alter the nature of technology, our understanding of how technology changes can only profit from them. For, by making contingency and choice actual rather than merely hypothetical, they throw into ever-sharper light the ways in which social relations shape technical development. Perhaps too the process can be dialectical, rather than one-way. Perhaps understanding how existing technology has been and is being socially shaped can help in reconstructing it. If that can be so, and if Marx's account of the machine is useful to that understanding, then the shade of Marx will surely be happy. For it was of the essence of the man that he believed, not simply in understanding the world, but also in changing it.[94]

[92]Seymour Melman, "Alternative Criteria for the Design of Means of Production," *Theory and Society* 10 (1981): 325–36.

[93]This is clearest in a book by one of the former leaders of the Lucas work force: Mike Cooley, *Architect or Bee? The Human/Technology Relationship* (Slough, n.d.). For an overall account, see Hilary Wainwright and Dave Elliott, *The Lucas Plan: A New Trade Unionism in the Making?* (London, 1982).

[94]See the eleventh of Marx's "Theses on Feuerbach," in Marx and Engels, *Selected Works in One Volume* (n. 20 above), pp. 28–30.