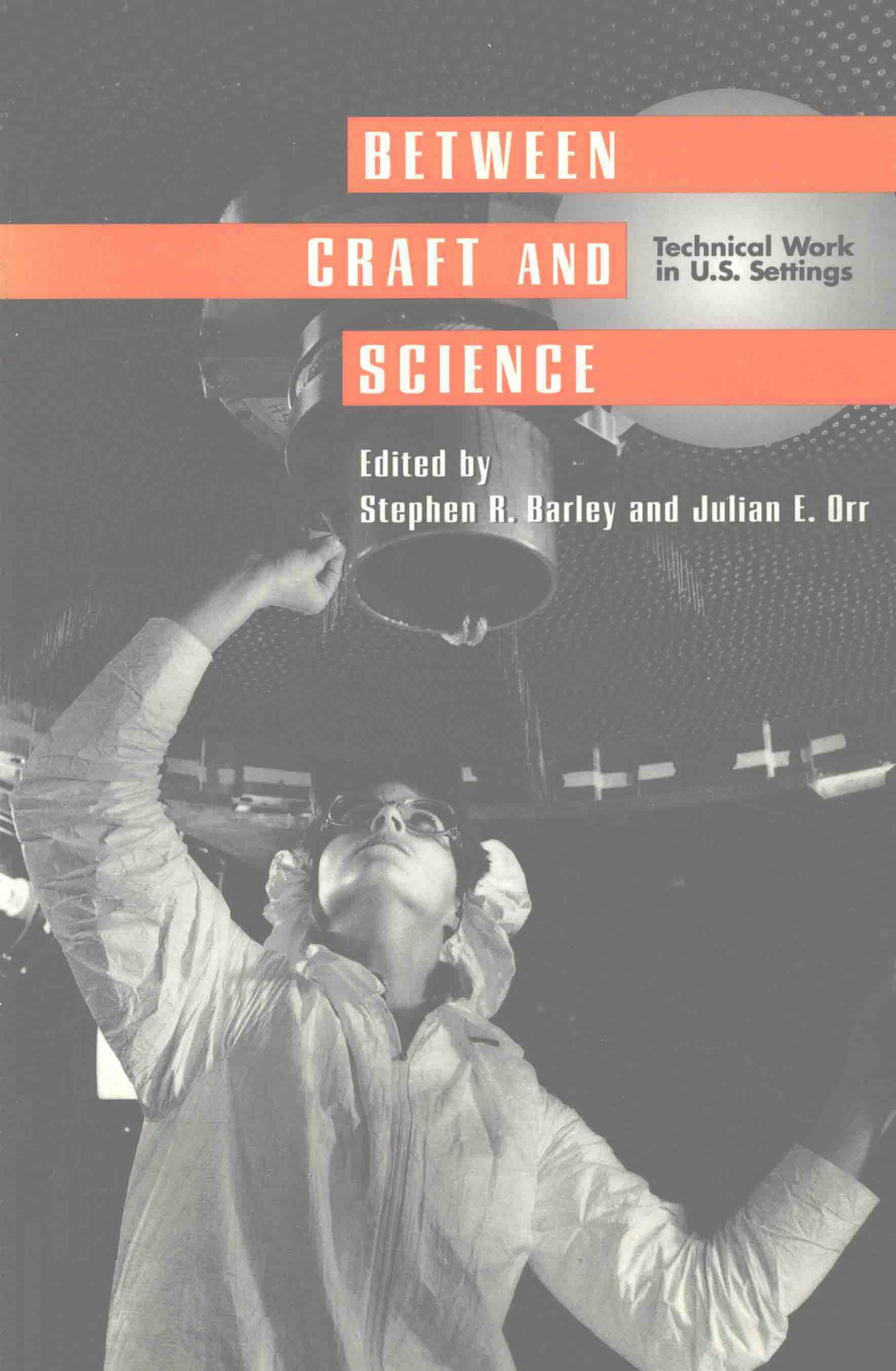
BETWEEN CRAFT AND SCIENCE

Technical Work in U.S. Settings

Edited by
Stephen R. Barley and Julian E. Orr



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PREFACE

Aside from the work of doctors, lawyers, and a handful of other visible professionals, relatively little is known about the content or the social organization of technical work. To be sure, science and engineering have attracted considerable attention over the years, but only recently have researchers begun to examine what scientists and engineers actually do and how their work is organized. Information on the work of technicians is even scarcer, although technicians now represent 3.6 percent of the American labor force and have been the fastest growing occupational category for several decades. The chapters in this book take a step toward remedying this situation.

Books are usually accretions of personal agendas, and this one is no exception. After studying technicians' work in several settings, we became convinced that the implications of the so-called shift to a postindustrial or service economy could not be fully understood without an appreciation of the expanding role that technical workers play in modern organizations. We thought progress toward such an understanding would be enhanced if researchers interested in technical work had an opportunity to pool their knowledge and lay the foundations of a research community. Although a small but growing number of scholars had become interested in technical work by the late 1980s, our perception was that many were unaware of each other's research because they spanned disciplines as diverse as sociology, anthropology, psychology, economics, engineering, and labor relations. We decided to remedy this situation. In 1991, under the auspices of the Program on Technology and Work at Cornell University's School of Industrial and Labor Relations, we embarked on the events that produced this volume.

In November 1992, with funding from the Department of Labor and Cornell's Institute for Labor Market Policy, we hosted a workshop at Cornell University on the technical labor force. The workshop brought together sixteen scholars from a variety of disciplines who had conducted field studies of technical work, but who were mostly unfamiliar with each other's findings. In addition to most of the authors whose chapters appear in this volume, Charles Goodwin, an anthropologist from the University of South Carolina, and Patricia Sachs, an anthropologist employed by NYNEX, also attended. The workshop's goals were to facilitate the sharing of information and ideas, to arrive at a working definition of technical work, to identify issues that all participants considered critical for future development, to facilitate collaboration, and, finally, to lay the foundation for this book and a second, somewhat larger, conference. During the workshop, the participants converged on a series of topics that they agreed deserved further elaboration. They then divided responsibility for developing papers on these topics. The commissioned papers clustered around four broad themes: (1) technical work's challenge to the established order, (2) detailed studies of technical work, knowledge, and practice, (3) detailed studies of technical workers' identities, values, and beliefs, and (4) training, credentialling, and careers in technical occupations. The goal was to develop papers that ranged coherently from the theoretical to the descriptive to the policy-oriented. This volume retains the organizational scheme developed at the workshop.

Between December 1992 and March 1994 the authors conducted additional research and produced initial drafts. These drafts were delivered at Cornell in March 1994 during a conference sponsored by the Alfred P. Sloan Foundation. The conference brought the authors together for three days with an audience composed of other researchers who have studied technical work as well as leaders from industry, labor, and government who are especially knowledgeable about issues pertaining to technical work and the technical labor force. After the conference, authors revised their papers in light of the dialogue that occurred.

This volume would not have been possible without the financial and intellectual support of Hirsch Cohen at the Alfred P. Sloan Foundation, Stephanie Swirsky of the Department of Labor's Employment and Training Administration, and Ronald Ehrenberg, Director of the Institute for Labor Market Policy. The researchers and organizers associated with Cornell's Program on Technology and Work are also deeply indebted to the U.S. Department of Education which, from the beginning, has funded our work on technicians through grants from the National Center for the Educational Quality of the Workforce.

Thanks are also due to Stacia Zabusky and Margaret Gleason, who organized the first workshop, to Renee Edelman, who orchestrated the conference, and to Paula Wright and Roger Kovalchick, who helped transform the papers into a single, integrated document.

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INTRODUCTION: THE NEGLECTED WORKFORCE

Stephen R. Barley and Julian E. Orr

THE CHANGING NATURE OF WORK

Work forms the bedrock of all economic systems. When the nature and social organization of work change, so does the fabric of society. On this dictum, Marx, Weber, Durkheim, and Tönnies anchored their analyses of the social transformation we now call the Industrial Revolution and, in the process, gave intellectual direction to the fledgling field of sociology. The Industrial Revolution transformed work in Western society in two related but analytically distinct ways. First and most obvious, it occasioned a massive shift in what people did for a living. Over the course of the nineteenth and early twentieth centuries, the balance of employment in every Western nation shifted from agriculture to manufacturing. Possibly more critical for the course of Western culture, however, was the second type of change: the shift in how people did their work, or what Marx referred to as a change in the "mode of production."

Most goods produced and consumed up to the late nineteenth century were not that different from those produced and consumed before the Industrial Revolution. What changed was how goods were made. Prior to the Industrial Revolution, textiles, plows, muskets, glassware, chairs, tables, and most other products were manufactured by hand with simple tools either in the home or in the shops of skilled artisans. The Industrial Revolution brought workers together in larger shops and factories, where propinquity allowed owners to divide tasks into constituent activities and assign those activities to individuals who performed them repeatedly. The advent of interchangeable parts and specialized machine tools furthered the progressive division of labor which, with time, became the distinctive signature of industrialization. By the early decades of the twentieth century, the shift in the nature of work was so far-reaching that "job" had come to mean employment in a vertically structured organization, and craft had been reduced to a secondary means of organizing work (Abbott 1989).

In the late 1960s, a handful of sociologists began to argue from several perspectives that the West was once again embroiled in an economic transformation whose scope would rival that of the Industrial Revolution. Their claim rested, in part, on the observation that the labor force was becoming increasingly white-collar. For Daniel Bell (1973) and other advocates of a "postindustrial economy" (Galbraith 1967; Touraine 1971), the transformation pivoted on the declining importance of manufacturing and the growing centrality of service industries that were heavily populated by "knowledge workers," whose elite consisted of scientists, technicians, and professionals. A number of French Marxists believed they saw in the same trends the rise of a "new working class." Because technical workers controlled the knowledge and technologies on which their expertise rested, Serge Mallet (1975) and André Gorz (1967) argued that the new working class would be more effective than the older working class at resisting the dynamics of capitalism. Still other sociologists argued that professional and technical workers actually represented a "new middle" rather than a "new working" class and that, therefore, their interests were largely aligned with the existing power structure (Poulantzas 1975; Wright 1978). All three schools of thought met with considerable skepticism, in part because each oversimplified the complexity of the changes it observed and in part because each postulated a shift in culture or social structure that was based more on wishful thinking than on evidence. Although the postindustrialists and the neo-Marxists may have overinterpreted the changes they observed, with each passing year it becomes more and more difficult to deny the accuracy of their most central observation: the occupational division of labor is again changing, and it is changing in an apparently consistent direction.

Trends in the United States since mid-century are illustrative. As Table I.1 indicates, even after a century of steady decline, agriculture still employed 12 percent of all Americans in 1950. By 1991, however, agriculture employed a mere 3 percent of the labor force. Considering it alone, one might view the continuing decline in agricultural employment as little more than the completion of a trend begun in the early years of the Industrial Revolution, but concomitant developments suggest a different scenario. During the Industrial Revolution, dwindling agricultural employment was offset by the expansion of semi-skilled and unskilled blue-collar labor and, somewhat later, by the expansion of the clerical and administrative workforce. Since mid-century, however, the number of unskilled and semi-skilled jobs has steadily declined. Whereas 26 percent of all Americans worked as operatives and laborers in 1950, only 15 percent of the workforce were

TABLE I.1
Occupational categories as a percentage of the labor force, 1950–1991

Category	*1950*	*1960*	*1970*	*1980*	*1991*	*Net Change*
Farmworkers	12%	6%	3%	3%	3%	−9%
Professional/Technical	8	10	14	15	17	9
Craft and kindred	14	14	14	12	11	−3
Operatives/Laborers	26	24	23	18	15	−11
Clerical and kindred	12	15	18	17	16	4
Service	11	12	13	13	14	3
Managerial/Administrative	9	8	8	10	13	4
Sales workers	7	7	7	11	12	5

Note: Percentage employment by occupational category from 1950 to 1970 was calculated from employment data presented on page 139 of *The Statistical History of the United States from Colonial Times to the Present* (U.S. Bureau of the Census, 1976). Data for 1980 were taken from Klein's (1984) article which transforms 1980 data using the Census Bureau's category system developed in 1983. Data for 1991 are taken from the *Statistical Abstract of the United States* (U.S. Bureau of Commerce, 1991).

so employed by 1991.[1] Over the same period, the proportion of Americans employed in skilled crafts also declined from 14 to 11 percent. The demise of blue-collar work is hardly news. Less well recognized is that clerical work has also begun to wane. Clerical employment in the United States peaked in 1970 at 18 percent of the workforce. By 1991, the proportion of Americans employed as clerical workers had fallen to 16 percent.

The upshot of these developments, as almost everyone knows, is that work has become increasingly white-collar and oriented to the provision of services. However, as Table I.1 makes clear, the nature of the change is not what many discussions of the service economy imply. For instance, although the proportion of Americans classified as service workers has grown since 1950, the 3 percent increase (from 11 to 14 percent) is actually smaller than the increases shown by all other occupational clusters that grew during the same period. Thus, we submit that if the data in Table I.1 indicate a shift toward a service economy, it does not appear to be an economy dominated by the low-wage, low-skill jobs that the government classifies as service occupations. Instead, Table I.1 suggests that professional and technical jobs are increasing faster than all others and may become the modal form of work for the twenty-first century.

The number of professional and technical jobs in the United States has grown by more than 300 percent since 1950 (see Figure I.1). No other occupational sector has experienced nearly as great a growth rate. Even sales (248 percent) and

1. The decline of unskilled and semi-skilled blue-collar labor actually began after 1940, when the proportion of Americans employed as operatives and laborers peaked at 28 percent of the labor force.

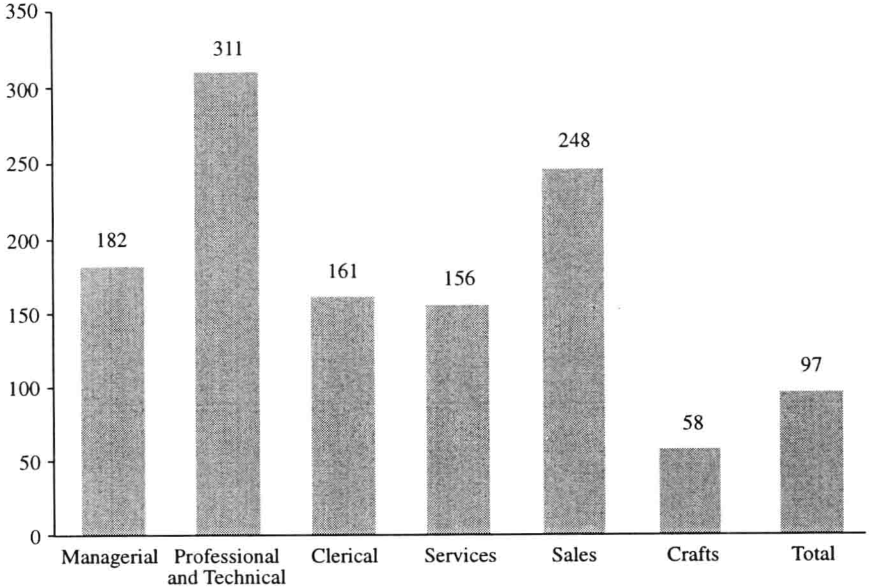

FIGURE I.1
Percentage growth in U.S. occupational categories, 1950–1991

managerial work (182 percent), which expanded tremendously over the last two decades, lag behind the growth of the professional and technical labor force. A quarter of all new jobs currently being created in the United States are either professional or technical in nature (Silvestri and Lucasiewicz 1991). As Table I.1 shows, by 1991 more Americans were found in professional and technical occupations (17 percent) than any other occupational category tracked by the Bureau of the Census. The Bureau of Labor Statistics' most recent employment forecast indicates that professional and technical workers will represent 18 percent of the labor force by 2005 (Silvestri and Lucasiewicz 1991). Similar trends are to be found in employment data from Canada and Great Britain, where professional and technical workers already account for 18 percent and 20 percent of the workforce respectively (Barley 1995).

Sociologists have long criticized aggregate occupational data for a variety of reasons, including the fact that government categories lump together occupations in an analytically naive, if not haphazard, way (Spenner 1980; Miller et al. 1980). This creates the possibility of either overestimating or underestimating the importance of change in any category; however, there is good reason to believe that in the case of professional and technical occupations, classification problems are likely to lead to conservative estimates of growth. Whereas most of the occupations classified as professional or technical by the U.S. government also satisfy sociological and cultural criteria for the label, numerous occupations that the government currently allocates to other categories also have strong technical components. For instance, the census classifies individuals who repair and maintain computers as craftspersons, even though they are typically called technicians in everyday life. Accountants are labeled managers, although sociologists of work and accountants themselves generally consider accounting to be a profession. Computer operators are classified as clerical and kindred workers. A sense of the extent to which census categories may undercount professional and technical workers can be gleaned from the fact that if classified differently, these three lines of work alone would raise the proportion of Americans classified as professionals and technicians by a full percentage point.[2]

If problems of "misclassification" were suddenly resolved, aggregate occupational data would still provide a hazy indicator of the shifting nature of work because, by definition, such schemes are based on job titles. At best, they index changes in what people do, but they are largely insensitive to changes in how people do what they do, unless shifts in technique also lead to changes in occupational nomenclature. Aggregate occupational data, therefore, are generally blind even to systematic changes in the way work is performed. Yet, as we have noted, the Industrial Revolution merits its name not simply because people began to pursue different lines of work, but because people also began to do old lines of work in radically new ways. Although it is difficult to gauge the extent to which qualitative changes are occurring in the nature of work, mounting evidence indicates that such change may be widespread. Moreover, it appears that the change points in a consistent direction, toward what might be called, for lack of a better term, the "technization of work."

By technization, we mean to characterize the emergence of work which is comparatively complex, analytic, and even abstract, because it makes use of tools that generate symbolic representations of physical phenomena and that often mediate between workers and the objects of their work. Controlling a nuclear power plant though an array of computer terminals is one example of such work; manipulating and studying the properties of cells using a cytometer is another. In some cases, technization describes the growth of new occupations. The work of sonographers and CT technicians, for example, arose *de novo* during the 1970s as hospitals added ultrasound and CT scanners to their arsenal of medical imaging devices. In other instances, technization proceeds by transforming existing lines of work. The second process is usually less visible than the first because it

2. Computer and electronics repair employed 0.1 percent of all working Americans in 1991. Another 0.1 percent of the population were employed as computer operators. Accountants represented 0.8 percent of the workforce (Silvestri and Lucasiewicz 1991).

does not change what an occupation is called and because practitioners appear to outsiders to be doing what they have always done, even though they now do it in dramatically different ways. The nature, implications, and potential scope of the second form of technization are most easily illustrated by examples drawn from lines of work that few consider technical: farming and the operation of continuous process plants.

A growing number of dairy farmers are beginning to rely on computer systems to manage their herds (Price 1993). As well as using computers to keep track of a farm's finances, dairy farmers can now monitor their cattle with electronic ear tags that identify individual cows. The tags work in concert with a coordinated system of sensors to generate data on how much milk each cow provides per milking, the rate of flow, how long each milking lasts, and the amount of feed a cow consumes over the course of a day. The data is used to make decisions about the cow's diet. When a cow's milk production falls, the tag issues a warning so the farmer may summon a veterinarian to examine the animal's health. In still other applications, sensors in fields send data on soil moisture and atmospheric humidity to a computer that combines these data with data from recent weather forecasts to control irrigation. Such systems are reputed to save both water and energy while producing healthier crops and more abundant yields (Smith 1984).

Operators in continuous process plants used to rely on sight, sound, smell, taste, and feel in addition to thermometers and pressure gauges to monitor production runs. As Shoshana Zuboff (1988) described in her influential study of pulp paper mills, operators now sit in elevated, air-conditioned control rooms where they monitor and intervene in production using an array of workstations that display and process data collected from hundreds of sensors spread across the factory floor. As a result, the operator's job has become increasingly analytical. Similar control technologies are rapidly altering production in other continuous process plants whose products range from peanut butter to petrochemicals.

ENGINES OF CHANGE

The Growth and Commercialization of Scientific Knowledge

Several interwoven dynamics appear to have occasioned both the technization of work and the expansion of the professional and technical labor force. Of paramount importance has been the harnessing of science for commercial advantage. Over the last century, industry has come to view science as a virtually limitless source of ideas for new products, new production processes, and even new industries. The commercialization of chemistry and physics during the last two decades of the nineteenth and the early decades of the twentieth century gave rise to the industries on which most Western economies now pivot: aerospace, energy, pharmaceuticals, petrochemicals, and electronics. Advances in the life sciences, especially in immunology, microbiology, biophysics, and biochemistry, made possible the expansion of the health care industry after World War II. More recently, molecular biology and computer science have created opportunities for entirely new industries and have revolutionized others.

The growth and commercialization of science has shifted the balance of employment toward technical work in three ways. First, the escalating demand for scientific knowledge, both basic and applied, has translated directly into employment opportunities for scientists, engineers, and other technical professionals. As the chemical and biotechnology industries grew, for example, so did their respective demands for chemists and molecular biologists. The demand for scientific and technical talent has done more than foster employment for members of existing disciplines, however; it has also triggered a proliferation of new fields and occupations. As a technical discipline grows, it becomes increasingly difficult for individuals to master the breadth of knowledge necessary to remain a generalist. Generalists are also less well prepared than specialists to provide "state-of-the-art" services. Consequently, most sciences and professions divide themselves into ever narrower subfields as their knowledge base grows. All else being equal, specialization should increase the number of employed professionals by requiring collaboration. Few specialists can execute alone tasks that require both breadth and depth of experience. Thus, as specialization proceeds, the number of experts necessary to accomplish a complex task, such as rendering a medical diagnosis, burgeons. The growth of scientific knowledge spawned technical work by yet a third path. As fields grow, scientists and professionals tend to allocate more routine duties to somewhat less well trained individuals. As Peter Whalley and Stephen Barley note in Chapter 1, numerous technicians' occupations are rooted in precisely such a "hiving-off" process. Thus, scientific specialization encourages the proliferation of secondary support occupations which are themselves technical.

Technological Change

Another critical factor in the shift to a technical workforce has been technological change. Throughout history, technologies have spawned new occupations: the wheelwright, the blacksmith, the machinist, the automobile mechanic, and the airline pilot are illustrations. In the past, technologies created occupations across the entire division of labor. Although modern technologies have also produced occupations in all strata, those with high technical content appear to have become more common (Adler 1992). The advent of computer technology and the subsequent shift from mechanical to microelectronic devices are largely responsible for the difference.

In 1950, for instance, few people worked with computers and most who did were mathematicians (Pettigrew 1973). By the 1970s, computers had given birth to such well-known occupations as programmer, systems analyst, operations researcher, computer operator, and computer repair technician. These occupations continue to be among the fastest growing. In the United States alone they are anticipated to provide employment for 2.3 million people by the turn of the century, or 1.6 percent of the American labor force.[3] The explosion of occupations directly related to the computer, however, is only the most visible sign that technology may now favor a technical labor force. Numerous technical occupations have been created over the last four decades by technologies other than the computer; nuclear technicians, nuclear medical technicians, broadcast engineers, and materials scientists are examples. Moreover, computers have altered the contours of many traditional jobs.

To grasp how computers have accelerated the technization of existing work, one must distinguish between substitutional and infrastructural technological change (Barley 1991). Most technological change is perceived to be a matter of substitution, replacing an earlier technology with a more efficient or effective successor. However, the simplicity of substitution is usually illusory. Work with a new technology will rarely be done in the same way as it was with its predecessor, and so the changes will necessarily be more complex than is suggested by substitution. Nevertheless, historically, substitute technologies have usually been adopted on the grounds that they make some parts of work easier to perform. Some have also generated considerable profits by reducing labor costs and allowing economies of scale. By comparison, infrastructural change is rare. Infrastructural technologies are the relatively small set of technologies that form the bedrock of a society's system of production during a particular historical era. Until recently, the economies of the industrial nations revolved around electrical power, the electric motor, the internal combustion engine, and the telephone (Coombs 1984). The diffusion of these technologies occasioned the Second Industrial Revolution.

New technologies, even those that alter the infrastructure of production, are initially perceived as substitutes for existing technologies, and microelectronics have been no exception. Early computers were adopted by organizations to streamline personnel, accounting, and other paper processing operations. Similar motives have underwritten the spread of most other digital technologies. Digital sensors, robots, production scheduling systems, and computer-integrated

3. Estimates are based on data from Silvestri and Lucasiewicz's (1991) estimates for a moderate growth scenario.