Chapter 5

The Effects of Programmable Automation on the Work Environment

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Summary

A number of factors determine the impacts of programmable automation (PA) on the work environment, such as how the technologies are designed and applied, the strategies employed to introduce them, and management's goals for automating. In general, the introduction of PA tends to improve the work environment. However, it has the potential to create new situations that are stressful or monotonous, resulting in negative psychological effects on the work force. PA offers a wide range of choices concerning its use—choices that, if made well, will help to ensure that PA is applied in ways that will maximize its potential for affecting the workplace positively.

Nothing inherent in automated technology makes a particular form of work organization ''imperative' PA affords many ways of organizing work and designing jobs. For this reason, it is possible to design and apply technology so that it will enhance, rather than detract from, the work environment, and to search for ways to design jobs that are compatible with both technology and the humanization of work. The search for such compatibility will be complicated by the potential tradeoff between conventional concepts of production efficiency and more complex concepts of worker satisfaction. There is some, but limited, evidence that using PA to organize work in ways that would enhance the work environment would lead to increased overall efficiency and a more motivated work force.

In the firms visited for the OTA work environment case studies, the implementation of PA made some jobs, such as maintenance, more challenging, and some, such as spot welding, less physically taxing. Other jobs, such as operating a numerically controlled (NC) machine, were less challenging when compared with operating conventional machine tools. Some jobs had high levels of stress due to the nature of the equipment (i.e., complex, highly integrated, and expensive), and to the relative lack of worker autonomy in controlling the content and pace of work.

Labor-management relations play an important role in the introduction of new technology. Using collective bargaining, organizing, and political strategies, unions in the United States have attempted to minimize what are perceived to be the socially harmful effects of new technologies on the labor force. Their efforts have generally been directed toward easing the adjustment process rather than retarding the process of change. Japan and many Western European countries rely on a number of government and organized labor mechanisms for dealing with the introduction of new technology and its effects on the workplace.

Introduction

Programmable automation has the potential to enhance the work environment in manufacturing. It will do so if it reduces the need for workers to undertake hazardous or unpleasant tasks and is applied in ways that provide variety and opportunities for decisionmaking in the workplace. As work becomes increasingly automated, it is important to consider the role people will play relative to equipment, and how we as a society will define and oversee that role.

The purpose of this chapter is to describe some of the effects on the manufacturing work environment arising from the introduction and use of PA, and to discuss some of the ways in which workers are likely to be affected—physically and psychologically. The approach is different from that usually taken in discussing PA technologies, their benefits, and their costs. While acknowledging the economic and technical issues surrounding PA development and use, the chapter focuses on the experiences and concerns of the people working with the technologies daily. These concerns seldom emerge in studies of R&D and industry characteristics, but they suggest additional social costs and benefits beyond the more obvious ones associated with changes in the number and types of jobs.

Attention to how PA affects the work environment may gain new urgency in the future due to reduced job mobility in manufacturing. As chapter 4 suggests, workers who are unhappy about their working conditions in the wake of new technology may have less freedom to change jobs because of reductions in production employment, changes in the occupational mix, and other developments constraining job opportunities. If the potential for job mobility decreases, the characteristics of remaining and new manufacturing jobs will become increasingly important, creating new imperatives for developing the potential capabilities of the technology to improve the work environment.

Background

The effects of PA on the manufacturing work environment in the United States must be considered within the context of traditional views of technological change. The apprehension surrounding technological progress and its potential to change the fabric of society is not new. What is different about current attitudes concerning new technology is directly related to its flexibility, its diverse applications, the large numbers of people that will be affected, and the social and political climate in which it is being introduced.

As early as the mid-1850's, America was viewed by Europeans as a country that eagerly and easily embraced technology as a replacement for manual labor. This was in stark contrast to the open resistance to industrial progress experienced in Europe. The American capacity for rapid innovation was variously attributed to such diverse factors as its public education system, a scarcity of labor, its democratic institutions, its utilitarian attitudes, an abundance of natural resources, and the enterprising spirit of its citizens.[1]

However, contrary to this idyllic view of American industrial progress as perceived by foreign visitors, historians record that even in the 1850's, technological change in the United States did not occur without very substantial costs to its citizens. For example, the work lives of skilled craftsmen were changed greatly through adjustment to the new requirements of industrialization, such as increased regimentation and less individuality. Unskilled workers were also affected adversely, since their skills were interchangeable and there were thus fewer opportunities for wage increases and other benefits.[2]

In the late 19th century, the principles of scientific management proposed by Frederick

[1]Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca and London: Cornell University Press, 1977).

[2]Ibid.

W. Taylor attempted to rationalize the production process by determining the "one best way' to do a job. * In addition, these principles helped to form the view that efficiency depends on the degree to which management controls both the production process and the workers. In many manufacturing settings, vestiges of Taylorism still exist in a top-down style of management control characterized by rigidly defined tasks, attempts to minimize errors through increased automation, and minimal worker involvement in workplace decisions.

Today, it is generally recognized that technological developments tend to continually outpace the capacity of individuals and social systems to adapt.[3] This period of adjustment may be characterized by considerable tension between management and labor.

One of the principal benefits of computerized manufacturing technology is that it offers a wide range of choices for system design and implementation. With respect to the problems encountered in earlier technological change, one author commented:

> The changes and disruptions that an evolving technology repeatedly caused in modern life were accepted as givens or inevitable simply because no one bothered to ask whether there were other possibilities.[4]

The very flexibility of PA provides a range of choice, not only in the equipment configuration, but also in the organization and management of production. As stated by a contemporary British researcher:

> We are not compelled to follow the path we have followed so long, of subordinating work to the machine, and fragmenting it, until the best thing we can do with the jobs that remain is to automate them out of existence. We can if we wish provide a path through which human skill is preserved, . . . by evolving into new skills in relation to new machines.[5]

While the design of a machine or system establishes a basis for its effects on the work environment, the specific circumstances in which the technology is introduced also play a crucial role in shaping the environment of the automated workplace. In practice, the impact of a programmable system is influenced by an array of "environmental" factors, such as managerial goals, the age and physical layout of facilities, the types of technology already in use, the ways in which work has been (and will be) organized, management policies and practices, the attitudes of workers, interpersonal relationships, and the character of labor-management relations. This context, together with the technical capabilities and actual performance of the new system, determines the effect of computerized automation on the work environment.

The choices made for system design and implementation reflect value judgments. The minimal attention devoted to work environment issues in this country reflects the view that production efficiency is a function of equipment design and selection, and a judgment that worker attitudes are secondary at best. On a more basic level, value judgments pertaining to workplace issues reflect a disparity in available evidence. It is relatively easy to measure the performance characteristics of a machine; it is difficult to measure reliably the effects of equipment designs and configurations on worker attitudes and related changes in productivity. The difficulty increases as the organization of production changes to accommodate new processes and products. Such organizational changes are central to the success of PA; they also distinguish the work environment effects of PA from those of more incremental changes in manufacturing technology.

How workers are affected by automation depends very much on their individual person-

*Frederick W. Taylor (1856-1915) revolutionized American factory production with his time and-motion studies. This standardization of tasks, known as Taylorism, left workers with little or no opportunity to exercise either control or judgment over their work or workplace.

[3] See, for example, Langdon Winner, *Autonomous Technology* (Cambridge, Mass.: The MIT Press, 1977).

[4] Winner, op. cit.

[5] H. H. Rosenbrock, "Robots and People," *Measurement and Control, vol.* **15**, March 1982, p. 112.

alities, expectations, and needs; it is therefore difficult to generalize about what is a "good" work environment for the introduction of PA. As one author recently pointed out:

> Workers are not all alike; they have different needs, interests and motivations. Moreover, these characteristics constantly change over the career of each worker?. . . .[6]

However, there are some characteristics that are generally recognized as having a positive effect on the work environment. Among them are fair wages and benefits, job security, a clean and safe workplace, interesting work, some control over the pace of work, the ability to make decisions concerning how work is performed, recognition for work done well, opportunities for personal growth and advancement, and good relationships with peers and supervisors.

Recognizing some of the important characteristics of a positive work environment, and recognizing that these can help to alleviate the tensions of a rapidly changing workplace, new technology can be utilized in ways that facilitate a harmonious interaction between people and machines. Achieving such harmony is the goal of interdisciplinary research in so-called sociotechnical systems. The literature on sociotechnical systems discusses ways of designing jobs and changing work methods to consider both the social system of the work environment and the technical system of production simultaneously in order to optimize the relationship between the two.[7]

It is possible to design and apply technology so that it will enhance the work environment, and to explore ways of designing jobs that accommodate both the technology and the needs of workers. The challenge is to introduce new technologies in ways that consider the economic and social impacts more equally. However, there are conflicting interests involved in considering simultaneously the economic, social, and technical aspects of new technology. One recent study of the impact of microelectronics on the workplace concluded:

> It is not yet clear just what are the economic costs of careful, or socially acceptable, applications of the chip. Nor is it obvious that the normal market forces, or union pressures, will bring out the best in microelectronics for society.[8]

Okun has suggested that pursuit of an efficient economy creates inequalities, and society faces a tradeoff between equality and efficiency. If both are valued, and neither takes absolute priority over the other, then compromises ought to be made in places where they conflict.[9] In the case of the effects of PA on the work environment, the failure to balance both social and economic questions as part of the overall decision to automate w-ill mean that the potential for PA to improve working life will not be realized. In the short term, only the economic costs of considering the social aspects may be recognized; over the long term, however, the cost of an unhappy worker may be realized as lower productivity. The concern extends beyond the individual PA user into a potential social services problem that could eventually affect whole communities.

The remainder of the chapter is divided into three sections. The first describes four OTA case studies of PA in selected manufacturing environments and discusses the principal themes that emerged from these studies. The next section discusses some of the impacts of PA on different aspects of the work environment, incorporating material from the case studies where it exemplifies these impacts. The final section provides an overview of approaches to work environment issues in Japan, Norway, Sweden, and West Germany and the experiences of these countries with the implementation of new technologies.

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[6]James O'Toole, Making *America Work, Productivity and Responsibility (New* York: Continuum, 1981).

'William A. Pasmore and John J. Sherwood (eds.), *Sociotechnical Systems: A Sourcebook* (La Jolla, Calif.: University Associates, Inc., 1978).

'*The Impact of Chip Technology on Conditions and Quality of Work, Worldwide Search and Examination of Evidence and Influential Opinion,* Report No. 1144, Ministry of Social Affairs and Employment, The Hague, 1982, p. 2.

'Arthur M. Okun, *Equality and Efficiency: The Big Tradeoff* (Washington, D. C.: The Brookings Institution, 1975).

OTA Work Environment Case Studies

In order to investigate the impact of PA on actual work environments in manufacturing settings, four case studies were conducted in companies that are leading users of PA—one each in the automobile, aircraft, and agricultural implements industries, and one encompassing a group of seven small metalworking shops. The three large companies studied were selected out of a list of approximately 30 firms that was compiled in consultation with a number of leading trade associations. The small metalworking shops were chosen after discussions with knowledgeable individuals and organizations in New England, the geographic region selected. While the companies are all advanced PA users, they differ in several important respects, including company size, product batch size, union representation, financial health, current level of market demand, and geography (see tables 48 and 49). *

*None of the participating companies is identified by name. One of the companies requested this courtesy, and OTA decided to follow it throughout.

Table 48.–Characteristics of Small Metalworking Shops Studied by OTA

	Alpha	Beta	Gamma	Delta	Epsilon	Zeta	Eta
Total employees	75	19	74	16	10	200	48
Employees on shop floor	60	16	60	15	6	130	40
Annual sales	$8.2M	$900,000	'$4.5M	$600,000	$300! 000	$25M	$2.75M
NC and CNC machine tools	21 NC-and CNC	2 CNC lathes 1 CNC miller 16 NC millers	3 CNC punch presses 1 CNC laser cutter 5 CNC press brakes	6 CNC	4 CNC millers 1 CNC lathe	12 CNC lathes 2 CNC vertical millers 30 NC machines	21 NC and CNC machines; more than half of these are CNC; 2 CNC in prototype
Year company founded	1969	1940	1973	1972	1974	1945	1942
Year first NC or CNC machine tool purchased	1974	1966	1976	1976	1979	1957	ca 1966
Principal client industries	Military aircraft, medical	Varied" electronics, hydraulics etc	Mostly electronics	Electronics, aircraft	Aircraft, medical	Aircraft. both military & commercial	Electronics, airrcraft
Programing system	Digital "APT"	Genesis "Encode"	Webber "Prompt"	Webber "Prompt"	Bridgeport "Easy Cam"	Digital "APT"	General Numeric "Numeridex "
Age of programing system	3-4 years	6 years	3 years	6 months	2 months	11 years	1 year
Lot size range[a]	10150	25-1.000	10-2.500	100-5,000	50-1,000	1-1,000	1-100
Average or typical lot size"	50	250-500	100	250-500	250	100	50
Employment level over time	Steady growth	Stable for 10 years, before that steady growth	Steady growth	Fluctuates. down from a peak of 19 in 1980	Growth, recent layoffs	Cyclical, twice as many employees in late 1960's Constant for last 7 years	Stable
Size of shop in square feet	23,000	10,000	30.000	8,000	2,500	66,000	28,000

[a]Lot size figures are rough estimates only

SOURCE Office of Technology Assessment (data current as of April 1983)

Table 49.—General Characteristics of Manufacturing Firms Studied by OTA

	Small shops	Agricultural implements	Commercial aircraft	Auto
Batch size	Small, one of a kind	Medium	Medium	Large
Company size	10-200	Components plant—10,000 at capacity Tractor assembly—2,500	40,000 in commercial aircraft division 630 In NC machine shop	Plant employs 4,000
Sales market share	300,000 to 25 million	Company agricultural equipment sales over $4 billion in 1981; dropped in 1982, but share of farm equipment market climbed	Company claimed 560/o of the market in 1981; in 1982, 48170	Company sales over $10 million in 1982
Unionized	No	Yes	Yes	Yes
Financial health	Good	Dominant in Industry	Dominant in industry	Improving over recent times
Market demand	Tends to fluctuate with demand for clients' products	Slack	Slack; operating at 50% of capacity	Recently picked up
Geography	Within an hour of major Industrial center in the East	Small, Midwestern city	Medium-sized west coast city	Within hour of major industrial center in East

SOURCE Offtce of Technology Assessment (data current–as of April 1983)

Six technologies were studied-numerical control (NC), flexible manufacturing systems (FMS), management information systems, automated materials handling, robots, and computer-aided design (CAD).* NC machine tools receive particular attention in the case studies because they are among the oldest modern examples of the application of digital technology to manufacturing, dating from the early 1950's. As such, NC represents the backbone of computerized production equipment, and is the most important application to date of computers in small and medium batch machining. In addition, although other programmable technologies may monitor the activities of workers or replace the worker entirely, NC machine tools continue to require the presence of an operator and significantly change the character of the person-machine interaction. The changes seen in the NC operator's job have implications for other situations in which the introduction of PA may change the nature of the interaction between person and machine. Thus, the work environment experience with NC may provide paradigms for other PA, including flexible manufacturing systems as well as nonproduction PA technologies.

The case studies are based on 3- to 8-day visits by two researchers to the three large companies, and l-day visits to each of the seven small machine shops. The aim of the case studies was to identify qualitatively some of the important ways in which PA is currently affecting the work environment in selected sites; quantitative analysis was not feasible given the small number and the diversity of observations.* (See app. 5A for method of study.) A brief summary of each of the four

*As was discussed in ch. 3, FMSS integrate NC and other PA technologies into a larger computer-controlled system that is the prototype of the automatic factory. Management information systems collect, transmit, and process data in a way that provides more comprehensive and immediate information to management about operations in both batch and mass production industries. Robots represent a versatile technology that can be used in a wide range of production settings either as stand-alone machines or as part of a larger system. CAD exemplifies the use of computers to transform the design process and the organization of the production process.

*'l"he sample of people interviewed was relatively small and nonrandom, and the interviews e lored a variety of issues within a defined range, rather thanfollowing a rigid format,.

case studies follows; a section is included describing the principal themes that emerged.*

Case l—Small Metalworking Shops

This case study investigates the introduction and use of numerical control in seven small metalworking shops—six machining shops and a sheet metal fabrication shop (see table 48). All of the shops work under contract to other companies (mainly aerospace, electronics, and defense industries), and have no commercial product of their own. The central production technology in these plants is NC, currently one of the most mature and sophisticated of the PA technologies, in which a preprogrammed code directs the operation of a machine tool by means of a controller. Generally, these machine instructions, or "part programs, " are prepared remotely by a part programer. Computerized numerical control, a refinement of NC that was developed in the mid-1970's, links a computer to the machine controller. This technical change brings about new organizational possibilities because the machine instructions can now be altered (edited), or even prepared, at the machine itself.

NC has a number of technical advantages over conventional equipment-e. g., easier machining of complex parts, repeatability, fewer fixtures and setups, and increased flow of production. In addition to these advantages, managers also cited two other motivations for installing NC equipment. One motivation was to respond to the perceived shortage of qualified machinists by providing the ability to transfer skills from the shop floor to a part program, hence depressing the level of skill actually needed to operate the machine. The second motivation for acquiring NC was to gain better control over shop operations. The predictability of the technology led to more accurate production cost estimates when bidding for new jobs and more reliable estimates of delivery times.

*The contractor report, "Automation and the Workplace: Case Studies on the Introduction of Programmable Automation in Manufacturing, " will be available subsequent to publication of this report.

Case Study Conclusions

By reorganizing production in such a way as to centralize control and reduce the overall skill requirements of the shop, these owners have brought about changes in the work environment that substantially reduce the attractiveness of machining jobs, especially for skilled machinists. In general, less experienced workers and those whose previous work experience was largely on NC preferred NC, while workers with high levels of skill and extensive backgrounds on conventional equipment did not like NC machines unless they had become involved in programing. When the planning function is removed from the shop floor and transferred to a programer, machining work is transformed in such a way as to be unattractive to the most skilled members of the work force –although the usefulness of high skill levels was still emphasized by most of the shopowners interviewed. While reducing machinist intervention in the production process helps to guarantee that a minimum standard of quality will be met, it also limits the ingenuity and skill that might help to achieve a higher standard of quality. If the input of the person closest to the production process is substantially reduced or even eliminated, the loss in terms of the quality of production could be sizable, particularly when a skilled worker is operating the machine.

Based on the sample of small shops visited, four strategies that would enhance the work environment appeared technically feasible and desirable from the point of view of workers on the shop floor:

1. Programing of machines by their operators, except in cases where there are compelling technical reasons for doing otherwise (e.g., some programs are very complex, and writing them may require several hours of careful expert attention, away from the distractions of the shop floor).
2. Increased control over the editing of programs by machinists who are at the machine, watching the execution of the program.

3. Training in programing for machinists, including rotation of machinists through the shop's programing department.
4. Training in machining that includes substantial work on conventional machine tools, and periodic rotation onto conventional machines to provide more challenge and variety.

Each of these changes that would enhance the quality of the work environment was present in an embryonic form in one or more of the seven shops studied. They are thus clearly technically feasible, since they have already taken place in a very limited way. They may also, in some cases, result in greater productivity. But it is also true that after a certain point, increases in shop floor autonomy with a view to improving the work environment tend to conflict with the shopowner's preferences for managing the business. At that point, further improvements in the work environment come at the expense of centralized control, which may also have implications for production quality. The issue of control, of course, is not peculiar to computerized automation in manufacturing settings; it represents one of the traditional workplace struggles between management and labor.

Case 2—Agricultural Equipment

Beginning in the early 1970's, the company, a midwestern manufacturer of agricultural implements and construction equipment, began to install a wide variety of computer-based systems in one of its principal businesses, the manufacture of tractors. Today, the company is regarded as one of the leading users of PA in medium-batch manufacturing. This case study focuses on two of the company's plants that have been widely recognized as pioneering automation efforts—the components plant and the nearby tractor assembly plant. Three major systems were selected for examination: 1) a management information system, particularly a labor reporting subsystem; 2) the automated materials handling system in the tractor assembly plant; and 3) the flexible manufacturing system in the manufacturing plant.

From management's point of view, PA has been vital to the company's success in an increasingly competitive industry. The technology has resulted in increased flexibility to respond to rapidly shifting market conditions, better product quality, and higher productivity. An important factor contributing to productivity improvement has been the transformation of what management saw as a series of difficult-to-control, stop-and-go operations into a more tightly controlled, centrally directed "even flow" of parts, suggestive of operations in continuous-process industries.

Case Study Conclusions

The effects of increased automation on the work environment seen in this case study fall into four broad categories. The first covers effects that are the intended result of management's desire for flexibility, rapid response, and closer managerial control of operations. For example, the ability of the company to track parts through the production process makes shop floor operations increasingly visible to middle- and upper-level managers, facilitating scheduling and making it increasingly possible to dictate the details of production from a high level in the organization. This decreases autonomy for supervisors by limiting their range of choices in certain scheduling and personnel matters.

The second category of effects on the work environment stems from the implementation process, broadly construed. For example, the disruption caused by downtime and scheduling irregularities resulting from the implementation and debugging process for highly complex and integrated computerized systems can degrade the work environment. The persistence of such problems over a period of years, not just months, raises the possibility that the debugging of one or another system could become a fact of life-and of the work environment-at technologically advanced companies. Workers at this site were particularly affected by frequent downtime because of their incentive pay system. * This system helps to create a highly motivated work force, and employees covered by the incentive pay system may use considerable ingenuity to keep machines running. Machine downtime is not welcomed by incentive workers, and most of the workers interviewed expressed intense frustration with automated systems that frequently broke down.

A third category of effects on the work environment is brought about by the complexity and highly integrated character of the capital-intensive installations. Maintenance workers found their work on a computerized system exciting and challenging (according to one electrician: "This new technology is scary as hell, but I love it"). However, the combined effect of the high cost of the system and the "domino effect' of a machine or system failure created considerable pressure as well. The integrated nature of the operation made the failure of any machine linked to the larger system a more serious problem than the failure of a stand-alone machine would have been. Additionally, most electricians interviewed felt that the diagnostics now required more skill than previously; however, the repairs were often easier, particularly when they only involved changing a circuit board. Under these conditions, collaboration increased among repairers and among different skilled trades.

The final category includes effects that result from system designs that attempt (with varying degrees of success) to minimize the necessity for operator intervention. One of the problems mentioned most frequently by operators of flexible manufacturing systems—as well as by maintenance workers on other highly integrated and expensive systems—is the alternating boredom and pressure that characterize their jobs. The FMS clearly required some operator input, yet it had not been designed to adequately acknowledge and accommodate that input; in addition, operator training may not have been sufficient.

*The 9 System combines a standard base rate with a bonus for production above the standard rate. An operator working at "incentive pace" earns about 130 percent of the "standard' base pay. The company aims to have production workers eligible for incentive pay about 85 percent of the time, the remaining 15 percent being set aside for 'inherent delay, " which includes those parts of a job whose pace is out of the control of the worker. During periods of inherent delay and downtime the worker is paid the standard rate. The introduction of automation can influence incentive pay in two ways: 1) by requiring determination of new incentive standards, and 2) by changing the proportion of inherent delay and downtime on the job.

Case 3–Commercial Aircraft

The manufacturer of commercial aircraft that is the subject of this case study is a division of a larger aerospace corporation. Both the division and its parent are widely regarded as being at the cutting edge of both product and process innovation in the aerospace industry. The case study has a dual focus: first, it explores the use of computer technology to revolutionize the organization of work, principally in the design and engineering of the airplane; then it looks at NC machining in a large production machine shop. Since the NC machine shop is a production terminus of a stream of data that flows from design to the manufacture of a part, it is directly affected by the organizational changes that are taking place.

The company's use of CAD has resulted in a number of important benefits: 1) elimination of routine work, 2) assured access to the most up-to-date design, 3) reduction in errors, and 4) the ability to revise designs more frequently and to experiment more fully with design alternatives. A central thrust is to link the separate design, business, and manufacturing computer systems into a centrally directed, integrated whole, and to thus move design decisions to a higher level in the organization. The goal is to create a controllable "stream" of information governing the development and production of the airplane from the point at which the airplane is initially designed to the point at which it first lifts off the runway.

As in the case study of the small metalworking shops, the use of NC has made it possible to remove from the shop floor much of the decisionmaking involved in part production, taking away a substantial amount of discretion from those involved at the point of production, and relocating it earlier in the design to build process. Many of these decisions are now made by programmers; however, the operator retains the critical control over the speeds and feeds at the machine.

Case Study Conclusions

The company goal to use CAD to establish a stream of shared data has significant implications for the work environment. For example, the jobs of engineers at earlier points in the design process will become broader and more challenging; but there will be proportionately less opportunity for creative work by engineers at later points in the design process. While this may be beneficial for the aircraft design process overall (in particular, because of the special concern for quality and reliability of aircraft, relative to other goods), it is likely to have a negative effect on middle-level workers who have been accustomed to more challenging work. Considerable amounts of routine data-handling will be eliminated by the establishment of shared data requirements and the automation of data transmission between groups. In addition, there will be increased interdependence among various groups and functions within the company as each group spends more of its time working with shared data.

Use of NC has a number of effects on the work environment of machinists at this site. NC has not eliminated the need for a skilled operator, since skill is still required in the form of alert supervision of the machine (rather than continuous active intervention); yet the removal of a substantial part of the traditional machining work makes it more difficult for the operator to remain engaged in the cutting process. The amount of latitude that NC machinists have in the performance of their duties is significantly reduced if all but the most routine programing is removed from the shop floor; this is a major factor in the boredom reported by operators.

The study found that interdependence has increased in the machine shop, since there are more support groups, e.g., programmers, involved in the production of any given part. This means that a delay in any one area affects the operator's ability to produce parts quickly and efficiently. The case study also found that the ability to dictate exactly how the machinist job will be done makes it possible for management to track an individual's performance more closely. In addition, an electronic system makes certain aspects of shop floor operations more visible to management. The system enables a machinist to page a support group member and also monitors production at the 66 NC machines.

Case 4—The Auto Company

This case study examines the application of robots to spot-welding operations in an auto company's assembly plant. In 1980, in response to the increase in consumer demand for small cars, the company designed a new model that required a $60 million retooling at the plant visited. The bulk of the retooling took place in the framing side of the body shop, where sheet metal parts of the car are welded together. In selecting machinery for its new welding facilities, the company chose a system that provides what is perhaps the most advanced frame welding technology available. It involves a single fixture or "gate" that holds the sides, underbody, and other parts in place while eight robots apply spot-welds that set the dimensions of the body. Most of the other robots in the plant apply "re-spot" welds which increase the mechanical strength of the car.

The automated area consists of two major components: 1) the subassembly areas where parts of the sides and underbody are welded together; and 2) the "main frame" line where the sides, roof, and underbody are welded by the robotic system and re-spot robots to form the complete car body. The case study focused on the side aperture area where parts are welded together to make the right and left sides of the car, and on the main frame line. Sixty-four robots are located in these areas.

The robotic system has a number of major technical and economic advantages over previous methods of welding: 1) the dimensional consistency of the body is assured because only a single gate is used for each car type; 2) the strength and quality of welded frames are improved because there are fewer missed welds, and the welds are placed identically in each body; and 3) subsequent retooling costs are substantially reduced by decreasing the number of gates and clamps that have to be purchased for each model.

Case Study Conclusions

Two important specific benefits resulting primarily from automation were observed. The first was that robots have eliminated a number of physically demanding hand-welding jobs that required operators to work in the midst of sparks thrown off each time a weld was made. The second benefit is that automation has substantially increased the breadth, challenge, and interest of maintenance positions. To some extent, welder repairmen have taken on responsibilities traditionally handled by basic tradesmen in that they maintain a wide range of electrical, hydraulic, and robotic equipment, and they also program the robots. The corporate director of manufacturing engineering regards welder repairmen as an important part of the company's move to increase productivity through combining job classifications.

However, the work environment has deteriorated significantly for many production workers and supervisors. An intensification of work and an erosion of the quality of life on the job for production workers in the body shop stem from the fact that subassembly jobs are now tied to a line. By tying subassembly work to a rhythm over which the worker has no control, the automated system has eliminated the principal feature of off-line jobs that made them more attractive than line jobs. Downtime on the automated system creates stop-and-go pacing that is beyond the worker's control; it also creates a situation where the subassembly and main frame lines are run faster in order to keep up with the rest of the plant. For repair supervisors, the responsibility for maintaining operation of the complex, highly integrated production system creates great stress.

It is important to note that these problems arise not from automation or the introduction of robots per se, but rather from the system design and operating practices. Two aspects of the design are especially important: the arrangement of successive subassembly operations in series, and the restriction of space for storing parts between these operations. The design decisions are complemented by the operating practice of storing even fewer parts between subassembly operations than space allows. By minimizing such "banks," manage ment believes it can assure a steadier, higher quality, and more efficient production flow.

Case Study Themes

At every company studied, a common theme emerged: establishing more effective managerial control over the activities of the enterprise. In the firms that produced parts in small and medium batch sizes, PA was the centerpiece of a strategy to establish a more managerially directed flow of parts through production, in some cases approximating the even flow of continuous-process industries. At the automaker, where the mass production of parts has been carried out for years on a moving assembly line, the company sought to extend this flow to the remaining off-line areas of the welding operation.

The aircraft company also sought to streamline the flow of information through design and engineering. In addition, it wanted to move decisionmaking to as early a point in the design and manufacture of the airplane as possible. An important corollary of these changes was minimizing human input. This extension of control in design and production, in management's view, makes possible a better coordination and a more efficient use of the firm's resources. These organizational choices, however, have important consequences for the work environment.

Because of the great variety of computer-based technologies, as well as the wide variation among companies in terms of the environmental context into which these technologies are placed, the findings of the four case studies do not suggest any one generalized impact of PA on the work environment. Instead, some overall themes emerged to varying degrees from the different companies studied:

- *Changes in skill requirements and occupational structure.*—There was a tendency to embody skill in machines or to move skill to an earlier point in the design and manufacturing process. In occupations such as highly skilled machining this meant that fewer skills would be required on the job. Maintenance work, however, tended to require more skills.
- *Training.–Some* operators and maintenance workers expressed a strong desire for more training that would allow them more effectively to run or to repair the machines to which they were assigned.
- *Increased interdependence.—The* introduction of PA brought about a greater interdependence among production workers, greater collaboration among maintenance workers, and the necessity for increased cooperation between production and maintenance workers.
- *Decreased* autonomy.—Computer-based automation is used in ways that result in decreased autonomy for workers, stemming from the removal of production decisions from the shop floor, the electronic monitoring of some work areas, and the attempt on the part of management to establish an even flow of parts through the plant and of information through the company.
- *Boredom. -One* of the consequences of systems intended to minimize operator intervention is that machines may run for longer, although not indefinite, periods of time without active intervention by the operator. For some machine operators, boredom on the job has become a widespread complaint. Some maintenance tasks, however, have become more challenging.
- *System downtime.*—Because of the complexity of programmable systems and their high level of integration, the effects of problems with any unreliable element of the system tend to spread, affecting the work pace of production workers and putting great pressure on those involved in the maintenance of the system. Downtime may decrease with better system design and more reliable components.
- Stress.—Two major sources of automation-related stress were identified: 1) working on very complicated, very expensive, and highly integrated systems; and 2) the lack of autonomy at work, extending in some cases to computerized monitoring by management.
- *Safety.–Some* applications of PA make the workplace safer, either by eliminating hazardous jobs altogether or by allowing the operator to stand farther from the machine during operation. Other applications introduce hazards of their own, such as automated carriers, clamps, and fixtures that move and close without direct human initiation and sometimes without warning. The net effect of PA, however, is a reduction in traditional physical hazards.
- *Cleaner and Lighter physical work for operators.—Some* forms of PA have reduced or eliminated heavy or dirty work. In some cases, new jobs requiring physical labor are created in the place of the old, heavier jobs.
- *Job security.*–The combination of substantial layoffs at all the large companies and the widespread perception among workers that the introduction of computerized automation caused significant displacement raised strong apprehensions among workers.

Further information on these case study themes will be included in the following section concerning impacts on work environment, as well as in other chapters of the report where appropriate.

Work Environment Impacts

The OTA work environment case studies demonstrated some of the effects of various PA systems in selected environments. Some recurrent themes emerged regarding the nature of those effects. This section examines some of the broader work environment issues within the categories of organization and nature of work, changing skill levels, training, occupational safety and health, and labor-management relations.

Organization and Nature of Work

The ways in which work is organized, together with the specific design features of PA technology, will help to govern the effects on the work environment. In the short term, the new and emerging technologies will be adapted to traditional structures of work organization; over the long term, the structures will change to reflect the characteristics of the new technologies. While it is too early to predict how these changes will develop, the experience to date may offer some insights.

One of the most vivid examples of how the organization of work in automated manufacturing can affect the quality of the work environment comes from the allocation of programing in an NC shop, as demonstrated in the OTA case studies. The introduction of NC machinery is usually accompanied by the development of a new programing department and a new division of labor. The planning of work becomes more centralized and is moved off the shop floor, so that planning and execution become increasingly separated. From the point of view of management, this results in increased efficiency and control over the production process. However, whether or not production workers are permitted to edit programs on the shop floor, or in general engage in planning, can determine whether their jobs are routine and relatively boring or involve, instead, an element of challenge and decisionmaking. The assignment of work is a function of managerial choice, but it also reflects the nature of the product. For example, in aircraft manufacture, concerns for precision, reliability, and safety make control especially important. Other settings provide more latitude for worker discretion.

The organization of work in ways that remove creative decisionmaking from jobs does not only apply to production workers. It is also reflected in the changes projected for engineering jobs at the aircraft manufacturer as CAD is used more widely. The jobs done earlier in the design-build process will be broader and more technically detailed, while the need for engineering skills later in the process will be reduced. The result will be less autonomy and decreased opportunities to contribute to the production process in meaningful ways for engineers who are not performing the broad and creative jobs at the beginning of the design-build process. According to the director of the CAD/CAM Integration Team:

> Once the system is in place, most of the decisions are made; so you're taking away a lot of individual decisions . . . whoever's involved downstream is working in a lot more controlled environment than he has in the past.

It is generally agreed that there is nothing inherent in automated technology that makes a particular form of work organization "imperative.[10] For example, West German researchers describe an alternative job structure for a flexible manufacturing system, although its viability is yet to be proven long-term.[11] Under the proposed alternative, the staff is composed exclusively of skilled workers, such as specialists in machine tools. Some would have additional training in electronics. All or most of the nonmachining tasks required by the FMS could be performed by the operators, working

[10] Joel A. Fadem, "Automation and Work Design in the U. S.: Case Studies of Quality of Working Life Impacts." published in *ILO International Comparative Study*, Federico Butera and Joseph Thurman (eds.) (Amsterdam: North Holland, 1984).

[11] Christoph Kohler and Rainer Schultz-Wild, "Flexible Manufacturing Systems—Manpower Problems and Policies, presented at the 1983 World Congress on the Human Aspects of Automation, Ann Arbor, Mich., August 1983.

Photo *credit: Beloit Corp*

The dramatic change in the nature of engineering work is demonstrated in the three photographs above. **(Top) pencil-and-paper operation at the turn of the century. (Middle) more recent paper-based engineering design. (Bottom) the manipulation of data through the use of computer-aided design** in job rotation. Only some of the programing jobs and major repair and maintenance tasks would have to be carried out by personnel working outside the system. This system would provide considerable job variety for operators, in contrast to the more traditional hierarchical approach of combining workers who have a relatively low level of skills, and whose jobs are highly specialized, with one or two group leaders or foremen with special skills.

Research currently under way at the University of Manchester (England) is attempting to develop software that will enable the equipment operator to program an FMS by making the first batch of parts.[12] In this experiment, the human qualities of skill and judgment are not eliminated, but are assisted and made more productive. However, some experts have expressed some skepticism about this proposal. They suggest that it represents a cosmetic solution that would not work well in practice, since the situation would be the same for the operator after the first batch of parts was made unless the parts were changed frequently.

PA also has an effect on the nature of work. A striking feature of the many systems observed during the company visits that has consequences for the work environment is their high level of integration. This results in an increased interdependence among workers who deal with these systems. For production workers, this interdependence chiefly meant that at certain stages of production the input or participation of others was necessary, requiring teams rather than individuals to complete a job. For subassembly production workers in the auto body shop, interdependence increased because each individual was more closely tied into the pace of the system as a whole. One subassembly worker explained:

> Before, you had more individual operations . . . you might have, maybe, two people working together. Well, now you have maybe five, six, seven, eight . . . and everybody dependent on everybody.

The higher degree of integration results in more synchronous work for all production workers, making it impossible for individual operators to work faster or slower than others in the system for more than several minutes at a time.

On the FMS at the agricultural equipment company there was evidence of a greater need for equipment operators to coordinate with the system superintendent in the computer control room and with other operators. Even stand-alone NC operators, both at the aircraft manufacturer and at the small job shops, commented on their increased need to rely on programmers and other support operations. No longer could a machinist execute an entire part alone, as was generally done on conventional machine tools. An NC operator at the aircraft company said:

> On a conventional machine it's pretty much just between you and the machine . . . . On the NC machine you've got the programer, . . . NC tooling, . . . planning, and if any one part of it breaks down, then the whole thing goes.

A supervisor in the same shop also felt the effects of this increased interdependence:

> Supervising NC, you have to deal with more support groups. You're more vulnerable to their preferences. There's more negotiation beforehand with people like programing and fixturing.

Maintenance workers experienced the increased interdependence in their work chiefly as an increase in the need for collaboration among the different skilled trades. The complexity of the new systems meant that, in many cases, diagnosis and repair required the input of workers with varying backgrounds. A skilled tradesman at the agricultural implement maker described the situation:

> You can save a lot of time by people working together and getting along. Otherwise a two-minute problem becomes a two-hour problem. A few years ago you could do it by

[12] H. H. Rosenbrock, The University of Manchester Institute of Science and Technology, "A Flexible Manufacturing System in Which Operators Are Not Subordinate to Machines, a proposal approved by the Science and Engineering Research Council in 1983.

yourself, but now you need two heads, one mechanical and one electrical, and a good operator.

There are opportunities for enlarging the scope of jobs with PA. The OTA case study on the seven small shops outlines a number of ways to improve job design for NC operators—including involving them in programing and editing, and providing opportunities for job rotation. With appropriate training, workers could be involved in a greater variety of tasks by rotating jobs; however, this would require cooperation between labor and management in agreeing to increased flexibility in work rules. Another opportunity for workers to perform a wide range of tasks rather than narrow, fragmented ones is in the application of group technology, through the use of manufacturing cells producing families of parts grouped on the basis of similar shapes and/or processing requirements.

The flexibility of PA provides the potential to achieve a better balance between the economic considerations that determine technological choices and the social consequences of those choices in the workplace. There are cases where organizational and technological changes have been combined successfully to yield dramatic improvements in productivity and effectiveness.[13] While these changes generally were motivated by factors other than improving the work environment, organizing work in ways that improve the work environment should result in economic payoffs as well through better worker morale and productivity.

Many of the concerns about the introduction of PA revolve around the changes it will bring about in the organization and nature of work. The choices made by those who design and manage automated systems will have a profound effect on how these systems influence the work environment.

Changing Skill Levels

Chapter 4 discussed the changes in skill levels and mixes that can be anticipated through the introduction of PA on a large scale. This section deals with work environment aspects of changing skills levels, including perspectives gained from the OTA case studies.

The ways in which work is organized and jobs are designed will determine both the skills needed to do a particular job and the overall level of skills required in a workplace using PA. In general, PA gives rise to a greater need for conceptual skills (e.g., programing) and a lesser need for motor skills (e.g., machining) than are required for conventional equipment.[14] Zuboff describes the new relationships between individuals and tasks that are created by information technology as "computer-mediated.[15] Computer-mediated work involves the electronic manipulation of symbols—an abstract activity rather than a sensual one. There will be a greater need for workers to monitor and maintain systems rather than to actually operate them, and more of the decisionmaking capability will be programed into the technology. For instance, NC machines have the potential to significantly lower skill requirements for operators, compared to conventional automation.

In the small machine shops visited for the OTA case studies, the owners all reported that the use of NC allowed them to run their machines productively using workers with less skill than would have been required on conventional equipment. The use of NC did not make machinists' skills superfluous, nor did it eliminate the need for some highly skilled workers in the shop, but it did allow the shop to function with a lower overall skill level in its work force than was previously possible. One shopowner commented:

[13] Robert Zager and Michael P. Resow (eds.), *The Innovative Organization: Productivity Programs in Action* (New York: Pergarnon Press, 1982).

[14] Barry Wilkinson, *The Shopfloor Politics of New Technology* (London: Heinemann Educational Books, 1983).

[15] Shoshana Zuboff, "New Worlds of Computer-Mediated Work," *Harvard Business Review*, September-October 1982, pp. 144-45.

> Five, six years ago we were very dependent on skilled labor, to the point where 1 spent half my life on my hands and knees begging somebody to stay and do something. And they tended to be prima donnas: "I won't work Saturdays" and "I don't work nights. " And this is one of the motivating factors in bringing in NC equipment. That reduced our dependency on skilled labor.

In situations where less overall skill is required the application of a higher level of skills will usually result in a more efficient operation. Even on a highly automated system, such as a flexible manufacturing system, human input remains important. The initiative and judgment that are occasionally required for optimum operation of such complex systems may not be present if skilled craftsmen and/or highly trained operators are not available.

The relative mix of skills required within the organization as a whole may change with the introduction of PA systems. This will vary among firms, depending on their products and processes. At the aircraft manufacturing firm, establishing a "data stream" would affect the company's skill requirements throughout its engineering operations. This would make the jobs done earlier in the design-build process broader and more technically detailed, while reducing the autonomy of engineers and the need for skills later in the process. This has advantages for the aircraft industry because of its particularly stringent needs for quality control. As described by a company official:

> A number of the people that are left will be an element of a very controlled process. The ingenuity of the craft will have been removed. The advantage is to have more consistent outcomes with the hiccups removed. People's actions will be more controlled by strict procedures. The human part of the job will be less evident.

At the same time, many relatively routine jobs would be eliminated. If accomplished, this would bring about a substantial reconfiguration of skill within the company, a reconfiguration that will not necessarily be obvious from a list of occupational titles.

At the body shop of the automaker, there has been a distinct rise in the ratio of skilled nonproduction workers to production workers. This is due to reductions in the number of production workers as well as increases in skilled maintenance labor.

Training

Chapter 6 discusses in detail the changes in education and training needs that will result from the widespread use of PA. This section provides perspectives that may go unrecognized in explicit education and training-oriented analyses and points to the fact that attitudes about training complement other attitudes and responses concerning new technology.

The OTA work environment case study interviews detected widespread concern among workers using automated equipment about what they perceived to be inadequate training, particularly for their present jobs. The chief complaints came from equipment operators and skilled trades people at the large companies visited. Some of the interest in training was motivated simply by curiosity about the new computerized technology. However, most often operators felt that their lack of training in the capabilities of their machines made them less productive workers.

Machinists in the NC shop at the aircraft company were the most vocal about their training needs. Although the company sponsored after-hours courses, the operators reported that these classes did not address the specific capabilities of their machines. NC operators were distressed about not knowing more about their machines; they felt that they could produce better parts if they were better versed in the use of their equipment. One machinist commented:

> It's like having a DC-3 pilot and walking him over to a 747 and saying, "Now look guy, it's an airplane, too—use it to the fullest extent it was made for . . . and if you don't know how to fly it, then check with the guy

in the right seat because he has probably been in it before and he will show you how the ropes work. ”

Some maintenance workers also complained about inadequate training. Maintenance personnel are expected to repair increasingly sophisticated and complex electromechanical equipment, and most of the maintenance workers interviewed felt inadequately prepared for this responsibility. Compounding their sense of inadequacy was the rate of technological change, which could quickly make even recently learned systems outdated, and the pressure they felt to repair the costly and complex technology in the minimum possible time.

Another force motivating workers' interest in further training is the fear of displacement as more and more jobs are affected by automation. The statement of an operator on the FMS, who had bid onto the system partly because of his concern about being left behind by changing technology, was typical--"If you don't get into it, you won't be able to get by. If you're looking at 15 years or so before retirement, you'll be sweeping floors. ”

The majority of the managers and machinists interviewed in the small shops believed that training on conventional equipment was an important prerequisite for effective performance on NC equipment. It was not clear whether they viewed the technical qualities of NC to be the principal drawback of learning machining on NC equipment only, or whether their concerns had to do with how NC machine operators are often trained (i.e., only on a single machine, not taught to plan work, set up, etc.). In the small shops, there were no complaints from workers about the adequacy of training. This may have been because the employees did not expect the employer to provide training, or perhaps because there was more informal training in small shops.

Occupational **Safety and Health**

The various forms of PA have both positive and negative effects on the safety and health of workers. In general, the introduction of PA tends to have a favorable impact on the work environment, although some new physical hazards associated with the lack of immediate worker control over system operations may emerge. However, PA will create new situations, or perpetuate old ones, that may have negative psychological effects on the work force.

Overall, the potential physical hazards appear to be more amenable to solution than some of the psychological ones because they are more easily recognized and are less subject to the subtleties of individual personalities. The relief of such symptoms as boredom and stress is more challenging because they are not as well measured or understood, affect different people in different ways, and are often complicated by other factors not directly related to the workplace. In addition, a commitment to alleviating monotony and stress in the workplace usually involves major changes in the way work is structured that can pose problems for both managers and other workers. These safety and health considerations are discussed below.

Effects of PA on the Workplace

Programmable automation has a variety of implications for health and safety in the workplace. For instance, robots are amenable to hazardous tasks in environments that are unpleasant and unhealthy for human workers. Thus, there can be a net positive effect on workers when a robot is installed for this purpose, providing the worker displaced is transferred to another job that is more pleasant or is trained to monitor or maintain the robot. A worker's lot is considerably improved when hard or dirty physical labor is assumed by a robot.

However, certain precautions are necessary to avoid unanticipated encounters between robets and humans. Statistics on such encounters in the United States are presently unavailable, although the Robotic Industries Association (formerly the Robot Institute of America) is planning to develop them. A recent Japanese Ministry of Labor survey indicated that in that country, since 1978, there had been 2 workers killed, 9 injured, and 37 "narrow escapes"; since near-accidents are not usually reported, the number of such incidents was presumed to be much higher.[16] As a result, the Ministry of Labor is currently drafting regulations dealing with robot safety. These regulations will make it mandatory to: 1) enclose robots with a protective screen or fence, 2) establish operating regulations with fail-safe on-off buttons and possibly auditory signals indicating the commencement of operation of mobile robots, and 3) install safety switches enabling immediate shut-down in case of emergency. Also being considered is specialized training on the safe operation of robots, as well as the provision of clearer operating instructions, including visual aids.

In response to concerns about robot safety, the Robotic Industries Association has organized a committee of robot producers to provide guidelines for the safe use of robots. In addition, major robot users in the United States, such as General Motors, Chrysler, and Ford Motor Co., apply their own sets of safety standards (see table 50). The National Institute for Occupational Safety and Health (NIOSH) has a planning project under way that will examine the potential health and safety problems associated with the introduction of robotics and define the need for further research. NIOSH is also developing guidelines on sensor-based methods to prevent fatalities and traumatic injuries during the maintenance of automated machines.

A recent report prepared by the British Machine Tool Trades Association described the potential hazards of robots and developed a method of assessing the risks.[17] According to this report, the major new hazard is the work envelope of the robot because it increases the complexity of guarding arrangements. Unpredictable action patterns, its ability to move in free space, and the possibility of reconfiguration all distinguish a robot from other automated equipment. The report refers to the following incidents of unpredicted robot movement which have occurred:

- aberrant behavior of a robot caused by a control system fault,
- jamming of a servo-valve,
- robot movement cutting its umbilical cord,
- splitting of a union on an exposed hydraulic pipe, and
- fault in data transmission causing a larger than anticipated movement of the robot arm.

In addition, the report discusses recommendations on design requirements and methods of safeguarding, including safe systems of work and rules for access to the robot. Advice

[16] "Microelectronics and Its Impact on Labor," report of the Japanese Ministry of Labor, August 1983.

[17] "Safeguarding Industrial Robots: Part I, Basic Principles," a report of the Machine Tool Trades Association, London, England, 1982.

Table 50.— GM Robot Safety Standards: Suggested Safeguards

Safeguards	Unauthorized intrusion	Authorized		
		Teach	Maintenance	Side by side
Mechanical stops			X	X
Barriers	x			x
Lockout			x	
Limit detecting hardware				x
Software limits				x
Proximity detectors	x			x
Presence detectors	x			x
Vision optical systems	x			x
Robot deactivation		x	x	x
Slow speed, low power		x	x	x
Excess-flow check valve (hydraulic fuses)		x	x	
Emergency stop (readily accessible)		X	X	X
Warning methods	X			

SOURCE General Motors Corp Operations Safety and Health Manual, sec 28, January 1983 on control systems, programing, maintenance, and operation is included, together with a brief summary of the legal requirements as they currently apply in the United Kingdom.

In one manufacturing site visited by OTA staff, a number of safety precautions for working with an arc-welding robot were observed. * For instance, the robot is programed to work in sequence at two stations, allowing the operator to set up or clear one station while the robot works at the other. Pressure-sensitive floor pads prevent the robot from working at a station if a person is standing in a risky location. Also, a flashing yellow light indicates that the robot is on, and an alarm sounds when the robot has finished a task. In order for the robot to move from station to station, a relay switch must be pressed. The opening of a protective chain around the area will cause a circuit to be broken and the robot will stop.

In the auto company case study, the introduction of robot spot-welding removed auto production workers from the point of contact between weld gun and sheet metal, where showers of sparks were generated. However, it was generally agreed that the danger of injury has escalated for repairmen who work with equipment that cannot be pulled to one side and replaced by a backup, but must be repaired in place before operation can resume. Dangers stem from the complexity, unfamiliarity, and automatic nature of the new equipment that may move without direct human initiation and sometimes without warning. The auto company safety administrator commented:

> . . . . In the old days, you had one [weld] gun, and you could shut it down and work on it. Now you've got this complicated mess. If you don't know what you're doing, you could get hurt. . . . We've had press injuries you didn't have before, and automatic clamps.

Production workers who were interviewed in the auto plant believe that safety is poor in the automated system. Two problems in particular disturbed them–pools of hydraulic oil surrounding much of the automated machinery and the increased risk of cuts with the robotic welding system. The union committeeman claimed that the pressure to quickly refill the conveyors when part of subassembly suffers a breakdown leads to safety hazards:

> This [the need to catch up] is a real incentive for people to cut corners . . . to take chances. It's one of the reasons we do have a large number of lacerations. . . .

It is important to note in this case that, while breakdowns are technological in nature, the pressure to meet quotas in spite of equipment failure is organizational. This situation is not unique to PA, but the problem is exacerbated by a system designed in such a way that equipment cannot be pulled to one side for repair, and by the complexity and automatic nature of the equipment. In addition, the high capital cost of the equipment increases the desire to use it to the fullest extent. This may entail operating the line faster to makeup for time when the machine is down, in order to meet production goals.

The potential safety and health hazards for workers using video display terminals (VDTs) for CAD are very different from those for workers using robots or other forms of PA on the shop floor. Both the work performed and the technology itself are substantially different. Although there is documentation of increased levels of stress among clerical workers using VDTs for long periods of time, the problems are lessened when the terminals are used as a tool to augment other activities, as in CAD, and when workers retain their autonomy and decisionmaking functions. Workers and worker representatives continue to be concerned about levels of radiation emitted by VDTs, although evidence to date suggests that the levels of radiation emitted by VDTs are too low to be hazardous to health.[18] Nevertheless, NIOSH is continuing research in this area. Eyestrain and postural problems are controllable to some extent through properly de-

*OTA site visit, Emhart Corp.; United Shoe Manufacturing Plant, Beverly, Mass., June 1983.

[18] "Video Displays, Work and Vision, " report of the National Research Council (Washington, D. C.: National Academy Press, 1983).

signed workstations, lighting, and frequent breaks.

Based on the technologies observed for the OTA work environment case studies, the field record of PA with respect to safety appears to be mixed, which is to be expected with relatively new technologies. On the one hand, some types of automation remove production workers from close contact with tools during actual operation. Three different field examples suggest that automation can improve safety by increasing the distance between workers and the part being machined, assembled, or processed: 1) the introduction of robot welding removes workers from the point of contact between the weld gun and sheet metal; 2) machinists on NC equipment work at a greater distance from cutting tools and often are separated by doors and enclosures; and 3) at the agricultural implements firm, robots rather than workers now spray-paint tractors in an atmosphere filled with fumes.

On the other hand, it was noted that automated carriers, clamps, and fixtures move and close without direct human initiation and sometimes without warning. This can be particularly dangerous where adequate precautions are absent and in highly pressured settings, e.g., for maintenance workers who deal with complex equipment on an assembly or processing line that cannot start again until they finish repair work. One worker at the agricultural implements firm noted:

> I've seen the thing move and nobody touched a button. You're dealing with something you can't control. It's created a whole different type of problem—not necessarily more problems—but different problems.

Working around complex machinery that can move in several different directions according to a plan that is not under the control of an operator or repair person—and may not even be well understood by those in the immediate area-was mentioned by workers as a significant safety hazard. The level of complexity on programmable systems may make it difficult for a worker to anticipate the system's behavior and avoid the risk presented by sudden and unpredictable motion. This was demonstrated in 1979 in Michigan when a worker was killed when hit in the head by a "robot arm. " The worker was attempting to climb a storage rack to get parts because a materials handling system designed to fetch parts automatically had been malfunctioning. Since the arm operated silently, the worker was unaware it had resumed activity.[18]

Nevertheless, with appropriate precautions the use of PA will reduce hazards in the workplace. It also will allow new work in hazardous environments such as toxic waste handling, nuclear powerplants, and undersea activities.

Psychological Effects of PA on Workers

Computerized automation in manufacturing has the potential for creating a number of psychological impacts on workers. Some of these effects may represent a temporary phenomenon resulting from a mismatch of worker skills and job requirements; i.e., experienced workers may be either over- or under-qualified for work they are doing on new automated systems.

Two of the principal effects, boredom and stress, are often closely related in that long periods of boredom at work can lead to stress in some individuals. In other ways, they represent opposite ends of a spectrum of individual reactions to work responsibilities. Boredom and stress in the automated workplace can result from the characteristics of the design of the technical system and work organization, as well as from such factors as lot size and the nature of the product manufactured.

Boredom.–PA technologies, such as NC machine tools and flexible manufacturing systems, are usually designed to run with minimal operator intervention. The human intervention that is planned into the system is of a relatively routine sort, such as making tool changes or performing other preventive maintenance duties. However, in OTA case study inter-

[18] "Millions Paid in Robot Death, " *Chicago Tribune,* Aug. 11, 1983.

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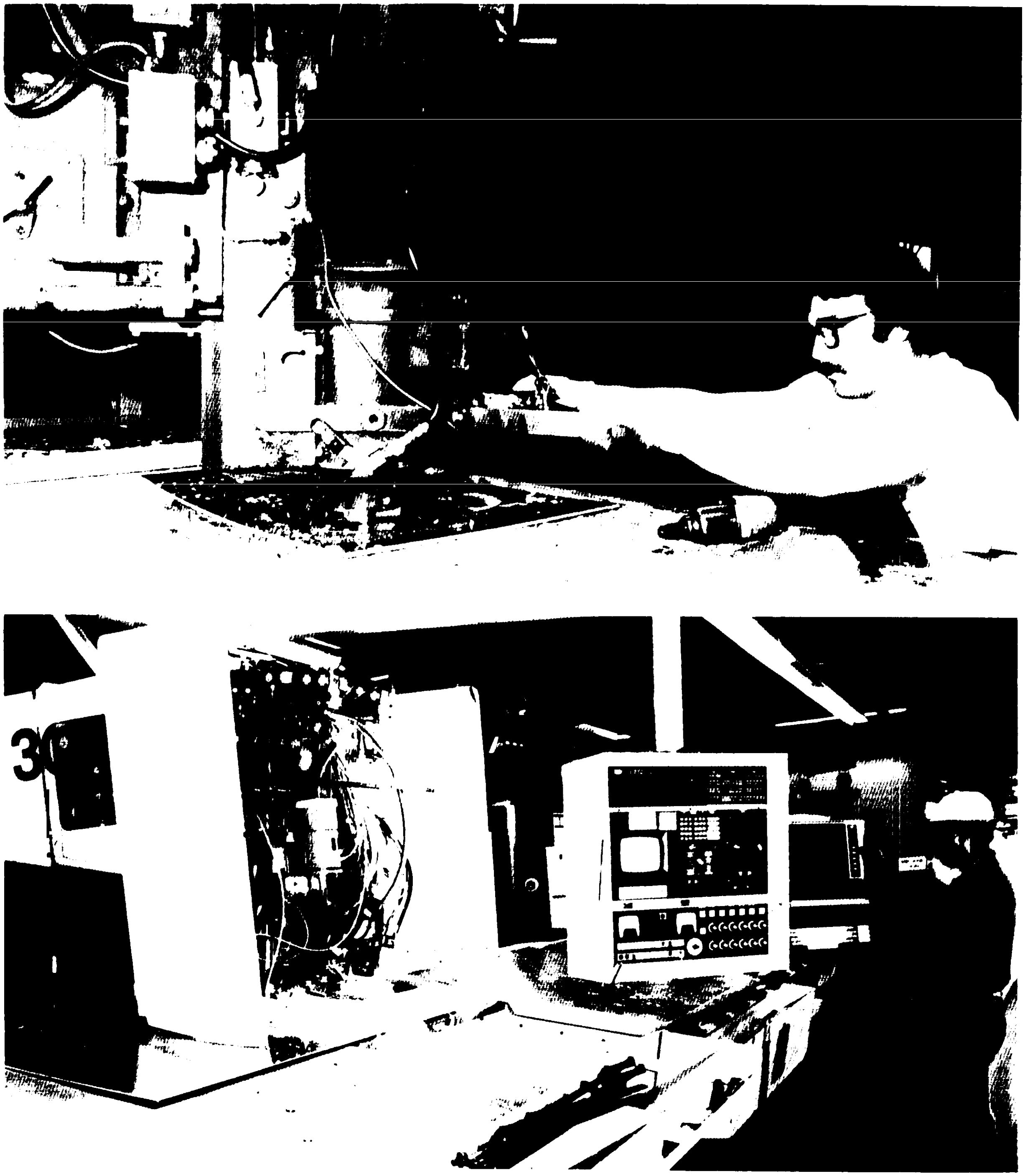

Photo credit: Lockheed-Georgia Co

Some types of automation remove production workers from close contact with tools, and considerably reduce the physical effort required to operate them. Top photo—old method of routing flat sheet metal parts. Bottom—new method, using an NC machine views, both the owners of small shops using NC machines and the project manager of the FMS acknowledged that operator input of more than a routine nature, such as being alert to problems and acting to eliminate or minimize difficulties that may develop, was important to the smooth functioning of the production process. This need for alert and intelligent operator intervention is at odds with an important aspect of the system's design-the attempt to remove the necessity for intervention as far as possible. (However, some believe that workers will always find ways to intervene in automated processes.[20])

Some NC operators, especially those making long cuts on NC machines, reported being bored for significant portions of their working day. NC operators reported that the lethargy that developed from long periods of inaction interfered with their ability to do their work most effectively. An NC machine operator at the aircraft manufacturing company said:

> The hardest thing to do is to keep yourself on your toes checking the measurements. Just because the tape says it's good, it not necessarily so . . . you get to relying on that tape, and what the machine can do, and sometimes the boredom—you know, you'd just as soon put another part on and just sit down again.

The boredom inherent in running a machine tool that can function automatically for periods of time is exacerbated in some cases by long running times for individual parts, so that there may be hours and sometimes even days between changeovers when a new setup is required. Parts with long running times are particularly common in the aircraft industry, so that machinists at the aircraft manufacturer and at the small shops that were subcontractors to the aircraft industry encountered many parts requiring lengthy cuts. Large lot sizes, which demand that an operator make the same part repeatedly, were also a factor in boredom.

On the FMS, boredom appeared to be less of a problem for operators; this may have been a function of the broader range of problems to which the system was subject. The larger the number and variety of unanticipated events, the less opportunity there was to be bored. As with NC machine operation, the slower periods when FMS operators appeared to be idle were actually times when they were overseeing the system and watching for problems. But it was difficult to sustain alertness during these monitoring periods. Boredom could set in because there was no immediate need for active intervention and the application of problem-solving skills. Because operators participated in the diagnosis and minor repairs of the costly and complex systems, periods of relative inactivity alternated with periods of considerable stress and pressure when problems arose with the system. This situation is similar to a number of other work environments that are highly computerized, such as nuclear powerplants.

Boredom that resulted from the way work was organized was a common complaint among NC operators who were interviewed for the case studies. Skilled NC operators who did not write part programs (i.e., the majority of those interviewed) reported that operating an NC machine was significantly less interesting and challenging than operating a conventional machine. While it is technically possible for NC machinists to do their own programing, at least for simpler parts, shop floor programing was rarely found in the sites visited for the case studies, either in the small shops or in the large NC machine shop at the aircraft manufacturing company. An experienced machinist in one of the small machine shops commented: "YOU get to be, in my opinion, on an NC, a little weak-minded. " Another said, "They're junk as far as I'm concerned. . . . You can take a chimpanzee, the light goes on, push a button. " In the sites visited, only the skilled machinists who were able to do some programing felt positive about NC machining. In the small shops, some relatively inexperienced NC operators who had been machinists for only 2 or 3 years reported fewer problems with boredom, indicating that a worker's previous experience is an important factor.

[20]O' Toole, op. cit.

By removing programing from the shop floor, the most interesting and creative part of NC machining work has been taken out of the hands of the machinist. If the equipment operator were given the responsibility for deciding how to make the part (to the extent this is technically feasible and assuming the operator wanted the additional responsibility), boredom would be substantially reduced. A machinist in a small machine shop said:

> How could you make the job more interesting? With a machine like this [an NC lathe], get a good operator who knows what he's doing, . . . give him a chance to do a setup and learn how to program the machine, so that he can look at the readout, and he can understand what the machine is doing, not just stand here and just wait and then push the button and take the part out–that would help for a while.

In some settings, however, programing or editing on the shop floor may be unavoidably constrained. In defense applications, for example, NC programs maybe certified by the Department of Defense, a situation that militates against ad hoc changes by machinists.

Stress.–As in many workplaces, work-related stress is a significant feature of computer-automated workplaces. Evidence from the OTA work environment case studies suggests that for many workers stress is an important factor in the work environment, particularly for employees who have responsibility for very complex and expensive systems. Two major sources of automation-related stress were identified: 1) stress associated with working on very complicated, capital-intensive, and highly integrated systems; and 2) the lack of autonomy at work, extending in some cases to computerized monitoring by management. In many cases, stress may be considered a temporary byproduct of the change process itself; in others, it may become a permanent feature of the work environment.

In the plants studied, maintenance workers and equipment operators who had some maintenance duties reported substantial stress associated with having the responsibility for maintaining sophisticated, costly, and interdependent automated systems such as the robotic welding system at the auto plant or the materials handling system at the agricultural implements manufacturer. The combination of the complexity of the system and the pressure to minimize downtime because of the high cost of lost production added up to substantial stress for some maintenance workers assigned to systems of this sort-a problem intertwined with but also distinct from the physical hazards that such stress produces.

The most vivid example of this type of stress was in the body shop of the automaker, where welder repair supervisors reported being under extreme pressure. In the area of the body shop where the side aperture robotic welding/automotic re-spot line is located, there had been a 150 percent annual turnover rate among first-line supervisors. A general foreman said:

> This has been the hardest 3 years of my life. There isn't any relaxation . . . I've walked out of here and sat in my car, unable to move, getting myself together.

The highly integrated nature of the automated framing system, which links in series complex electronic and mechanical components, means that a failure in one part of the system spreads quickly to other areas.

The high cost of the equipment in the automated body shop is a further source of stress. Thousands of dollars worth of damage maybe done if a supervisor, in haste, misdiagnose a problem. The same problem was mentioned in regard to the FMS of the tractor producer. As one operator put it:

> When you're first down there you're just nervous. Because everything's so expensive you don't want to break anything.

Another source of stress for workers on automated systems comes from system unpredictability. Computerized automation, as an electrician at the tractor assembly plant said, "is made to go and stop on its own program. " A machinist at a small machine shop made a similar comment about working on NC machine tools:

> These NC machines—they're unpredictable. You don't know what it's going to do, the first time you run that program. You're always on edge until it's proved out.

The reduction in autonomy at work can take its toll in stress on the worker. In all of the work sites visited for the case studies, managers spoke about using PA to establish better planning and allocation of all the firm's resources. A frequently mentioned benefit in batch production was faster throughput, the ability to complete the production of a part in less time, as a result of more effective direction of the part's movement through the shop. The particular organizational choices managers made to establish greater control resulted in less autonomy for the workers involved. In general, reduction in amount of autonomy on the job is likely to be more stressful where workers previously had a greater degree of autonomy and now have either less or none at all. It also would be different in degree depending on the experience and expectations of the individual worker.

Analyzing studies of Swedish and American men, Dr. Robert A. Karasek found that work-related strain was a function not of heavy job demands alone, but of the combination of heavy job demands with restricted job control and decisionmaking latitude.[21] He concludes:

> . . . the opportunity for a worker to use his skills and to make decisions about his work activity is associated with reduced symptoms (of stress) at every level of job demands. We do not find, therefore, support for the belief that most individuals "overburdened" with decisions face the most strain in an industrialized economy. Literature lamenting the stressful burden of executive decisionmaking misses the mark. Constraints on decisionmaking, not decisionmaking per se, are the major problem, and this problem affects not only executives but workers in low status jobs with little freedom for decisionmaking . . . e.g., assembly workers, garment stitchers, freight-and-materials handlers, nurse's aides and orderlies, and telephone operators.

Machine-paced work, such as was found at the agricultural implements company and at the auto manufacturer, affects autonomy. Assembly workers at both companies were paced by the speed of the line, so that both the rate of their work and the timing of their breaks were out of their control (and also unpredictable, in the case of downtime). Lack of autonomy is not, of course, a new issue on the shop floor; it is not easily alleviated, and may indeed be aggravated, by the introduction of PA.

The increased visibility of shop operations made possible by computerized monitoring and scheduling systems allows management to spot bottlenecks more readily and take corrective action when necessary. However, what information is gathered and how it is used can result in new forms of control, both subtle and direct, over worker activities. Electronic monitoring of worker performance, and the apprehension it engenders in workers, can also add to stress in the workplace.

One system observed in the site visit to the aircraft manufacturer monitored production at 66 NC machines that are directly wired into the system. The goal is to establish direct feedback from the shop floor to management about how an important element of the NC program —the control of machine feeds—is carried out. The system and a panel that shows the status of each machine-running, running at less than 80 percent, down, or temporarily halted for part handling-is housed above the shop floor in a control room with a view of the surrounding machines. By looking at a panel, a supervisor can tell the status of all the machines in a given jurisdiction. Moreover, supervisors obtain daily reports from the system, and weekly and monthly tabulations are made in chart form for upper management.

The system seems to be widely accepted, even though some operators are apprehensive about its monitoring capabilities. (One machinist said: "It's like having a big television cam-

[21] Robert A. Karasek, Jr., "Job Demands, Job Decision Latitude, and Mental Strain: Implications for Job Redesign," *Administrative Science QuarterI-v (24)*, June 1979, p. *303,*

era looking over my shoulder.") One of the reasons it has been accepted is that certain limits on its use by management are fairly well established after several years of operation. The company has an agreement with the union that information from the system will not be used to discipline employees, although operators said that individual supervisors could exercise various sorts of informal discipline if they so chose. Monitoring, which is not a new issue on the shop floor, was also emerging as an issue among engineers at the company because of the potential use of CAD terminals for monitoring the amount of time spent at the terminals by individual engineers. The capabilities of the technology are thus expanding the concerns about computer monitoring into higher levels of the organization, affecting personnel who lack prior experience with or coping mechanisms for it.

Labor-Management Relations

The effects of PA on the work environment will be determined in part by management's motivations for automating and by the nature of labor-management relations. * Management might decide to introduce PA for a variety of reasons, such as: 1) to improve productivity, 2) to reduce costs, 3) to standardize production methods, 4) to enable the use of workers with fewer skills, 5) to increase control over the pace and quality of production, and 6) to get on the technological bandwagon. Who makes the decision in the organization will also have an important effect on the results. Research suggests that managers often lack the background to assess the technological options, while staff familiar with the new technologies are less able to appreciate associated strategic dimensions.[22]

*This discussion focuses on work environment issues; it excludes wages, benefits, and other industrial relations issues. For additional discussion, see OTA Technical Memorandum "Automation and the Workplace: Selected Labor, Education, and Training Issues, " March 1983.

[22]Stephen R. Rosenthal and Homayoun Vossoughi, "Factory Automation in the U. S.: Summary of Survey Responses and Initial Commentaries, " School of Management, Boston University, March 1983.

Once the decision is made, the strategies employed by management for introducing PA are key in determining its impacts. Prior experience seems to be an important factor in how an organization copes with additional automation.[23] Also, the introduction of new technology may be facilitated by good intracompany communications and a "participative" management style.[24] Where the knowledge and expertise of workers is factored into the decisionmaking surrounding new technology, and information is shared, implementation problems may be minimized somewhat. In the agricultural implements case study, when asked what he would do differently, given another opportunity, the plant's manager of manufacturing replied:

> We would bring in the electrical and mechanical skilled trades people earlier so they could see the equipment installed. . . . We would have our own skilled trades people look over the shoulder of the installers. . . . We would also have brought in more systems people earlier, especially systems people with shop savvy.

Cooperative arrangements between universities and manufacturing firms may be useful devices for introducing new technologies. For example, Worcester Polytechnic Institute and the Emhart Corp. joined together to form an on-campus research center to work on practical applications problems involved in introducing robotic systems to Emhart's operating divisions.[25] Relevant personnel at all levels (production, support, and professional) participated in applications development and preparation.

The nature of labor-management relations will affect the implementation of new technology and its consequences for the work environment. Cooperation between employers, workers, and society in determining the design, implementation, and pace of change would tend to minimize potential negative effects of tech-

[23]Donald Gerwin, "Do's and Don'ts of Computerized Manufacturing, " *Harvard Business Review,* March-April 1982, p. 110,

[24]The Impact of Chip Technology, op. cit., p. 8.

[25]OTA Education and Training case study.

nological innovation.[26] Such cooperation, however, will require mutual trust among the parties involved. While such trust traditionally has not been a hallmark of labor-management relations in the United States, some observers predict that American industrial relations will become more hospitable to collaboration in the near future due to such pervasive circumstances as intense foreign competition and technological change.

In response to changing worker expectations, management increasingly has been forced to pay greater attention to the needs of its work force, beyond the traditional ones of fair wages and benefits. This trend has been growing since the 1960's and 1970's, and is not limited to either new technology or PA. In addition to such provisions as profit-sharing and job security, workers have been demanding a greater say in matters that directly affect their workplace; where management has begun to tap into this knowledge and experience they have often discovered a new source of support and insights.

The attention being given in the United States to the Japanese style of labor-management relations seems to be affecting the nature of labor-management relations in this country. In particular, cooperative labor-management efforts in solving workplace problems have been gaining popularity in the United States. These innovative work experiments are known by a variety of names, including Quality of Working Life Programs, Quality Circles, Labor/Management Committees, and Employee Involvement Programs. A recent Department of Labor document identifies and describes over 200 cooperative labor-management programs;[27] the International Association of Quality Circles promotes quality circles through conferences, training activities, and educational materials; and consulting firms are beginning to provide guidance for setting up such efforts. Membership in participative programs is usually voluntary, and training in problem-solving techniques is provided. Generally, their purpose is to identify and help to solve everyday problems on the job. Such programs have had mixed results, reflecting the diversity of approaches taken, management styles, and work force heterogeneity. This makes it difficult to generalize about the goals of these programs or to evaluate their effectiveness.

Cooperative efforts can occur in either union or nonunion settings. Indeed, their presence in nonunion settings is attributed by some as a factor constraining further unionization. In plants that are unionized, cooperative groups usually deal with workplace issues that fall outside the collective bargaining framework. Quality circles, modeled after the quality control circles in Japan, are usually management-initiated to improve product quality and productivity. For this reason, some unions view them as management devices to increase productivity at the expense of workers, and sometimes as a way to fight unions, rather than as efforts to increase worker participation. The fragility of some quality of work life (QWL) programs has been demonstrated recently when UAW union locals in GM plants in both Michigan and California called for either disbandment or reevaluation of QWL programs, criticizing management for abusing the cooperative spirit of the programs.

In the case of the introduction of new technology, successful labor-management cooperative efforts should have a positive effect on the way in which it is perceived in the workplace. For instance, the UAW-Ford Employee Involvement Program is viewed by employees as having a beneficial effect on their jobs and the work environment.[28] Where such programs are functioning well, they could help to ease the changes brought about by the introduc-

“Donald Kennedy, Charles Craypo, and Mary Lehman (eds.), *Labor and Technology: Union Response to Changing Environments* (Department of Labor Studies, The Pennsylvania State University, 1982).

“"Resource Guide to Labor-Management Cooperation, " U.S. Department of Labor, Labor-Management Services Administration, October 1983.

“"UAW-Ford Employe Involvement: A Special Survey Report, " Center Report 1, UAW-Ford National Development and Training Center, 1982.

tion of PA. The principal uncertainty surrounding such programs appears to be, however, their relationship to the perhaps more fundamental issue of job security. Labor-management cooperation appears to be sounder where the fact of jobs is not in question.

If PA is perceived to be a growing threat to job security, that perception may interfere with other labor-management cooperative programs. Other factors that may hinder new joint programs are the reluctance of parties to fundamentally revise their attitudes, external events such as a recession, and lack of commitment by one or the other party.[29] Some experts believe that shifts in labor-management relations in recent times have been the result of recession and do not represent any fundamental change in the attitudes of either management or labor.[30] The tenor of negotiations in major collective bargaining to take place in 1984 and beyond will bear watching to see if there are perceptible trends in a changing climate of labor-management relations.

The latest Bureau of Labor Statistics data (September 1981) give the number of employed wage and salary workers in labor organizations as 23 percent and the percentage represented by labor organizations as 25.7 percent, although the proportion varies among industries (see table 51).[31] Experts suggest that these percentages are currently a few points lower. The approaches to new technology and accompanying levels of concern have varied among unions, although overall concern is growing. While the views of unionized workers concerning new technology are known, less is known about the attitudes of workers in nonunionized companies. However, they would likely cover a broad range depending on the size of the company and the type of labor policies employed. One study found that some of the large nonunion companies resembled the large unionized companies in their labor practices, and some even had policies that were more restrictive than those of union contractual arrangements.[32] In the small nonunion shops visited for OTA work environment case studies, workers interviewed seemed to accept the fact that the future lies in increasing automation, whether or not they like it personally.

Unions have attempted to minimize what are perceived as the socially harmful effects of new technologies on the labor force, such as job displacement and deskilling. Such efforts include collective bargaining, organizing, and political strategies.[33] For instance, technology clauses are becoming more common in collective bargaining agreements, and some unions provide model contract language to their local bodies that covers the introduction of new technology. Adjustment procedures and programs, such as advance notice and provisions for training related to new technology, increasingly are included in union contracts. Recently AT&T and the local operating companies that were spun off in January 1984 agreed to offer retraining for other company jobs at company expense, and thus job security, to any worker whose job will be eliminated by the introduction of new technology.

The International Association of Machinists and Aerospace Workers' Technology Bill of Rights, which outlines a specific list of worker rights with respect to the introduction of new technologies, has been provided to local unions as a guide to be used during contract negotiations (see table 52). However, in a recent contract negotiation in California the company ignored the union request for one of the items listed on the Bill of Rights–the retraining of workers whose jobs are eliminated because of new technology.[34]

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[29] Irving H, Siegel and Edgar Weinberg, *Labor-Management Cooperation: The Amen"can Experience* (Kalamazoo: W. E. Upjohn Institute for Employment Research, 1982).

[30] Sar A. Levitan and Clifford M, Johnson, "Labor and Management: The Illusion of Cooperation, " *Harvard Business Review*, September-October 1983, p. 8.

[31] "Earnings and Other Characteristics of Organized Workers, " U.S. Department of Labor, Bureau of Labor Statistics, September 1981,

[32] Jack Stieber, Robert B. McKersie, and D. Quinn Mills (eds.), U.S. *Industrial Relations 1950-1980: A Critical Assessment* (Madison, Wis.: Industrial Relations Research Association, 1981), from chapter entitled "Large Nonunionized Employers" by Fred K. Foulkes.

[33] Kennedy, Craypo, and Lehman, op. cit.

[34] "Machinists Clear Pact With McDonnell, Bolstering Firm's Tough Stand on Costs, " *Wall Street Journal, Nov. 8, 1983.*

Table 51.–Employed Wage and Salary Workers Represented by Labor Organizations[a] by Occupation and Industry, May 1980
(numbers in thousands)

Occupation of current job	Total	Agriculture	Mining	Construction	Manufacturing	Transportation and public utilities	Wholesale trade	Retail trade	Finance and services	Forestry and fisheries	Public administration
	Percent of employed wage and salary workers										
All occupations[b]	25.7	3.8	35.2	33.1	34.8	51.5	12.6	10.5	19.7	16.1	40.5
White-collar occupations	18.5	2.7	10.2	12.2	12.3	38.4	4.6	8.5	20.5	(c)	36.3
Professional, technical, and kindred workers	27.7	(c)	6.5	19.4	11.3	33.8	4.1	6.4	32.4	(c)	31.3
Managers and administrators, except farm	9.7	(c)	(c)	12.7	5.9	16.9	3.9	6.1	10.1	(c)	26.2
Clerical and kindred workers	19.2	(c)	16.7	8.2	18.2	49.2	7.8	13.9	11.2	(c)	42.6
Sales workers	5.0	(c)	(c)	(c)	5.4	(c)	2.2	5.4	4.4		(c)
Blue-collar workers	41.4	8.1	47.1	39.6	46.9	62.6	28.9	21.3	20.8	(c)	41.0
Craft and kindred workers	41.2	(c)	51.0	41.1	45.8	67.7	21.8	12.9	23.2	(c)	45.0
Carpenters	33.9	(c)	(c)	31.3	42.7	(c)	(c)	(c)	(c)	(c)	(c)
Construction craftworkers, except carpenters	50.4	(c)	(c)	46.4	67.6	70.3	(c)	(c)	40.7	(c)	(c)
Mechanics and repairers	42.9	(c)	(c)	39.3	57.1	66.0	16.8	10.8	21.1	(c)	46.2
Operatives and kindred workers	43.5	(c)	42.7	39.6	46.9	57.0	36.1	22.6	22.3		41.4
Operatives, except transport	42.4	(c)	41.1	39.9	46.1	60.9	33.7	22.4	20.0	—	(c)
Drivers and delivery workers	43.0	(c)	(c)	39.9	45.6	53.2	37.4	21.7	26.6		(c)
Other transport equipment operatives	58.2		(c)	(c)	69.8	88.3	(c)	(c)	(c)		(c)
Nonfarm laborers	35.1	7 5	(c)	34.4	52.2	64.8	24.1	28.9	13.2	(c)	32.5
Construction	34.4		—	34.4	—	—		—	—		
Manufacturing	52.2	–	—	—	52.2	—		—	—		
All other nonfarm laborers	29.7	7 5	(c)	—	—	64.8	24.1	28.9	13.2	(c)	325
Service workers including private household	18.4	(cl	(c)	(c)	3 6 5	60 1	(c)	5.8	17.0	(c}	55 0

[a]Includes members and nonmembers in bargaining units

[b]Includes farm workers not shown separately

[c]Base less than 75,000

NOTE Due 10 rou ndmg sums of individual items may not equa totals Dashes ( ) indicate no workers in cell

SOURCE Bureau of Labor Statistics, "Earnings and Other Characteristics of Organized Workers, May 1980, " Bulletin 2105, September 1981, p 27

Table 52.–Workers' Technology Bill of Rights

I. New Technology shall be used in a way that creates jobs and promotes community-wide and national full employment.

II. Unit Labor Cost savings and labor productivity gains resulting from the use of New Technology shall be shared with workers at the local enterprise level and shall not be permitted to accrue excessively or exclusively for the gain of capital, management, and shareholders.

III. Local communities, the states and the nation have a right to require employers to pay a replacement tax, on all machinery, equipment, robots, and production systems that displace workers, cause unemployment and, thereby decrease local, state, and federal revenues.

IV. New Technology shall improve the conditions of work and shall enhance and expand the opportunities for knowledge, skills, and compensation of workers. Displaced workers shall be entitled to training, retraining and subsequent job placement or re-employment.

V. New Technology shall be used to develop and strengthen the U.S. industrial base, consistent with the Full Employment goal and national security requirements, before it is licensed or otherwise exported abroad.

VI. New Technology shall be evaluated in terms of worker safety and health and shall not be destructive of the workplace environment, nor shall it be used at the expense of the community's natural environment.

VII. Workers, through their trade unions and bargaining units, shall have an absolute right to participate in all phases of management deliberations and decisions that lead or could lead to the introduction of new technology or the changing of the workplace system design, work processes and procedures for doing work, including the shutdown or transfer of work, capital, plant and equipment.

VIII. Workers shall have the right to monitor control room centers and control stations and the new technology shall not be used to monitor, measure or otherwise control the work practices and work standards of individual workers, at the point of work.

IX. Storage of an individual worker's personal data and information file by the employer shall be tightly controlled and the collection and/or release and dissemination of information with respect to race, religious or political activities and beliefs, records of physical and mental health disorders and treatments, records of arrests and felony charges or convictions, information concerning sexual preferences and conduct, information concerning internal and private family matters, and information regarding an individual's financial condition or credit worthiness shall not be permitted, except in rare circumstances related to health, and then only after consultation with a family or union-appointed physician, psychiatrist or member of the clergy. The right of an individual worker to inspect his or her personal data file shall at all times be absolute and open.

X. When New Technology is employed in the production of military goods and services, workers, through their trade union and bargaining agent, shall have a right to bargain with management over the establishment of Alternative Production Committees, which shall design ways to adopt that technology to socially-useful production and products in the civilian sector of the economy.

SOURCE International Association of Machinists and Aerospace Workers

One of the most controversial subjects of labor-management relations involving the introduction of new technology will be work rules. Work rules are central to the collective bargaining system in the United States, and are viewed by some as one of its great strengths.[35] This system of job control is also closely related to the tenets of Taylorism that break down work into sets of discrete tasks.[36] In work sites that are becoming more and more automated, management is likely to demand increasing flexibility in deploying workers. As noted in chapter 4, successful implementation of PA may involve substantial changes in production processes and in the nature of work to be done by people as opposed to machines. These changes will raise questions concerning job definition-about which tasks are combined to make which jobs. Work rules assure that certain jobs contain certain tasks, but PA may make such jobs obsolete. Job definition changes may be reflected in collective bargaining requests from management for relaxing and changing work rules, in return for union demands for worker benefits such as job security or profit-sharing. In this respect, nonunion shops may be able to respond more quickly to the changing workplace demands of new technology.

Any discussion of restructuring work in automated environments in ways that would enhance the workplace needs to be framed in the context of how the work rule issue evolves. Management's ability to take innovative approaches to implementing PA may be constrained by work rules that are outmoded and difficult to change. In return for increased flexibility in deploying workers, management may need to be more responsive in such matters as increased labor involvement in decisions concerning the implementation of new technology or job security.

[35]Robert M. Kaus, "The Trouble With Unions," *Harper's*, June 1983, p. 29.

[36]Michael J. Piore, "American Labor and the Industrial Crisis," *Challenge*, March-April 1982, p. 9.

European and Japanese Experiences

In Western Europe and Japan, mechanisms for dealing with workplace concerns have generally been applied to the introduction of new technology, and in many cases the laws specify how such introduction is to be handled. For example, the laws of West Germany, Norway, and Sweden provide for worker involvement in technology issues, and labor is routinely represented on corporate boards. It is important, however, to point out that the culture and traditions of Europe and Japan regarding attitudes and practices in the workplace differ from the those of the United States, especially in the area of labor-management relations. In general, the labor-management relations of these countries are characterized by a more cooperative atmosphere and greater worker participation than has been the case in the United States.

Japan

There seems to be a broad consensus among labor, management, scholars, and the government in Japan that new technologies should be applied in ways that will humanize life and the quality of work.[37] For example, in 1983, a joint effort of government, industry, and academia began to develop robots to perform jobs too hazardous or unhealthy for human beings (known as "extreme-job' robots).[38]

Much has been written about Japanese management style and its effect on the work environment. In particular, the nature of labor-management relations provides many opportunities for information exchange and sharing, both between management and labor and among workers themselves.[39] Such information-sharing is key in Japanese companies, and provides the basis for quality circles at firm, plant, and workshop levels. It is also effective in the introduction and use of new technologies such as PA.

There are two principal types of worker participation in Japan that exist primarily in the private sector: 1) direct shop floor participation, such as small group participative activities like quality control circles; and 2) indirect representational forms, such as labor-management consultation systems.[40] Small production study groups have played a vital role in developing employee participation in problem-solving. Unions and quality control circles have often been involved in designing robot applications within the plants. Those companies with the most active quality control circles have also been the leaders in the use of robots.[41]

Participatory work structures represent one of a number of actions designed to deal with the effects of labor shortages in Japan.[42] They were usually introduced as part of a corporate strategy to make firms more attractive to highly educated potential recruits and to reduce the likelihood of turnover and labor unrest. Thus, worker participation originally was more an obligation of each employee than an opportunity to actively participate in solving workplace problems.

Quality control circles often provide a good opportunity to promote "humanization of work" in the workplace.[43] Workers are taught fairly simple statistical quality control techniques and modes of problem-solving. They are guided by leaders, often foremen, in the selec-

[37] Kazutoshi Koshiro, "The Employment Effect of Microelectronic Technology, " *Highlights in Japanese Industrial Relations,* The Japanese Institute of Labor 1983, p. 87.

[38] "Gov't-Industry Project Will Start On 'Extreme-Job' Robets, " *The Japanese Economic Journal,* Mar. *8, 1983,* p. 10.

[39] Haruo Shimada, "Japanese Postwar Industrial Growth and Labor-Management Relations, paper presented at the 35th Annual Meeting of American Industrial Relations Association, December 1982, p. 7.

[40] Robert E. Cole, "Participation and Control in Japanese Industry, " prepared for Conference on Productivity, Ownership and Participation, Agency for International Development, U.S. Department of Labor, May 1983.

[41] Paul H. Aron, "Robotics in Japan: Past, Present, Future, " a presentation to Robots VI Conference, March 1982, p. 4.

[42] Cole, op. cit.

[43] Takeshi Inagami, "QC Circle Activities and the Suggestion System, " *Highlights in Japanese Industrial Relations,* The Japane`se Institute of Labour, 1983, p. 67.

tion and solving of job-related quality problems.

The second type of worker participation is the labor-management consultation system, a representational form of participation by union officials on behalf of employees in which employers and employees discuss management policies and plans.[44] The focus is on improving communications between management and labor, improving working conditions, and stabilizing labor relations. Joint consultation provides a framework in which negotiations on working conditions can be conducted on a continuous basis rather than as a focus of collective bargaining. Participants do not view them as providing the primary basis for increased worker participation in management.

While popular accounts of Japanese labor-management relations highlight labor's input, on closer inspection it can be seen that managerial control is strong. Matters relating to the operation of the firm, production, and personnel are most often settled by company notification or explanation.[45] Management retains its prerogative to act unilaterally but, where possible, uses the joint consultation system to solicit worker and union opinion. Management carefully controls and guides the activities of small group participatory activities, and would resist more direct threats to its prerogatives that might be tried through legislative means.[46] This system is facilitated by a relatively high level of homogeneity in the Japanese population and labor force.

The Japanese system offers several advantages relative to the introduction of new technology. Generally, where new technology is introduced workers are reassigned rather than laid off. However, there are signs that this Japanese practice, which in the past has been an understanding and not contractual in nature, may be changing (see ch. 4). Recently there has been evidence that Japanese workers are becoming more concerned about the impact of new technology on employment. Unions have begun to win agreements aimed at protecting workers against the potential negative effects of automation.

For example, Nissan Motor Co. and auto workers have negotiated what is likely to become a model technology agreement for other unions. It requires "consultation" between labor and management before the introduction of labor-saving automation and prohibits the company from dismissing or laying off workers because of new technology. Nissan promises not to downgrade positions or reduce wages and working conditions, and agrees to provide union members with necessary education and training to facilitate adjustment, in accordance with their aptitude and ability. The fact that this is a written agreement rather than a tacit understanding makes this contract important and unique in Japan.

While quality control circles are widely used in Japan, it is interesting to note that the Japanese companies operating in the United States have been much more cautious about instituting such mechanisms because of differences in the work environment and a much more heterogeneous work force. Where such practices are instituted, they are usually introduced very gradually to allow time for workers to adjust to the information-sharing and to learn the problem-solving techniques of quality circles. The Nissan truck plant in Smyrna, Tenn., which opened in 1983, will be watched carefully as an experiment in Japanese management applied to an American work force. Early reports give it high marks, but some observers suggest that it is too early to evaluate how well it will work over time.

Norway and Sweden

There are several Scandinavian attempts to ensure worker involvement in anticipating and controlling the effects of new technologies on the workplace.

In both Norway and Sweden, workplace legislation is in effect and workers are represented on corporate boards.

In Norway, the unions, employers, and the state have tried to shape the actual direction

[44]Cole, op. cit.
[45]Ibid.
[46]Ibid.

of technological change.[47] The 1977 Working Environment Act gave workers the right of advance notice of all proposed technological changes, access to company data banks, and participation in all decisions that affect the form and content of their jobs.[48]

Legislation has specified conditions to the extent of mandating efforts to avoid undiversified, repetitive work and work that is governed by machine or conveyor belt in such a manner that the employees themselves are prevented from varying the speed of the work. Otherwise "efforts shall be made to arrange the work so as to provide possibilities for variation and for contact with others, for connection between individual job assignments, and for employees to keep themselves informed about production requirements and results."[49]

Technology agreements negotiated by labor and management also affect the ability of workers to influence the direction of workplace technological change.") They establish a variety of rights for workers in the areas of information, training, participation, and bargaining concerning technology-related matters in the workplace. Workers are guaranteed both job-related training and general education about technical systems and their design.

In Sweden, two laws protect employees in relation to workplace changes. The first is the Act on Employee Participation in Decision-making (1977), which obliges the employer to inform and negotiate with the union before making decisions on any major operational changes, including implementation of new technology .5' The second law, the Swedish Work Environment Act of 1978, sets out general demands that can be made with regard to working conditions. It includes basic rules on both the physical and the psychological work environment. An essential point is that employees are to have an opportunity to influence the design of the work environment. The focus is on the working premises, equipment, techniques, and working methods. Both laws are supplemented by collective agreements between employers and employees.

In addition to work environment laws, indications are that the Swedish Government is committed to research in how changing technologies affect workers.[52] The pivotal research institution in the work environment field in Sweden is the research department of the National Board of Occupational Safety and Health. A large proportion of total funds allocated for work environment research in Sweden is awarded by The Swedish Work Environment Fund. Founded in 1972 and financed by means of a payroll tax levied on all employers, the Fund supports research and development, training, and information to improve the work environment in a broad sense, including co-determination (requirement that employers negotiate with unions on any plans for major changes in company activities), psychosocial work environment problems, and work organization.[53]

The Swedish Centre for Working Life is an independent research institute supported by the Fund and the government. It focuses on research problems concerned with individuals and groups in working life, industrial relations, co-determination, the organization of work, and its mode of operation.

A recent summary of considerations and proposals put forth by the Swedish Commission on the Effects of Computerization on Employment and Working Environment, published in April 1981, states:

[47] Leslie Schneider, "Technology Bargaining in Norway." prepared for the Ministry of Local Government and Labor, Oslo, Norway, March 1983,

[48] Robert Howard, "Brave New Workplace," *Working Papers for a New Society*, vol. 7, November-December 1980, p. 28.

[49] Act of 4 February 1977 relating to Worker Protection and Working Environment, as subsequently amended last by Act of 13 June 1980, Directorate of Labour Inspection, Oslo, Norway, November 1980.

[50] Schneider, op. cit.

[51] Kerstin Norrby and Barbara Klockare, The Swedish Agency for Administrative Development, "Decision-making, Assessment of Effects and Participation Regarding Computerization in the Swedish Governmental Administration, a paper to the Conference on System Design, IFIP Working Group, September 1982.

"Dennis Chamot and Michael D. Dymmel, "Cooperation or Conflict: European Experiences With Technological Change at the Workplace" a publication of the Department for Professional Employees, AFL-CIO, Washington, D. C., 1981.

""Programme of Activities and Budget 1981 -82-1983-84," Swedish Work Environment Fund, 1982.

> It goes without saying that the Commission holds the view that all possibilities to influence how computer technology is used should be fully exploited.[64]

This includes the use of industrial robots to eliminate heavy, monotonous, restrained jobs and jobs that are hazardous to health. The Commission also concluded that an increase in the use of computer technology in manufacturing processes increases isolation at work. It endorsed new technology if its use includes both an effort to create a better working environment and co-determination exercised by employees.

West Germany

In West Germany, research in the areas of humanization of work and co-determination are considered to be closely related.[55] The government has funded work humanization projects since 1974, including safety and health and work reorganization. Germany's co-determination law requires that workers be represented by an elected works council that works with management on productivity and other issues. However, the extent to which ordinary employees have input to the works councils is questionable.[56] German managers are legally obligated to negotiate all major decisions at the plant level with the work councils and submit the outcome to the supervisory boards (equivalent to American boards of directors). According to a recent analysis, "Their [German] commitment to technological expertise, enduring customer relationships, long-term results, and the achievement of consensus leads most successful German companies to work closely with their employees in integrating new technology with the capabilities of the work force. "[57]

[54]"From a summary of considerations and proposals put forward by the Swedish Commission on the Effects of Computerization on Employment and Working Environment in its report "Computerization in Industry-Effects on Employment and Working Environment, " April 1981.

[55]Chamot and Dymmel, op. cit.

[56]"Moving Beyond the Assembly Lines," *Business Week*, July 27, 1981, p. 87.

"Joseph A. Limprecht and Robert H. Hayes, "Germany's World-Class Manufacturers, " *Harvard Business Review*, November-December 1982, p. 142.

During the 1960's, the social implications of increasing automation and rationalization measures fueled the debate over the reform of working conditions. In addition to the prevention of accidents and occupational diseases, the improvement of working conditions began to include, for example, ergonomic workplace and machine design, as well as new forms of organization of work permitting greater individual responsibility and more opportunities for acquiring qualifications.

These activities gave rise to the Humanization of Working Life Program in 1974 in the Federal Ministry of Research and Technology and the Federal Ministry for Labor and Social Affairs. The general objective of this research program is to investigate the possibilities for better adapting working conditions to human needs. It combines the goal of establishing improved health protection on the job with that of achieving better opportunities for employees to gain qualifications and develop their abilities. The program includes projects to redesign workplaces where monotony is often combined with time pressure, social isolation, and a low skill requirement.

The program, which is supported at least in principle by all the parties represented in the German Bundestag and by both employer organizations and trade unions, has as its aims:

- to formulate safety data, standards, and minimum requirements for machinery, installations, and workplaces;
- to develop work technologies adapted to the worker;
- to elaborate models for work organization and workplace design; and
- to disseminate and apply scientific findings and industrial experience.

The humanization program has led to increased sensitivity to problems regarding working conditions and work rationalization in industry and administration, and to an interdisciplinary science in the field of labor, It has given rise to projects to improve health protection on the job, in particular projects looking at stress problems and the development of technologies for the reduction of heavy, dangerous, or monotonous work. The program also fosters experiments with new forms of work organization, aimed at new technical and organizational production systems.

The results of humanization research have already been incorporated into national legislation in several cases–e.g., into the 1975 Workplaces Regulation Act and the guidelines governing it. Since mid-1980, the Federal Center for the Humanization of Work has been affiliated with the Federal Center for Occupational Safety and Accident Research as an independent organizational unit. It is responsible for incorporating the results of government-promoted research concerning the humanization of work into everyday working conditions.

One of the workplace areas to be studied is the introduction of robots, with a view to avoiding the creation of jobs that are uninteresting and monotonous for humans and that may entail considerable strain and stress. Continued support is to be given to improved forms of work organization as well as to solution of technical and organizational problems in general.[58]

[58]Alfred Hassencamp and Hans-Jurgen Bieneck, "Technical and Organizational Changes and Design of Working Conditions," a summary of the experiences and results of the West German research program "Humanization of Work," 1982.

Appendix 5A.—Methodology Employed in OTA Case Studies of the Effects of Programmable Automation on the Work Environment

Case 1
Small Metalworking Shops

This case study is based on visits to seven metalworking shops in Connecticut. They were chosen from a group of sites suggested by the Numerical Control Society, a trade magazine, and two interviewees at the job shops themselves. They span a range of shop sizes. Shops were not chosen for study because of their "representativeness"; indeed, the chief selection criterion was that the establishment be particularly advanced, for its size, in the number of NC machines in use. Every shop contacted agreed to participate in the study. The final group of 7 was drawn from a pool of 11 shops that agreed to participate.

Visits lasted from a half day to a full day. At each site, the researchers began by speaking to the president or vice president, generally for an hour or more. Subsequent interviews were held with programers, foremen, working foremen, and shopfloor workers. For the most part, the people interviewed were selected by a manager or foreman based on the research team's preferences for talking to a cross section of the shop's work force. In cases where the researchers asked to speak to a specific person, these requests were honored. At some shops, the interviewers were invited to select any of the employees for interviews.

Interviews were open-ended, based on a prepared interview guide. Generally, they lasted from one-half to 1 hour, with the longest running over 2 hours. Nearly all of the interviews were tape-recorded, with the consent of the interviewees, and most of the quotations used in the report are based on transcripts of the taped interviews. Interviews were held in an office or room in the plant. In some cases, they were conducted in the president's or vice president's office. With very few exceptions, the interviewers were alone with the interviewee. All interviews except one focused on one person only; at one plant, the president and vice president were interviewed together.

Altogether, four presidents, four vice presidents, five programers. five foremen and working leaders, one quality control supervisor, one full-time machine repairer, and fifteen machinists and operators were interviewed.

Agricultural Equipment Company

This case study is based on data gathered during a 6-day trip to the city in which the components plant and the nearby tractor assembly facility are located. Three days were spent touring the company's manufacturing facilities and conducting interviews with members of management. The balance of the visit was spent interviewing members of the local union.

The company was extremely cooperative, providing the research team with an excellent overview of plant operations and affording them freedom to explore areas of particular interest in greater depth. The first 2 days were spent gaining a broad introduction to the components plant and the tractor assembly facility, and the third day was spent in followup investigation and interviews, particularly at the site of the flexible manufacturing system (FMS). Interviews were conducted with company personnel ranging from the vice president for manufacturing to first-line supervisors in the tractor assembly plant. Also interviewed were the plant manager; the managers of manufacturing engineering, mechanical services, and process and tooling; several supervisory personnel; and the project manager and systems manager for the FMS—all at the components plant. Interviews were also conducted with the plant manager, manager of manufacturing engineering, and the controller at the tractor assembly plant.

Interviews were open-ended, based on a prepared interview guide but tailored to the individual being interviewed, and lasted from 15 minutes to several hours. Tours and interviews were supplemented by several brief presentations by company personnel focusing on different aspects of automation at the company, by written materials supplied by the company, and by relevant articles and information obtained by the researchers from other sources.

The worker interviews on which this study is based were arranged by the union, the United Automobile Workers, and carried out in the local union hall. The local union was very cooperative about arranging interviews and providing the space in which to conduct them. A semistructured open format, similar to that used at the company but designed specifically for interviewing workers, was used to interview people both individually and in groups. The union was asked to arrange interviews with workers from the FMS area and from those utilizing the company's labor reporting system. Also requested were interviews with workers from the components plant and the tractor works, in skilled trades as well as production, of varying ages and seniority. A total of 18 workers were interviewed through the union. In this situation selection bias was unavoidable, but the workers interviewed appeared to represent a range of viewpoints with respect to computerized technology.

Even the workers who were most critical of the way in which the company was implementing new programmable technologies expressed a basic respect for the company and its management.

Commercial Aircraft Company

The fieldwork for this case was conducted during an 8-day visit to the west coast in April 1983. Before the arrival of the research team, contact was made with the company and with the two major unions at the research sites, the international Association of Machinists and a professional engineers' association. Both the company and the unions were very cooperative, allowing access and arranging interviews which form the basis of the analysis.

At the company, a series of interviews had already been scheduled when the researchers arrived. Interviewees were selected by the company management based on the researchers' request for interviews with a wide range of managerial personnel, from higher level management involved in the implementation and management of computerized technology to first-line supervisors in production departments where programmable automation was in use. These interviews were supplemented with additional interviews arranged at the request of the research team during the 5-day visit to the company. All interviews with members of management were conducted at or near the worksite of the particular manager or supervisor, with a member of management, who acted as host to the research team, present at the interview.

Interviews were open-ended, and their structure was based on an interview guide prepared before the start of the visit. The actual content of each was tailored to the particular individual being interviewed, based on his role in the company. The length varied from one half hour to several hours in length. In some cases, a tape recorder was used, and all lengthy quotations are transcribed from the tapes. A few of the interviews were preceded or followed by prepared presentations which outlined the features of a particular computerized system or technology-related issue at the company. Followup interviews, where necessary, were conducted by telephone, and additional written material was obtained from the company. Company sources were also supplemented with written material available elsewhere.

Interviews with union members were conducted through the auspices of the two unions. Interviewees were chosen by the unions, based on general guidelines set by the research team. The researchers asked to interview members of the bargaining unit who were affected by new technology, particularly engineers affected by the use of computer-aided design, and machinists and other workers (e.g., inspectors, programmers, and layout workers) affected by computerized technology, especially NC. Because of the way in which interviewees were selected, the workers interviewed cannot be viewed as being a randomly selected sample of all workers at the company. While some attempt was made to ensure that a range of views was represented, the intention of the researchers was to capture a sense of the variety of reactions to programmable automation in a few selected work areas, rather than to attempt in a very brief visit to assemble a "representative" group.

Interviews with union members were conducted at or near the union hail, and were, like the interviews with managers, open-ended, Again, an interview guide was used, and the specific questions adapted to the particular employees interviewed. Most interviews were group interviews, and all were tape-recorded. Generally, interviews with union members lasted from 1 to 2 hours, depending on the size of the group.

In total, interviews were conducted with 14 members of management, 4 first-line supervisors, 6 engineers and technicians, and 38 shop floor employees, as well as with officers of both local unions, including the presidents.

The Auto Company

The 3-day visit to the auto plant took place in May 1983, and included an introductory discussion and tour of the plant conducted by the Personnel Department and a brief interview with the plant manufacturing engineering manager on the third day. The research team spent the remainder of the 3 days interviewing workers, shop floor managers, union stewards, and union committeemen who work in the automated welding facility—the "body shop. "

Throughout the visit, both management and the union cooperated completely with the research team. The plant management permitted unrestricted access to the body shop. The superintendents in the body shop, in turn, allowed unrestricted access to supervisors and workers. This access included the freedom to move independently around the shop floor and to speak with workers on break at their workstations. Only through this unique cooperation was the research team able to gain, in a brief time period, a detailed knowledge of how automation affected individual jobs and how the workers on these jobs perceived the affects of the system.

During the 3 days, the research team interviewed:

- the welder repair and production superintendent;
- two welder repair general foremen and one welder repair foreman;
- one production general foreman and one production foreman;
- three welder repairmen;
- 19 production workers (6 first-shift workers were interviewed for more than an hour at the union hall and an additional 15 to 45 minutes on the job; the remainder were interviewed either in the union hall or in the plant);
- the production and skilled trades' union stewards on first shift, and the production and skilled trades committeemen; and
- a number of other managers, union officials, and workers with knowledge of some aspects of automation and the body shop.

The group above represented about 30 percent of the production workers, 15 percent of the skilled tradesmen, 70 percent of the supervisors, and all of the union officials with first-shift responsibilities in the part of the body shop containing robots.

Interviews with supervisors, union officials, and workers were open-ended and loosely structured, based on a prepared interview guide, The interviews at the union hall were taped, with the consent of the interviewees. The quotations used in the report are from the taped interviews or from notes taken during the meetings by someone other than the principal interviewer. The research team conducted followup interviews of 15 to 45 minutes with certain individuals on the second and third day. Additional followup interviews were conducted with union officials and body shop supervisors over the telephone. An interview of the corporation's director of manufacturing was also conducted over the telephone.

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