5-1993

Organizing Engineering Work - A Comparative-Analysis

Peter F. Meiksins
Cleveland State University, p.meiksins@csuohio.edu

Chris Smith
Aston University

Original Citation

Meiksins, P., , & Smith, C. (1993). Organizing Engineering Work: A Comparative Analysis. Work And Occupations, 20(2), 123-146. doi:10.1177/0730888493020002001

ORGANIZING ENGINEERING WORK
A COMPARATIVE ANALYSIS

Peter Meiksins, *Cleveland State University*
Chris Smith, *Aston University, England*

This article was originally published in:

Meiksins, Peter and Chris Smith (1993). Organizing Engineering Work a Comparative Analysis. *Work and Occupations,* 20(2), 123-146.

Post-print standardized by MSL Academic Endeavors, the imprint of the Michael Schwartz Library at Cleveland State University, 2013

This article analyzes the organization of engineering work in six industrial capitalist countries. It identifies four major models for the organization of engineering work; the engineering profession did not succeed in achieving professional "closure" in any of the six countries under review. A review of the historical evolution of the organization of engineering work in each of the six countries reveals that engineering has been shaped by a complex interaction among the profession itself, employers, the state, labor, and preindustrial forces. However, none of the national variations on the four models for organizing engineering labor is stable or without internal contradiction because of the ambiguous "intermediate" position of engineers.

Organizing Engineering Work

A COMPARATIVE ANALYSIS

PETER MEIKSINS
Cleveland State University
CHRIS SMITH
Aston University, England

In the past decade or so, a growing amount of attention has been paid to the comparative sociology of engineering. Studies of engineers in national context have revealed the fact that engineers in different countries are organized quite differently. The comparative student of engineers is confronted by a bewildering variety of ways of organizing technical labor. There is no agreement, among the major industrial powers, over such basic questions as, What is an engineer? Where does one draw the line between the professional engineer and the nonprofessional technician? How and where should engineers be produced? Are unions or/and professional associations appropriate institutions for engineers?

This diversity has spawned a vast "literature of emulation," in which analysts of engineering and industry have attempted to persuade their compatriots that some other country has a superior system for producing and organizing technical workers. Nineteenth-century Americans admired German technical education and the French École Polytechnique (Calvert, 1967), whereas late 19th-century Germans emulated the practicality of British and

American engineering (Gispen, 1989). More recently, critical observers of British engineering have advocated the adoption of elements of German or American practice (Lawrence, 1992), whereas American critics look to Japan for ways to recapture the technological lead (Kinmoth, 1986). After a quick survey of this literature, one comes away with the impression that there is a limitless variety of ways of organizing technical workers.

Perhaps the most remarkable feature of this debate about the organization of technical work is the absence of any serious suggestion that engineers should be organized as a "profession." Although there is a general sense that engineers are "professionals," and not just "employees" or "workers," there appears to be an equally general recognition that organizing engineers on a professional basis is not very likely to succeed. No matter which theory of professionalism one considers, engineers are regarded as examples, at best, of incomplete or imperfect professionalization.

Thus traditional "trait" theorists generally treat engineers as a special case because they lack some of the defining traits of a true profession—for example, unified professional organizations and a sense of community (Perrucci & Gerstl, 1969). More recently, sociologists arguing for a conflict or Marxist approach to the professions have seen engineers as examples of failed or imperfect professionalization because of their relative lack of autonomy and their employee status within organizations (Larson, 1977). Even the recent, revisionist "neo-Weberian" approach to the professions implies a similar conclusion. If, as these writers have argued, professionalism is the attempt to achieve "closure," or exclusive "jurisdiction" over an area of knowledge, it is clear that engineers, who lack such mechanisms as mandatory licensing and do not restrict professional practice to the holders of specific formal credentials, are at best a borderline case of a profession (Abbott, 1988; Halliday, 1983). Because professionalization does not work for engineers, analysts are left groping for answers to the question of how this "special" group of employees should be organized.

In this article, we argue that there is an important lesson to be learned from the debate about how to organize technical workers. Drawing on material that will appear in a forthcoming volume (Smith & Meiksins, in press), we compare the organization of technical work in six industrialized countries: the United States, Great Britain, France, Germany, Sweden, and Japan. Our central observation is that the apparent diversity in the organization of technical labor is real; we identify four major models of organizing technical labor that are combined in different ways in these six countries. However, we argue that there is a common element lying beneath the diversity of organizational forms. Technical workers, as occupants of the middle levels of organizational hierarchies, seem to represent a kind of intermediate

stratum within the organization (hence the tendency to see them as employees, professionals, middle class, etc.). But, their apparent intermediate position is nowhere expressed in the creation of a distinct *occupational* community that unifies technical workers. This is a consequence of the fact that built into the structural position and role of qualified technical labor is a common set of tensions that cuts across national boundaries and links together the experience of engineers in all six countries. These tensions are not something that can be organized away; they consistently impede the organization of technical workers as an intermediate social group. They also tend to undermine the various forms of organization that have been adopted as alternatives. It is thus our conclusion that there is no stable, "best" way of organizing technical workers.

THE ROLE OF THE ENGINEER

Before turning to a comparison of the organization of engineering labor in the six countries under review, a few preliminary remarks about the role and social position of the engineer are necessary. As we have already remarked above, engineers have long been seen as unusual among the professions because most engineering practitioners are employees of large organizations. As employees, engineers are subject to various bureaucratic controls that may be in tension with norms of professional autonomy and make it more difficult to maintain truly "professional" conditions of work. We agree that this is an important feature of the engineering occupation. However, it is only part of the story. A full understanding of the nature of engineering requires that we recognize that engineers are not simply employees of *organizations*, but that they are employees of *industrial organizations*. That is, they are an important, intermediate group of highly qualified employees located between management and shop floor workers in productive industry.

The conditions of modern industry make necessary the employment of a large number of such intermediate workers. As industry has grown larger, more complex, and more technically sophisticated, it has become necessary for firms to employ a complex, diverse group of technical workers who are engaged in the labor of designing industrial processes and products and/or in overseeing and coordinating the functioning of the workers and equipment used in production. What this reflects is the dependence of management on a "class" of qualified technical workers; managers cannot any longer perform this labor themselves or rely on relatively untrained workers to design products and production systems.[1]

The relationship of this intermediate stratum of technical workers to both employers and manual labor is complex. On the one hand, engineers are of great importance to employers—they must rely on this kind of qualified employee if their firms are to be profitable. Yet, as employees, engineers pose something of a problem of control for employers; how can they ensure that their technical employees perform their tasks satisfactorily? On the other hand, engineers function as a kind of directing authority within the workplace. Although they may not be in direct contact with production workers, their designs, specifications, instructions, and processes are imposed on workers from above and are experienced as coercion. Thus there is an element of tension built into their relationship with other kinds of employees as well.

A comparative study of technical workers reveals a number of persistent problems generated by their ambiguous, intermediate role. First, industry is dependent on qualified technical labor; therefore, a method of producing and recruiting large numbers of such workers must be found. Second, a division of labor must be created to perform this necessary technical work. Finally, the relationship of various kinds of "intermediate" technical workers to the other classes within the enterprise must be defined. No best solution has been found to these intractable problems. On the contrary, the history of technical workers is the history of ongoing struggles between employers and a diverse, divided stratum of technical workers, often involving the state and other social groups as well, over how to resolve these dilemmas.

FOUR MODELS FOR ORGANIZING TECHNICAL WORK

Our analysis of the six countries covered in our survey reveals four major approaches to the organization of technical workers. Each of these models represents a different strategy for producing a technical work force and for defining the social position of technical workers. Of course, these four models are abstractions; no country perfectly exemplifies a single system. Indeed, in many cases, a country's manner of organizing technical work combines elements of several of these systems. Nevertheless, these abstractions help us to identify what is truly distinctive in each country's experience.

CRAFT ORGANIZATION

In this model, the vast majority of technical work is defined and organized as if it were the top of the hierarchy of manual labor. Technical workers are produced and organized in ways that resemble traditional craft methods. The

central feature of this method of organizing technical work is the reliance on the acquisition of technical skills within the firm or "craft community" through methods of apprenticeship and pupilage. Coupled with this is a distinct hostility to formal, abstract educational credentials as a route into technical work. The engineer is constituted not by the possession of credentials, but by the laborious acquisition of practical experience. There is no sharp class wall, buttressed by credentials, between the engineer, the technician, and the skilled manual worker.

This form of technical organization produces an occupational community that is both homogeneous and highly fragmented. On the one hand, there are no formal credentials to serve as the basis for stratification within technical work; thus all engineers are, in a basic sense, alike. On the other hand, however, engineers' skills tend to be narrow, specialized and firm specific. Having learned their "trade" in a particular workplace, and lacking formal credentials, which would tend to make their expertise more "portable," engineers of this type are tied to individual firms and their internal labor markets.

It is also significant that this form of technical organization implies a relatively low status for the engineer: Technical workers are produced in the same manner as craft workers and are seen as a kind of manual labor. Engineers' practical experience on the shop floor blurs the distinction between expert and worker. And the rejection of credentialism, coupled with the emphasis on experience, makes it possible for manual workers to move up into engineering positions. One result is a fairly distinct division between engineers and management, as the manual skills of engineers are not seen as providing appropriate background for managerial careers. Yet it is also true that this system of technical work tends to produce a sense of superiority and exclusivity among engineers. As craft workers, they see themselves at the top of the productive labor force, as an elite within the hierarchy of skill and crafts. Although they may be regarded as part of manual labor, they are hostile and superior to manual workers with lesser (or no) skills. Thus, looked down on by management, yet feeling superior to most of the work force, engineers of this type are predisposed toward craft unionism, a form of occupational organization that suits their sense of being an elite community of skilled workers within the larger mass of blue-collar workers.

MANAGERIAL ORGANIZATION

The managerial model of technical organization defines a substantial portion of technical work as part of management. As in the craft model, the enterprise is seen as divided into labor and management. However, in this

case, with the exception of the routine functions carried out by relatively poorly trained technicians, most technical work is seen as managerial work to be carried out by a distinct type of managerial specialist, the engineer.

For the most part, the production of engineers takes place within formal educational institutions (especially as access to management positions comes to require university training). Engineering is cast as expertise, rather than as manual skill, which must be acquired through formal training, generally in a university context. In this respect, the managerial model mimics purely professional forms of organization. However, it would be incorrect to label this a professional system for organizing technical work. Despite the emphasis on credentialing, there is no requirement that practitioners possess formal degrees, nor is there mandatory licensing of those who call themselves engineers. Indeed, such occupational closure is explicitly rejected, so that the term *engineer* may be applied to someone who lacks formal university training, to someone with a first degree, or to someone who has completed the highest level of university education. Engineering, thus, is expertise, but it is not to be monopolized by the possessors of specific credentials.

The status of the engineer within this system is markedly higher than it is within the craft form of organization. As possessors of university training, engineers are part of society's elite; their expertise qualifies them for responsible managerial careers and the distinction between them and manual labor is sharply drawn. This kind of engineer is much more likely to see her or his role as placing her or him on the management side of the divide; to see manual workers as subordinates, not cooperators, as a problem that needs to be "controlled." As a result, unionization is seen as inappropriate for engineers. In contrast, relatively weak professional associations are compatible with this model, although stronger ones that seek effective closure and autonomy from management produce tension with the model's insistence that engineers are *part* of management. To the extent that engineers do enjoy access to managerial careers, this tends to tie them to the firm and its internal labor market, thus weakening the appeal of strong professional associations.

ESTATE ORGANIZATION

Whereas the first two models are based on a dichotomous form of organization, with the bulk of technical workers all allocated either to management or to labor, what we are calling the *estate* system of organization is characterized by the creation of an explicitly stratified hierarchy of technical occupations in the middle levels of the firm. This model is shaped by the effort of high-level, credentialed technical workers to consolidate their hold

on a professional jurisdiction in the context of the industrial capitalist enterprise.

As in the managerial model, formal school-based training is considered a legitimate means of producing engineers. However, in this model, the possessors of engineering credentials are more successful in pursuing a professional project. That is, they seek to restrict access to engineering positions to those technical workers who possess credentials. They emphasize raising standards in engineering schools and they try to restrict numbers to maintain engineers' standard of living. The result is the creation of a stratum of credentialed, highly trained engineers who identify strongly with their profession and are distinguished thereby from both labor and management.

This successful professional project tends to limit the supply of technical labor. Employers, however, demand a far larger supply; however, status-conscious, professional engineers do not always fit well into the many modest, practical technical jobs employers need to fill. The result is substantial pressure to create other sources of technical labor—this may take the form of programs offering alternative, lesser credentials or of producing some skilled technical workers through craftlike methods. Thus, although the elite professional engineers succeed, up to a point, in their professional project, they are obliged to coexist with a variety of other technical workers with varying claims to the title engineer.

What emerges is a hierarchy of technical labor stratified by credentials and mode of entry into the technical work force. Whatever the mode of entry, however, there is a direct correspondence between the type of qualification possessed and the engineer's position in the division of the labor within the firm. Those with lesser qualifications are excluded from higher technical positions, whereas those with higher qualifications start off higher up the technical ladder. The hierarchy of technical labor within the firm is, in some cases, strengthened and coordinated by the state, which defines the various categories of technical worker and may accord special legal privileges to some of them. In sum, the distinctive characteristic of the estate model is the development of an explicit, readily recognized, nondichotomous hierarchy of technical labor.

Because there are different kinds of technical labor within this model, technical workers constitute a more fragmented occupational community than in other models. Different kinds of technical workers occupy a different social place and see themselves as distinct. Members of the technical elite, who generally possess the highest formal educational credentials, have relatively high status and access to higher positions. The distinction between them and subordinate technical and blue-collar workers is clear, and they

tend to develop exclusive professional associations restricted to engineers who possess the appropriate qualifications and status. Indeed, it could be said that this group represents the closest approximation of a successful professional project in any of the models under discussion (in that, in the abstract at least, they approach a successful form of occupational closure through credentialing). As one moves down the technical ladder through those technical workers with more modest educational levels toward those who have been trained within industry itself, this sense of elitism and professionalism diminishes, although there is still a tendency to define them as different than production workers. These technical workers develop a variety of forms of organization; however, all are more "workerlike" and "unionlike" than the professional associations of the elite and some are willing to create or join white-collar or craft unions.

CORPORATIST ORGANIZATION

The corporatist model of organizing technical workers is distinguished by its efforts to foster a sense of solidarity with the enterprise as a whole, and with all of the groups that compose it, rather than a sense of occupational sectionalism and class division. Although the familiar hierarchy of occupations in industry persists, this model is designed to play down, as much as possible, the significance of occupational differences. Even the distinction between management and labor is deemphasized, in stark contrast to managerial organization, where this distinction is central.

The system of recruitment and training is primarily degree based with engineers trained in universities. In this respect, the corporatist system resembles the managerial and estate models. However, this does not produce rigid strata within the enterprise, with professional workers setting themselves apart from those with lesser credentials. In part, this reflects the character of the educational training, which is too broad to encourage a sense of occupational solidarity or to produce real functional specialization. It is also rooted in the nature of the labor market. New hires with this relatively broad training are recruited directly into the enterprise from the university and then trained and promoted from within. There is relatively little lateral mobility between firms by technical personnel.

Within the firm, technical workers are not sharply distinguished from managers or production workers. Engineers are routinely given experience in production jobs early on in their careers and a high percentage of engineers are concentrated in production functions (rather than research and development) where they have direct contact with manual workers. At the same time, there is no "glass ceiling" for technical workers. On the contrary, the internal

labor markets within firms are constructed so that many engineers can look forward to promotion into managerial positions.

As might be expected, this form of technical organization is not characterized by the development of strong, occupationally based organizations. Instead, because engineers are encouraged to identify with the firm and with all of the employees within it, this system is most compatible with firm-specific organizations that group together a wide variety of occupations.

DISCUSSION

If we turn from the abstract models sketched out in the preceding pages to a consideration of actual historical cases, we find that none of the models exists in pure form in reality. However, when we apply these models to an analysis of actual societies, we learn a great deal about the central tendencies of their systems for organizing technical workers.

Great Britain has been most strongly influenced by the craft model. In part because Britain was the first case of industrialization and faced no real industrial competitor, the British state played a relatively small role in the industrialization process. In particular, there was little of the kind of conscious effort to build up technical education as a way of "catching up" with more advanced competitors that was typical of later industrializers (Ahlström, 1982). The state's limited role was also the result of the British industrial class's "liberal" hostility to government, which was viewed as aristocratic and backward. This, combined with the fact that the industrial sector was dominated by small, entrepreneurial firms, encouraged the production of technical workers outside of formal educational institutions through a craft-like apprenticeship system. Hand in hand with this, technical workers have historically had a relatively low status in Great Britain; technical work was seen as a kind of extension of manual labor and, thus, not something best taught within the universities or something to which members of the upper classes should aspire. In contrast to their equivalents in most other industrial capitalist societies, British engineers have had limited access to managerial careers (Whalley, 1986). From the outset, they were not seen as part of management; if anything, they were pushed closer to the labor movement than in most industrialized societies (Buchanan, 1986; Lawrence, 1992; Meiksins & Smith, 1992).

As industry has become more technically complex, the craft model has become increasingly antiquated. Although business hostility to the state and to the suspect universities slowed the transition, there is no doubt that, by the 1960s, engineers were more and more likely to be trained in rapidly expand-

ing university programs and the old system of apprenticeship had begun to atrophy. Nevertheless, their low status and a tendency toward union organization has persisted. British engineers continue to opt for union rather than professional or other types of organization. Indeed, professional organizations may have weakened in recent years, as their traditional function as a gatekeeper for apprenticeships atrophied. In the most recent period, moreover, British engineers have shifted toward more comprehensive general unions (rather than craft unions), although it should be added that this has not eliminated a sense of elitism and of difference among technical workers. The legacy of the craft system of organizing technical work, with its tendency to treat engineers as manual labor, has been this preference for unions and a social position for technical workers closer to labor than to management (Meiksins & Smith, 1992; Smith, 1987).

The case of the United States, by contrast, exemplifies many of the features of the managerial model. Although there was an early struggle between craftlike "shop" methods and school methods for producing engineers (Calvert, 1967), this was quickly resolved in favor of university training for most engineers. With the dramatic growth of giant, science-based corporations in the late 19th century, business demand for engineering labor expanded rapidly. At the same time, American industrialists, although also "liberal" when it came to state intervention, had little to fear from legislation such as the Morrill Act, which underwrote the creation of university engineering programs across the United States. On the contrary, perhaps more than in any other country, business proved able to shape legislation governing engineering education and to exert direct influence over the content and character of university engineering programs. Since the late 19th century, most American engineers have been trained in university-based engineering schools that, in addition to more technical training, have emphasized socializing engineering students into their future role as part of management (Noble, 1977). This managerial definition of technical work has been buttressed by engineers' career structures, which include relatively good access to management positions (Zussman, 1985). Despite the suggestion that the professionalization of management may reduce this traditional mobility pattern, engineer-managers (often with MBAs) continue to be a common feature of American industrial corporations (see Markusen & Yudken, 1992; Zussman, 1985).[2]

American engineers have generally organized themselves into professional associations; but these associations are, in fact, quite different from their counterparts in a "true" profession such as medicine. Most important, these organizations have never restricted membership to the holders of specific university credentials and have traditionally opposed efforts at manda-

tory licensing for engineers. There have been attempts to create something like classical professional forms for engineers and to use these forms to develop an explicit distinction between the engineer and management.[3] However, these have invariably failed, in part because of the presence within engineering organizations of engineer-businessmen who opposed such attempts (fearing that they might exclude managers and would raise the cost of engineering labor). Although the effort to equate engineers with management has never been completely successful, and the tension between high-level engineer-managers and rank-and-file engineers has flared up on a regular basis, it has been strong enough to block the development of truly professional forms of organization (Layton, 1986; Meiksins, 1988).

The weakness of professional organization in the United States has left the door open for occasional experiments with unionization, or at least union-like organization. This has been particularly true in hard times, when rank-and-file engineers grew discouraged by the inactivity and lack of independence characteristic of their professional representatives. These efforts have been significantly less successful than those in Great Britain, reflecting a number of factors, including the higher status (as part of management) of American engineers. It is also significant, indeed ironic, that engineer-businessmen, who have often led the effort to block professional organization among engineers, have deployed the rhetoric of professionalism in their efforts to head off engineering unionism—engineering leaders have always contended that such unions were unprofessional (Meiksins & Smith, 1992).

Germany exhibits many of the features of what we have called the estate model of technical organization. However, a closer examination reveals that the estate system is combined with, and may be giving way to, a system much more like the managerial model. The German system has been profoundly influenced by the fact that Germany was a late industrializer (Ahlström, 1982). Faced with the reality of catching up with Great Britain, the German state became actively involved in encouraging industrialization, in part through the creation of a network of formal institutions of technical education. The result was the early triumph of a school-based system for training engineers. This development took place, however, in a society still deeply influenced by a status system inherited from the preindustrial order. Consequently, engineering leaders sought to raise the status of engineers (which was lower than that of university graduates) by emulating the behavior of classically educated, theoretically inclined civil servants and professionals. Early engineering education, thus, emphasized abstract scientific principles and the production of cultivated men (Gispen, 1989; Jarausch, 1990).

As German industry emerged and grew, and as industrialists gained in strength and confidence, the emphasis on science and abstraction in German

technical education was called into question. Industrialists complained that engineers were in short supply and that those whom they could find lacked practical skills appropriate to industry. The result was the creation, by the early 20th century, of a second tier of technical schools, below the original Technische Hochschulen, which soon began turning out large numbers of more practically trained engineers (Gispen, 1989).

On the surface, at least, this created a hierarchy of technical labor in Germany. At the top were the graduates of the Technische Hochschulen, below them were the graduates of the lesser technical schools, and below them technical workers without formal credentials. To an extent, at least, a higher credential increased one's chances of achieving a higher position in the industrial hierarchy. In practice, however, this estate system has always been imperfect. Employers historically resisted attempts to restrict high positions and the title engineer to the graduates of the Technische Hochschulen. Tensions between the various kinds of graduates have often run high, especially when bad times created resentment of the elite's privileged economic and social position. And, in recent years, partly as a result of external pressure from the European Economic Community (EEC), the two types of graduate have tended to blur together (although the different degrees remain and mobility chances are not identical) (Gispen, in press; Hutton & Lawrence, 1981; Lawrence, 1992).

Attempts at creating a true professional association, limited to those with specific credentials, failed in the early 20th century and had virtually disappeared by the 1930s. The most lasting organization of German engineers is the Verein Deutscher Ingenieurs (VDI), which is an American-style engineering association bringing together engineers of all ranks and qualifications. Also, as in the United States, German engineers have experimented with unionization, especially in bad times when their weak professional associations failed them (Gispen, in press). However, it is probably true that the tendency toward union organization is stronger in Germany, in part because of the greater legitimacy of unionism as a whole.[4] This may also reflect the more explicit stratification of German engineering. It may encourage those with lesser qualifications to see unions as appropriate; in any case, it is more difficult for elite engineers to appeal to their minors in the name of an allegedly shared set of professional characteristics when the technical work force is more explicitly stratified.

A similar pattern of engineering stratification developed in Sweden, although here the estate system seems to have eroded less. Many engineers have only a gymnasium-level education. These engineers are much more likely to be in lower-level, routine jobs; indeed, there is evidence that some of them are employed in what have traditionally been manual jobs. As a

result, such engineers have been the backbone of engineering unionism since the 1930s (Amark, 1990); although few of them join the largely manual Confederation of Labor Unions (LO) trade union federation, they are most likely to be affiliated to white-collar Confederation of Industrial Employees (SIF) unions. Because SIF and LO cooperate on many issues, it is apparent that there is not a clear sense of conflict between lower-level engineers and production workers in Sweden. Those engineers with university degrees, which in Sweden tends to mean a master's-level qualification, typically have higher positions and better access to managerial careers. Like their German counterparts, such engineers traditionally gravitated toward professional associations, but in the period since World War II, many have joined a union, the Association of Civil Engineers, which is an affiliate of the Confederation of Academically Educated Employees. This does not mean that the divisions within Swedish engineering are disappearing, however, as these unions represent a clear rejection of the SIF and LO and, indeed, were established and grew largely in response to the fear by educated workers that they were losing ground as unionized workers made gains (Berner, in press).

The greater stability of the estate model in Sweden reflects distinctively Swedish conditions. Even more than Germany, Sweden industrialized late, and the demand for engineers grew very slowly until the World War II era. As a result, there were no German-style shortages of engineers in the late 19th century (Gispen, 1989) and there was probably less pressure on the educational system to expand the production of technical workers for industry. Moreover, the establishment in the 1930s of the Swedish welfare state, with its characteristic class compromises, tended to limit the potential for conflict over technical work in the postwar period (Berner, in press). In particular, the Swedish government has shown a willingness to try to forecast the demand for technical (and other professional) labor and to work with engineering organizations to try to regulate production accordingly (Amark, 1990). Given relatively secure employment and salaries for all technical workers, elite technical workers did not have to fear the expansion of the technical work force. There was little basis for resentment and competition between different strata of technical workers. As a result, there was no need for an aggressive move toward formal professionalization to limit numbers and establish full occupational closure. This, in turn, blunted any desire by employers to attack the effective stratification of technical labor, because the Swedish version of the estate model did not prevent the expansion of the technical labor force when this became necessary.

The case of France also presents features of the estate model, especially the stratification of the technical work force by credentials. France developed a formal program of technical education early in the 19th century, with the

creation of the École Polytechnique and, slightly later, the École Centrale. Influenced by aristocratic ideals and by the philosophies of Comte and Saint-Simon, these schools placed enormous emphasis on abstract principles and theory and were intended to train an elite of civil servants and managers (Ahlström, 1982; Crawford, in press; Weiss, 1982). This left French industry without a source of practical engineers; faced with the state's lack of concern, private interests created the École des Arts et Métiers in the 1830s. This school had a somewhat tenuous position for much of its early history, only winning the right to confer engineering diplomas late in the 19th century. Its graduates functioned as engineers and middle managers, but lacked prestige because of their association with manufacturing (Day, 1987). Finally, the post-World War II French government, concerned to "modernize" French industry, sought to increase the production of qualified engineers through the creation of the so-called *petites écoles*, a move that was resisted by many engineers, concerned that their credentials would become less valuable (Crawford, 1989, in press). Thus a distinct hierarchy of credentials has emerged within French engineering. Added to this is the fact that it has traditionally been possible to become an engineer in France without a formal degree. These so-called *ingénieurs autodidactes* are often recruited from the shop floor or from the ranks of the *techniciens supérieurs*,[5] although they may have some formal training as well. Their mobility chances are less good than those of engineers with credentials, although they are not formally excluded from managerial positions (Boltanski, 1987; Crawford, 1989).

In short, French engineers are stratified by credentials; there is a rough correspondence between one's level of credentials and the kind of position to which one can aspire (although complete closure does not exist). In this sense, the French system of technical organization is very much an estate system. However, the organization of technical work in France is made more complicated by the existence of the social category of the cadres. This category emerged initially in the 1930s when credentialed engineers and others, squeezed by the depression and threatened by the polarizing class relations of the period, began pressuring the French state into according special legal status to middle-class employees who exercised "responsibility" within the firm (this was granted in the postwar period). Over time, this category has become increasingly amorphous, as ingénieurs autodidactes, some techniciens supérieurs, and others have adopted or been accorded cadre status. To some extent, the category provides a kind of unifying middle-class identity to the various strata of the engineering work force, and thus counteracts the rigidity and fragmentation of the estate system. However, the evidence suggests that its unifying power is not that great, and that the divisions and tensions within the cadre category have become greater rather

than weaker over time (Boltanski, 1987; Crawford, 1989). The salience of the stratified organization of the technical work force is demonstrated by the fact that unionization decreases as one rises through the various levels of the technical hierarchy (Crawford, 1989).

Finally, Japan is most influenced by the dynamics of the corporatist model of technical work. Japanese engineers are trained in universities that, to an extent, tend to create a series of education classes. However, the general character of the education tends to diminish the significance of educational credentials (McCormick, in press). Moreover, several distinctive features of the Japanese political economy have helped to create institutional forms that are designed to break down class barriers in the workplace.

First, as a "late industrializer," Japan borrowed much of its technology from more advanced economies. As Alice Amsden (1989) has pointed out in her analysis of the newly industrialized countries of Southeast Asia, this tends to focus attention on the shop floor, on making the borrowed technology work. Under these circumstances, engineers need to be in close touch with shop floor workers. In Japan, engineers are given direct experience in production jobs and are highly concentrated in production-related jobs. The direct contact with manual labor seems to discourage the development of elitist sentiments among engineers.

This might have been expected to create a British-style craft orientation among Japanese engineers. However, other features of Japanese society have made this unlikely. The famous doctrine of permanent employment provides for the eventual promotion of many engineers into management; thus the social distance between engineers and management is not great. Japan's status as a late industrializer has also played a role, because it has meant a state-led industrialization in which large firms tend to dominate. This, combined with the repression of Japanese labor in the aftermath of World War II (Moore, 1983) has produced a weak labor movement and the predominance of internal rather than external labor markets. It has also helped to promote enterprise unionism, which organizes all classes of workers in a firm into a single "house" union. Like most Japanese employees, engineers have a weak occupational identity; their professional associations are relatively unimportant. Instead, they belong to enterprise unions and thus are linked to other classes of employees and, most important, to the firm. Joining such a union does not imply any antagonism for the employer, as it is normal for an engineer to use a stint as a union officer as a kind of "career move." All in all, the Japanese system seems designed to tie engineers to the firm and to make them see themselves as being on a ladder, close to manual labor but with good prospects of moving up (Kinmoth, 1986; McCormick, in press).

CONCLUSIONS

Clearly, there are significant differences in the way technical work is organized in the major industrial countries. We have attempted to summarize some of these differences in our four models. Technical workers in different countries are trained in different ways, the technical division of labor is structured differently, their relationships with employers and production workers are different, and they develop and join different kinds of organizations. Nor do these differences seem likely to disappear. Despite the decline of the craft model, and the continued evolution of each of the six cases, there remain persistent differences among them. It would be beyond the scope of this article to develop a complete analysis of why these differences have arisen. We can only point briefly to some of the more important factors that have conditioned the organization of technical work.

First, the timing and nature of industrialization have had a great deal to do with shaping the evolution of the technical work force. In particular, later industrializers, because they had to catch up to existing industrial powers, are all characterized by active state involvement in stimulating the development of formal technical education (and a corresponding rejection of exclusive reliance on the craft model). The timing and nature of industrialization has also had other effects. For example, both Japan and Sweden were able to avoid, at least for a while, the most extreme pressures to expand rapidly the production of technical workers. Sweden's demand for engineers grew slowly, thus reducing the tensions we have seen to be common in stratified educational systems. Japan, on the other hand, was able to get by with relatively few engineers because of its ability to make use of "borrowed" technology (McCormick, in press).

Given the importance of the timing of industrialization, it should not surprise us that preindustrial conditions helped shape the evolution of technical work. It is now a commonplace that preindustrial conditions in Japan helped shape the doctrine of permanent employment and the corporatist character of the Japanese firm (Kumazawa & Yamada, 1989); we have seen both of these to be important to the shaping of the technical work force. Preindustrial elites and social relations were influential in the other cases under review as well. For example, in Germany and France, the continued salience of a preindustrial status hierarchy and the strength of preindustrial elites helped give the system of technical education its distinctive character, imposing this on a reluctant, but weak industrial management. In contrast, the stronger British industrial elite rejected formal technical training precisely because they were suspicious of the anti-industrial bias of the university system. Ironically, it seems that the allegedly modern German system of

technical education owes more to preindustrial influences than does the allegedly backward British one (see Anderson, 1964; Meiksins Wood, 1992).

We could add to this list factors such as the strength of the industrial class and its ability to "control" the state (clearly of importance in the American case); ideological factors such as the social status of technology and the prevailing social attitudes to those who worked with it;[6] the relative strength of unionization in society as a whole, which affected engineers' desire to make use of union organization;[7] and the different ways in which countries have sought to emulate perceived "best practices" from abroad.[8] No doubt there are many other factors we have omitted from this brief discussion.

What is undeniable, however, is that the organization of technical labor has been the product of a complex process of struggle among employers, technical workers, the state, manual labor, and preindustrial forces.[9] And, despite the different outcomes and the reality that there are complex, historical reasons for them, there is a recurrent, universal theme in all of these processes that cuts across all of these national variations. In none of the cases described here have technical workers *as a group* developed a distinct occupational community as an intermediate stratum within the enterprise.

In several of the cases we have examined, technical workers have been defined, and have defined themselves, as part of the two main classes within the organization: labor and management. There have been real tensions within this definition, as we will note below. Nevertheless, it is certainly the case in Great Britain, where technical workers have been allocated to labor, and in the United States, where they have been treated as part of management. In each of these cases, there exists a kind of community of technical workers, but *not* entirely distinct from the main classes within the organization. Japanese technical workers, in contrast, lack strong occupational identity; corporatist organization in Japan has effectively discouraged this. In none of these cases are engineers constituted as a distinct, intermediate occupational group.

To be sure, there *have* been attempts in some of our cases to achieve something like this, through the process of professionalization. But these attempts have met with strong resistance (especially from employers), and have generally been defeated or at least significantly weakened. Thus, as we have seen, even in those countries most strongly influenced by the estate model, nothing like the strong professional associations or effective occupational closure characterizing the classical professions has emerged. When one turns to the Anglo-American world, supposedly the stronghold of engineering professionalism (Child, Fores, Glover, & Lawrence, 1983), its "failure" becomes even more apparent. In Britain, the strength of the craft model and the low status of engineers indicate the weakness of professional forms.

And although the United States makes more use of the rhetoric and forms of professionalization, the resistance to closure has been consistent and effective. If anything, the rhetoric of professionalism has been used as a form of social control of engineers, not as a means for empowering them.[10] Although some American engineers have favored the latter, as the early 20th-century "revolt of the engineers" indicated, efforts to achieve this kind of professional power have been consistently defeated (Layton, 1986; Meiksins, 1988).

In short, engineering professionalism has proven to be incompatible with all of the versions of industrial capitalism under review. What this reveals is the predicament of qualified, educated labor in the industrial capitalist enterprise. Contrary to some of the cruder versions of the "deskilling" thesis, qualified workers have not disappeared under advanced capitalist conditions. On the contrary, the capitalist firm has continued to spawn a wide variety of jobs for educated labor. Yet, despite the arguments of revisionist students of this type of labor, such workers have been able to sustain little more than a shell of professional forms.[11]

In many ways, classical professionalism is revealed as a preindustrial capitalist vestige. Occupations such as medicine, which were able to carve out an arena of practice sheltered from direct control by the capitalist enterprise (even if this meant working for organizations such as nonprofit hospitals) were able, for a time at least, to maintain professional forms. But for technical workers, whose work placed them in the heart of the capitalist enterprise, there is no shelter from capitalist dynamics. Professional aspirations might live on and even achieve a degree of temporary success where, as in Germany, precapitalist institutions and classes remained strong. But even these "projects" could not be sustained; the needs of industrial employers proved incompatible with the restrictions imposed by professional organization.[12] If engineers were to succeed in the classic professional project (i.e., if they were to develop exclusive claim to a "jurisdiction," to develop control over entry into the profession, to claim effectively the right to police themselves, to develop strong, unified professional institutions), employers would find themselves in an untenable situation. The professionalization of engineering would mean that a class of employees on whom employers depend for the day-to-day functioning of the firm, to whom they are obliged to delegate a degree of responsibility, would become extremely expensive, scarce, and difficult to control.

Technical workers, thus, find themselves in a peculiar, contradictory position. They are "in the middle" of the capitalist firm, between capital and labor, and they bear a superficial resemblance (as ostensibly middle-class, educated people) to classical professionals such as doctors. Yet, as we have seen, their situation is not compatible with real professional organization,

which would constitute them as a distinct, intermediate stratum. The result is that they are constantly torn between the two opposing classes within the enterprise, constantly forced to decide whether they are labor or management. And whether they persist in seeking to define themselves as an intermediate group, as professionals, or whether they choose to side with (or are allocated to) one class or another, the tension built into their intermediate position generates persistent instability and conflict. Consider the internal contradictions of each of the four models of technical organization we have discussed.

Craft organization, as illustrated by the British case, has encountered several basic difficulties. First, it has proven impossible to sustain this system of producing technical workers in an era of complex technology. Perhaps more important, the consequence of this mode of organizing technical work is to treat engineers like workers and to encourage both trade unionism and a clear sense of difference from management. Yet, despite their "attraction" to the labor movement, technical workers' "superior" role and qualifications tend to create tension between them and less qualified employees.

Managerial-professional organization, as illustrated by the American case, also produces distinctive tensions. Because it encourages a sense of elitism among engineers, it tends to maximize the degree of conflict between them and production workers; engineers seek to control blue-collar workers, whereas the latter, with some justice, see the engineer as an integral part of the system of corporate authority. Indeed, David Noble (1984) has argued that this gap may be growing wider in some branches of American industry as new control-oriented computerized machine tool technology eliminates the need for personal contact between engineers and machinists.[13] Moreover, this model is plagued by internal conflict among engineers. It is difficult to sustain the central premise of this model, that is, that *all* engineers are managers. Lower-status engineers are constantly reminded of the differences between them and engineer-executives. Even recent efforts to overcome this within high-technology companies through an emphasis on corporate culture have not succeeded in overcoming professional employees' skepticism about the claim that there is no meaningful stratification within the enterprise (Kunda, 1992). This becomes the basis for internal conflict, as rank-and-file engineers have shown a willingness to organize more effective professional bodies and even, occasionally, unions, which might be able to improve their material and social status. Engineering employers, realizing that an effective professional organization for engineers would make technical work very expensive and more difficult to control, have traditionally led the opposition to mechanisms for developing professional closure.

The estate model also has internal contradictions. As we have already seen, the technical elite's desire to achieve closure and occupational control typically founders on employers' need to obtain a plentiful supply of appropriately trained, relatively inexpensive technical workers. The only partial exception is Sweden, where the welfare state has tempered this kind of class conflict. However, even here, the partial rollback of the welfare state in the 1980s seems to be intensifying the latent conflicts among management and different strata of the work force (Berner, in press). It should be added that the estate model has the disadvantage of drawing clear lines of stratification. The result is the absence of a unifying community of technical workers. Many of the lower and middling technical workers, freed of ties to elite colleagues, find it easy and logical to unionize. In all of the cases influenced by estate organization, there have been historical periods, particularly when times are tough and economic reorganization is taking place, when the various technical strata have become quarreling or even warring groups. Estate-professional systems, thus, make apparent the disunity of the class of technical workers and have shown a tendency to foster a kind of class conflict *within* engineering.

The corporatist form of organization, as exemplified by Japan, appears to be the most stable, harmonious system of all. However, it too has its contradictions. First, it may reflect Japanese backwardness, that is, their development on the basis of borrowed technology. Having caught up, can the Japanese become technologically innovative (which would mean more emphasis on research and development engineering) while maintaining their emphasis on production, their broad educational system, and their low levels of specialization? They may have to widen the gap between engineers and workers to achieve innovation, or settle in as a second-rate industrial power. (Or, at least, if they manage to sustain their "borrowing" by simply buying innovations developed elsewhere, it would appear that Japan's model cannot be generalized. Someone has to come up with the innovations that the Japanese system does not generate.)

Probably most important, can the model be sustained? The Japanese economy experienced a well-documented slowdown in the 1970s and 1980s. What happens to all of those engineers who were promised promotions when firms experience slower growth? If the economy requires greater creativity, can a firm continue to carry significant quantities of "deadwood" under the permanent employment doctrine? There is already evidence of a tendency by some Japanese employers to shed some of their less productive, older employees. If this becomes more common, as it is likely to do, it will be difficult to sustain the corporatist principles that have sustained the Japanese model (Kumazawa & Yamada, 1989).

None of these models, then, are able to do away with the dynamic, contradictory position of technical labor. Technical workers are in the middle of a hierarchically organized capitalist enterprise, but its dichotomous, polarizing tendencies will not allow them to stake out a middle ground. Technical workers are in the middle, but the middle will not hold.

The lesson of comparative analysis of technical labor is that the question of how these polarizing tendencies work themselves out, of where the "class lines are drawn," is to some extent historical, with different outcomes possible. Technical workers, at times, identify with management, at times with labor. More often than not, the class divide seems to run right through the technical labor force itself. But what is most important is that none of these solutions are stable or correct. Each has a tendency to come undone, as we have seen. In a sense, the conflict between labor and capital is being fought out *through technical workers*. It is hardly likely that so dynamic a relationship could be stabilized by a "correct" form of organization. It is also unlikely that it would take the same forms in different times and places.

NOTES

1. A full analysis of the evolution of the division of labor and of the related rise of technical labor is far beyond the scope of this article. For discussions of the processes involved, see Braverman (1974) and Carchedi (1977). An application of some of these authors' ideas to the case of engineers can be found in Meiksins (1982).

2. Markusen and Yudken (1992) note that this is particularly true in defence industries, which employ a significant percentage of American engineers.

3. For example, a group of "patrician insurgents" sought to persuade engineers to weaken their links to corporate management and to emulate the American Medical Association and other classical professional organizations in the early 1920s. This movement was defeated, in part because of managerial resistance from within the engineering community (Meiksins, 1988). More recently, during the Vietnam War era controversy, efforts by engineering reformers to develop strong codes of ethics and to encourage professional rather than managerial identity among engineers did not significantly alter the major professional associations' traditional stance (McMahon, 1984; Meiksins, 1992).

4. See Meiksins and Smith (1992) for a discussion of the weakness of engineering unionism in the United States and its relationship to the overall weakness of the American labor movement.

5. *Techniciens supériéurs* are not equivalent to American technicians. They typically have 2 years of formal training after the bachelor's degree, and often are given supervisory responsibility (Crawford, 1989).

6. Lawrence (1992) and Ahlström (1982), among others, argue that the high status of technology in Germany helped strengthen the position of German engineers. However, see Gispen (1989).

7. See Meiksins and Smith (1992) for an extended discussion of this factor and its effect on American and British technical workers.

8. For a discussion of this kind of emulation, and a general model of cross-national analysis, see Smith and Meiksins (1991).

9. Burrage, Jarausch, and Siegrist (1990) correctly point out that countries with similar economies (e.g., industrialized countries) can have very different forms of professional organization. Although broad economic forces may affect the development of the professions, the key to understanding national variations lies in exploring the interaction among professionals, clients, other professions and, above all, the state. Our analysis suggests that this is too narrow a focus for an attempt to explain the sources of national diversity in the organization of technical work. Our approach involves placing the development of technical labor in the context both of the development of industrial capitalism and of a *variety* of specific historical forces (including patterns of class relations, national economic histories *and* state policy). For a full statement of this argument, see Smith and Meiksins (1991).

10. We have already noted that a rhetorical form of professionalism has been deployed by opponents of engineering unionism. See Meiksins and Smith (1992) for a more extended discussion. Others have argued that professionalism has been used by employers as a way of containing the frustrated career aspirations of engineers who have hit "glass ceilings" in the workplace. See Goldner and Ritti (1967).

11. Andrew Abbott (1988, pp. 150-156) argues that organizational employment for engineers is not incompatible with professionalization. As organizational employees, engineers' struggle for jurisdiction becomes centered on the workplace, rather than the public sphere, professional associations become less salient, and professionalism becomes more inclusive and less focused on rigid boundary demarcation. Torstendahl (1982) contends that, in Sweden, professionalism and bureaucratization arose simultaneously. We do not deny that bureaucratic employment and professional rhetoric coincided in many cases. However, there is a difference between the form and the content of professionalism. It is one thing to call oneself (or be called) a professional; it is quite another to translate this into effective occupational closure and control.

12. Elliott Krause (1991) has argued that professions are, in effect, continuations of "guild" controls. Our comments on the precapitalist character of professionalism are consistent with his view.

13. Ironically, it may be that this emphasis on engineering as control may be turned against the engineering profession. There is some evidence that new computer-aided design (CAD)/ computer-aided manufacturing (CAM) technologies may have the effect of controlling some kinds of engineering work. A full analysis of the effects of new technology on engineers is beyond the scope of this article. For a discussion of some of the issues involved, see Smith (1987).

REFERENCES

Abbott, A. (1988). *The system of professions*. Chicago: University of Chicago Press.

Ahlström, G. (1982). *Engineers and industrial growth*. London: Croom Helm.

Amark, K. (1990). Open cartels and social closures: Professional strategies in Sweden, 1860-1950. In M. Burrage & R. Torstendahl (Eds.), *Professions in theory and history: Rethinking the study of the professions* (pp. 94-114). London: Sage.

Amsden, A. (1989). Third World industrialization: "Global Fordism" or a new model? *New Left Review, 182*, 5-31.

Anderson, P. (1964). The origins of the present crisis. *New Left Review, 23*, 30-51.

Berner, B. (in press). Professional or wage worker? Engineers and economic transformation in Sweden. In C. Smith & P. Meiksins (Eds.), *Engineering class politics*. London: Verso.

Boltanski, L. (1987). *The making of a class: Cadres in French society*. Cambridge: Cambridge University Press.

Braverman, H. (1974). *Labor and monopoly capital*. New York: Monthly Review.

Buchanan, A. (1986). Education or training? The dilemma of British engineering in the 19th century. In M. Kranzberg (Ed.), *Technological education—Technological style* (pp. 69-73). San Francisco: San Francisco Press.

Burrage, M., Jarausch K., & Siegrist, H. (1990). An actor-based framework for the study of the professions. In M. Burrage & R. Torstendahl (Eds.), *Professions in theory and history: Rethinking the study of the professions* (pp. 203-225). London: Sage.

Calvert, M. (1967). *The mechanical engineer in America, 1830-1910*. Baltimore: Johns Hopkins University Press.

Carchedi, G. (1977). *On the economic identification of social classes*. London: Routledge Direct Editions.

Child, J., Fores, M., Glover, I., & Lawrence, P. (1983). A price to pay? Professionalism and work organization in Britain and West Germany. *Sociology, 17*, 63-78.

Crawford, S. (1989). *Technical workers in an advanced society*. Cambridge: Cambridge University Press.

Crawford, S. (in press). The making of the French engineer. In C. Smith & P. Meiksins (Eds.), *Engineering class politics*. London: Verso.

Day, C. R. (1987). *Education for the industrial world: The École des Arts et Métiers and the rise of French industrial engineering*. Cambridge, MA: MIT Press.

Gispen, K. (1989). *New profession, old order: Engineers and German society, 1815-1914*. Cambridge: Cambridge University Press.

Gispen, K. (in press). The long quest for professional identity: German engineers in historical perspective. In C. Smith & P. Meiksins (Eds.), *Engineering class politics*. London: Verso.

Goldner, F., & Ritti, R. R. (1967). Professionalization as career immobility. *American Journal of Sociology, 72*, 489-502.

Halliday, T. (1983). Professions, class and capitalism. *Archives Européenes de Sociologie, 24*, 321-346.

Hutton, S., & Lawrence, P. (1981). *German engineers: The anatomy of a profession*. Oxford: Clarendon.

Jarausch, K. (1990). The German professions in history and theory. In G. Cocks & K. Jarausch (Eds.), *German professions, 1800-1950* (pp. 9-24). New York: Oxford University Press.

Kinmoth, E. (1986). Engineering education and its rewards in the United States and Japan. *Comparative Education Review, 30*, 396-416.

Krause, E. (1991, August). Doctors, states and capitalism: Theoretical and research issues. Paper presented at the American Sociological Association Meeting, Cincinnati, OH.

Kumazawa, M., & Yamada, J. (1989). Jobs and skills under the lifelong Nenko employment practice. In S. Wood (Ed.), *The transformation of work*. London: Unwin Hyman.

Kunda, G. (1992). *Engineering culture: Control and commitment in a high-tech corporation*. Philadelphia, PA: Temple University Press.

Larson, M. S. (1977). *The rise of professionalism: A sociological analysis*. Berkeley: University of California Press.

Lawrence, P. A. (1992). Engineering and management in West Germany: A study in consistency? In G. Lee & C. Smith (Eds.), *Engineers and management: International comparisons* (pp. 72-99). London: Routledge.

Layton, E. T., Jr. (1986). The revolt of the engineers. Baltimore: Johns Hopkins University Press.

Markusen, A., & Yudken, J. (1992). *Dismantling the cold war economy*. New York: Basic Books.

McCormick, K. (in press). Japanese engineers as corporate salary men. In C. Smith & P. Meiksins (Eds.), *Engineering class politics*. London: Verso.

McMahon, A. M. (1984). *The making of a profession: A century of electrical engineering in America*. New York: IEEE Press.

Meiksins, P. (1982, August). Science in the labor process: Engineers as workers. In C. Derber (Ed.), *Professionals as workers* (pp. 121-140). Boston, MA: G. K. Hall.

Meiksins, P. (1988). The revolt of the engineers reconsidered. *Technology and Culture, 24*, 219-46.

Meiksins, P. (1992). Professional ethics and professional segmentation: The material basis of engineering protest in the era of the Vietnam War. Paper presented to the ASA Meetings, Pittsburgh, PA.

Meiksins, P., & Smith, C. (1992). Why American engineers aren't unionized: A comparative perspective. *Theory and Society, 22*, 57-97.

Meiksins Wood, E. (1992). *The pristine culture of capitalism: A historical essay on old regimes and modern states*. London: Verso.

Moore, J. (1983). *Japanese workers and the struggle for power, 1945-1947*. Madison: University of Wisconsin Press.

Noble, D. F. (1977). *America by design*. New York: Alfred A. Knopf.

Noble, D. F. (1984). *Forces of production: A social history of industrial automation*. New York: Alfred A. Knopf.

Perrucci, R., & Gerstl, J. (1969). *Profession without community: Engineers in American society*. New York: Random House.

Smith, C. (1987). *Technical workers: Class, labour and trade unionism*. London: Macmillan.

Smith, C., & Meiksins, P. (1991, July). Theories of cross-national organisational analysis: A new explanatory model. Paper presented at the 10th EGOS Colloquium, Vienna, Austria.

Smith, C., & Meiksins, P. (in press). *Engineering class politics*. London: Verso.

Torstendahl, R. (1982). Engineers in industry, 1850-1910: Professional men and new bureaucrats. A comparative perspective. In C. G. Bernhard, E. Crawford, & P. Sörbom (Eds.), *Science, technology and society in the time of Alfred Nobel* (pp. 253-270). Oxford: Pergamon.

Weiss, J. (1982). *The making of technological man: The social origins of French engineering education*. Cambridge, MA: MIT Press.

Whalley, P. (1986). *The social production of technical work*. Albany: SUNY Press.

Zussman, R. (1985). *Mechanics of the middle class*. Berkeley: University of California Press.