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ABSTRACT

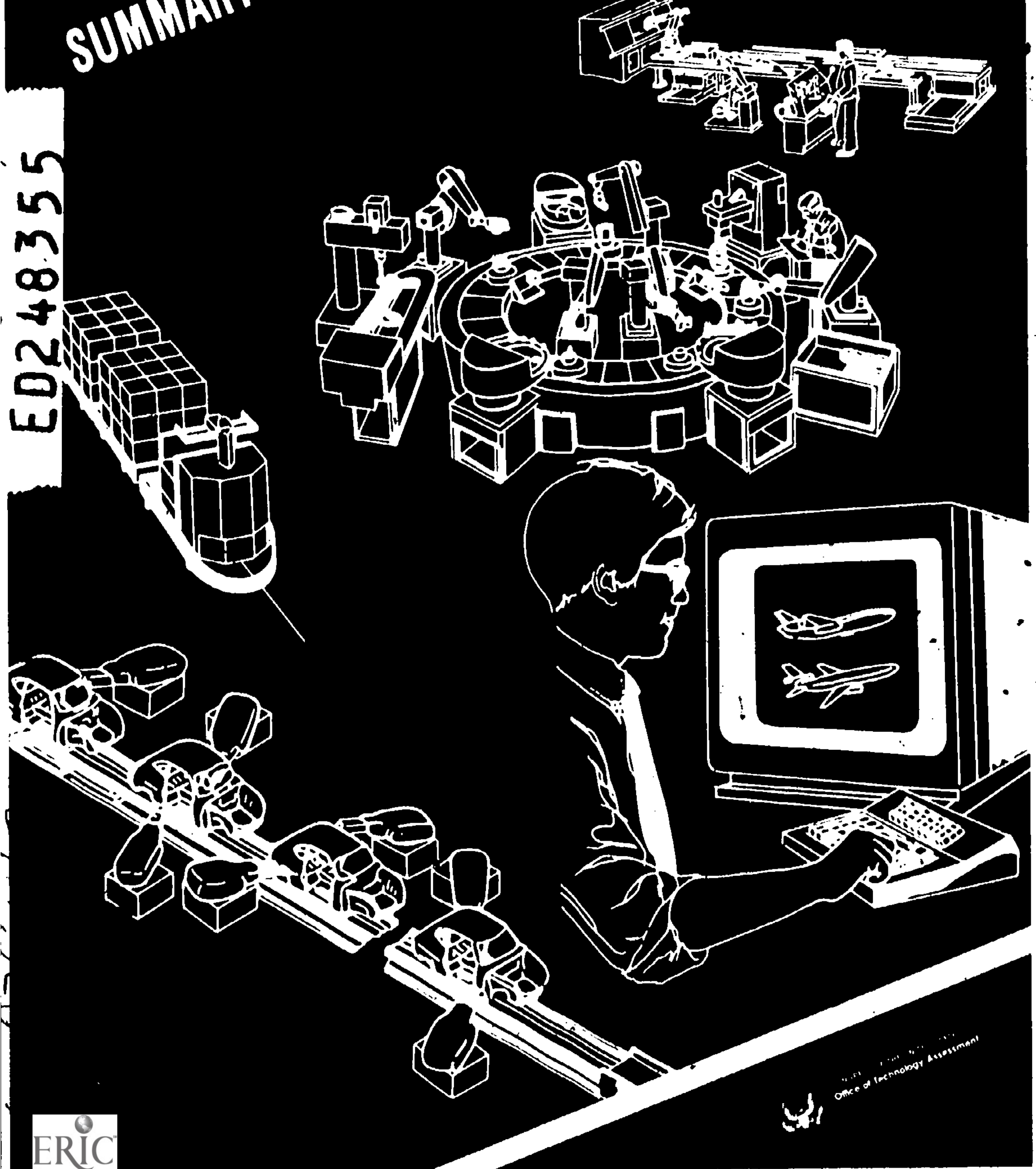
The application of programmable automation (PA) offers new opportunities to enhance and streamline manufacturing processes. Five PA technologies are examined in this report: computer-aided design, robots, numerically controlled machine tools, flexible manufacturing systems, and computer-integrated manufacturing. Each technology is in a relatively early stage of development and even earlier stages of application. PA is not likely to generate significant net national unemployment, but its use may exacerbate regional unemployment problems. Due to PA, the white-collar work force will constitute a larger proportion of manufacturing employment. The introduction of PA will create situations that have negative psychological effects on the work force but will tend to have a favorable impact on the physical surroundings of work. PA will reshape instructional services and create new demands for high quality education, training, and retraining programs; career guidance; job counseling; and placement services. PA industries concentrate on software and customer services and are characterized by high levels of interchange between firms. Both industry and government fund a broad range of PA research and development. Successful Federal policy regarding PA must mesh actions in several areas through a multifaceted strategy. (YLB)

CE

COMPUTERIZED MANUFACTURING AUTOMATION

EMPLOYMENT, EDUCATION, AND THE WORKPLACE

SUMMARY



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Foreword

This assessment culminates OTA's examination of the technical, economic, and social issues surrounding the spread of programmable automation in manufacturing. Its genesis was a public workshop in 1981 on robotics that resulted in the OTA Background Paper entitled *Exploratory Workshop on the Social Implications of Robotics* (February 1982). The assessment was requested by the Joint Economic Committee, the Senate Committee on Labor and Human Resources, the Senate Committee on Commerce, Science, and Transportation, and the Subcommittee on Labor Standards of the House Committee on Education and Labor. It was endorsed by the House Committee on Science and Technology. The assessment looks not only at robots but also at related computer-based technologies for design, production, and management.

The technologies of programmable automation, their uses, and future capabilities are described in this report. The assessment goes beyond technology description to characterize the industries producing and using programmable automation and to discuss the ramifications of the technologies for industrial structure and competitive conduct. It pays special attention to three labor-related areas: the potential for employment change, effects on the work environment, and implications for education and training. Preliminary work in those areas, including conceptual discussions and background material, was published in the OTA Technical Memorandum entitled *Automation and the Workplace: Selected Labor, Education, and Training Issues* (March 1983). Since the development and sale of programmable automation have been international phenomena since at least the 1960's, comparisons between this country and others are made as far as data allow.

A wide range of sources contributed to this assessment. While OTA drew on existing literature and conferences, it also developed its own information through workshops on labor markets, programmable automation technologies, and programmable automation (producer) industries; and through informal site visits and consultations. Eighteen case studies, including 4 on the work environment and 14 on education and training programs, and a survey of education and training activities commissioned for this assessment were particularly rich sources of data. Case study material will be made available in a companion volume.

OTA is grateful for the assistance of the assessment advisory panel, workshop participants, contractors, and many others who provided advice, information, and reviews. The cooperation of individuals at case study sites, who accommodated lengthy site visits and follow-up consultations, is especially appreciated. OTA assumes full responsibility for this assessment, which does not necessarily represent the views of individual members of the advisory panel.

John H. Gibbons

JOHN H. GIBBONS
Director

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Roy Amara, *Chairman*
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William D. Beeby
President
William Beeby & Associates, Inc.

Erich Bloch
Vice President, Technical
Personnel Development IBM Corp.

Barbara A. Burns
Manufacturing Technology
Group Engineer
Lockheed Georgia

Jack Cahall
Manager, Training and
Development
Cincinnati Milacron, Inc.

Dennis Chamot
Assistant Director
Department of Professional
Employees AFL-CIO

Robert Cole
Director, Center for Japanese
Studies
University of Michigan

Alan E. Drane
Manager of Automated
Systems Emhart Corp.

Audrey Freedman
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United Auto Workers

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SRI International

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Vice President
GCA Corp.

Michael Wozny
Director, Center for Interactive
Computer Graphics
Rensselaer Polytechnic
Institute

Robert Zager
Vice President, Policy Studies
and Technical Assistance
Work in America Institute

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by these advisory panel members. The views expressed in this OTA Report, however, are the sole responsibility of the Office of Technology Assessment.

OTA Manufacturing Automation Assessment Staff

John Andelin, *Assistant Director, OTA*
Science, Information, and Natural Resources Division

Frederick W. Weingarten, *Communications and Information Technologies Program Manager*

Project Staff

Marjory S. Blumenthal, Project Director*

Beth A. Brown, Senior Analyst

Jean E. Smith, Analyst

Jim Dray, Research Assistant

Beth Glassner, Research Analyst

Administrative Staff

Liz Emanuel   Marsha Williams   Shirley Gayheart

Contractors and Consultants

Eileen Appelbaum

N. Jeanne Argoff

Industry and Trade Strategies

Massachusetts Institute of Technology: Harley Shaiken, Sarah Kuhn, and Steve Herzenberg

WESTAT

Courtland S. Lewis (editor)

*Zalman A. Shavell served as Project Director from April to August 1982.

Automation Technology Workshop

David Grossman
Manager of Automation Research
IBM Thomas J. Watson Research Center

Robert Hocken
Chief, Automated Production Technology Division
National Bureau of Standards

Stuart G. Miller
Manager, Automation and Control Laboratory
Corporate Research and Development
General Electric Co.

Brian Moriarty
FMS Specialist
Charles Stark Draper Laboratories

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Control Data Corp.

Michael Radeke
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Cincinnati Milacron, Inc.

Bernard Roth
Design Division, Mechanical Engineering Department
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Ali Seireg
Department of Mechanical Engineering
University of Wisconsin-Madison

Richard Simon
Director, Product Management
CAM Systems
Computervision Corp.

Theodore J. Williams
Director, Laboratory for Applied Industrial Control
Purdue University

Automation Industries Workshop

Kenneth Anderson
Publisher
Anderson Reports

Laura Conigliaro
Vice President
Prudential-Bache Securities, Inc.

Joseph Franklin
Statistical Director
National Machine Tool Builders Association

Eli Lustgarten
Vice President
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Carl Machover
President
Machover Associates Corp.

Bernard M. Sallot
President
Advance Technologies Group Services

Dennis Wisnosky
Vice President
GCA Corp.

Labor Markets and Industrial Relations Workshop

Eileen Appelbaum
Department of Economics
Temple University

Steven Confer
Consultant
Communications Workers of America

William Cooke
Krannert School of Management
Purdue University

Faye Duchin
Institute for Economic Analysis
New York University

Alan Fechter
Executive Director
Office of Scientific and Engineering Personnel
National Research Council

Sheldon Friedman
Director, Research Department
United Auto Workers

Louis Jacobson
Center for Naval Analyses

Michael Pilot
Manager, Office of Occupational Outlook
Bureau of Labor Statistics

Markley Roberts
Economist
AFL-CIO

Myron Roomkin
Kellogg School of Management
Northwestern University

Jim Smith
Labor and Population Program
Rand Corp.

Computerized Manufacturing Automation: Employment, Education, and the Workplace

Computer technology offers new opportunities to enhance and streamline manufacturing processes. Many industry observers believe that computerized manufacturing automation will help troubled U.S. manufacturers become more productive and competitive. At the same time, this new wave of automation is raising concerns similar to those that accompanied the first wave of automation technology in the 1950's and 1960's. Will the new technologies put a significant number of people out of work? Will their introduction "dehumanize" the work environment for those who remain? And how can the United States best prepare its education and training system to respond to the growing use of computerized manufacturing automation?

Though manufacturing automation technologies can be applied in a wide range of industries, the focus of this report is the application of programmable automation (PA) in discrete manufacturing—the manufacture of discrete products ranging from bolts to aircraft. Most traditional metalworking industries fall in this category, although other materials (e.g., plastics, fiber composites, ceramics) are increasingly important parts of discrete manufacturing as well. Discrete manufacturing plants are often characterized by the quantity of a product which they produce, ranging from mass production of hundreds of thousands of products, to batch production of a few dozen or a few hundred, to custom production of a single item. Because of its ability to perform a variety of tasks, programmable automation is usually associated with batch production. However, it has been used extensively in mass production, and it could be useful in custom production as well.

PA tools differ from conventional automation primarily in their use of computer and communications technology. They are thus able to perform information processing as well as physical work, to be reprogramed for a variety of tasks, and to communicate directly with other computerized devices. PA is divided into three general categories: 1) computer-aided design; 2) computer-aided manufacturing (e.g., robots, computerized machine tools, flexible manufacturing systems); and 3) computer-aided techniques for management (e.g., management information systems and computer-aided planning). When used together in a system with extensive computer-based coordination, these tools are known as computer-integrated manufacturing.

Three principal themes have emerged from OTA's study:

1. **Programmable automation is an important and powerful set of tools, but it is not a panacea for problems in manufacturing.** In part because of historic U.S. strengths in manufacturing, and because the prestige of manufacturing engineering is low relative to other engineering fields, U.S. companies have devoted relatively little effort to improving manufacturing processes in the past few decades. This neglect must be remedied in order to realize the full benefits of PA. In addition to using automation, other steps that need consideration by management include redesigning products for more efficient production, minimizing inventory levels, and improving job design and labor relations.
2. **The change in national employment induced by programmable automation will not be massive in the near term (i.e., the remainder of the 1980's).** Although the rate of application is accelerating, aggregate use will still be relatively limited for the rest of this decade. Also, the capabilities of PA remain immature. Depending on macroeconomic conditions, use of automation can increase without significant growth in national unemployment. However, PA will exacerbate unemployment problems for individuals and regions. The potential long-term impact of PA on the number and kind of jobs available is enormous, and it is essential that the Federal Government, educational institutions, and industry begin to plan with these considerations in mind.
3. **The impact of programmable automation on the work environment is one of the most significant, yet largely neglected issues.** Depending on how it is designed and used, PA can substantially change the nature and organization of the manufacturing workplace, and consequently influence levels of job satisfaction, stress, skills, and productivity. The Federal Government has traditionally had a role in workplace concerns, and could take action to help ensure that the work environment effects of PA are favorable.

Principal Findings

The Technologies

This report emphasizes five of the PA technologies. **Computer-aided design** (CAD) in its simpler forms is an electronic drawing board for draftsmen and design engineers. In its more sophisticated forms CAD is the core of computer-aided engineering, allowing engineers to analyze a design and maximize a product's performance using the computerized representation of the product.

Industrial **robots** are manipulators which can be programed to move objects along various paths. Though robots receive a great deal of popular attention, they are only a small part of the family of PA tools.

Numerically controlled (NC) machine tools are devices that cut or form a piece of metal according to programed instructions about the desired dimensions of a part and the steps for the process. **Flexible manufacturing systems (FMSs)** combine a set of workstations (usually NC machine tools) with robots or other devices to move material between workstations, and operate under central computer control. Finally, the use of PA tools for design, manufacturing, and management in an integrated system, with maximum coordination and communication between them, is termed **computer-integrated manufacturing** (CIM).

The advantages of PA for management lie primarily in its ability to **facilitate information flow, coordinate factory operations, and increase efficiency and flexibility**. Further, the technologies promise an increase in management's degree of control over operations. The more closely tied manufacturing processes are to one another, and the more information about those processes is readily available, the less chance there is for human error or discretion to cause problems. However, this drive toward increased control can also reduce opportunities for constructive work input and degrade the work environment.

Each of these technologies is in a relatively early stage of development, and even earlier stages of application. Robotics is well established only for spot welding, spray painting, and some materials handling uses; NC machine tools and CAD are somewhat more mature technically, although there are still many unsolved problems. FMS and CIM are very young; virtually every application is a prototype. As systems, their potential benefits and problems are much greater than those of stand-alone automation equipment. Because of their complexity, the implementation of integrated automation systems requires extensive planning and support.

Though current technology is adequate for the vast majority of near-term uses, the level of penetration of PA into possible applications is relatively low. Technical factors that tend to slow the rate of adoption of PA technologies include its complexity, the lack of standard programing languages and interfaces between PA devices, and problems in "human factors" (essentially, the system's ease of use). A wide variety of nontechnical factors also affect the use of PA, including the availability of capital and know-how, organizational resistance to change, and the availability of appropriate education and training programs.

For various reasons, most manufacturers choose to apply automation in a stepwise fashion, beginning perhaps with one or a small number of robots, CAD terminals, or NC machine tools. Though in many cases these "islands of automation" can result in productivity and quality improvements, the full benefits of PA are only realized when these devices are connected into an integrated system. Such integrated systems are more than the accumulated substitution of PA tools for human workers or for other machines; they often involve redesigning the product or streamlining the production process itself to best make

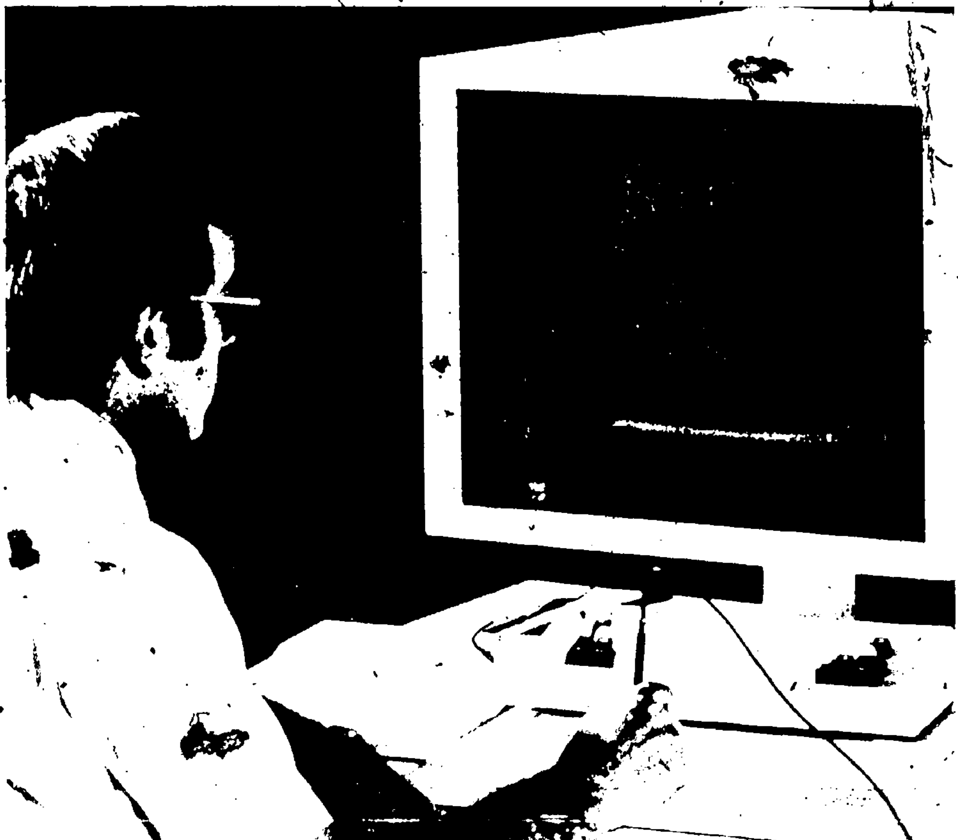

Photo credit Cincinnati Milacron Corp

An engineer using a computer-aided design system

use of PA. Because an integrated system can produce more products more quickly than other manufacturing schemes, manufacturers can reduce their investment in finished product and work-in-process inventories. **These and other materials savings are often more significant than labor savings in the use of programmable automation systems.**

Researchers are working to increase the versatility and power of PA tools, to enhance their capability to operate without human intervention, and to develop the ability to integrate the tools. While there has been progress in virtually all key technical areas, the problems are sufficiently numerous and complex to keep researchers busy for many years to come. **An analysis of expected trends in the technologies indicates, however, that many important technical advances in programmable automation are expected in the 1990's** (see table 1).

Though there is much discussion of "unmanned factories," experts differ about whether the removal of virtually all humans from the manufacturing process is necessary or desirable. Some express concern that manufacturers will be preoccupied with removing humans from the factory floor at the expense of more practical and cost-effective improvements in manufacturing processes. In any case, each factory

Table 1.—Programmable Automation: Selected Projections for Solution of Key Problems
(excerpts from tables 11-15—of full report)

	Current (1984)	1985-86	1987-90	1991-2000	2001 and beyond
1) Low-cost, powerful microcomputer-based workstations for:[a]					
a) electronics design	▲	●	■		
b) mechanical design		▲	●	■	
2) 3-D vision in structured environments which have been planned to simplify the vision task	▲ ●		■		
3) 3-D vision in unstructured complex environments which have not been planned to simplify the vision task			▲	●	■
4) FMS for:[b]					
a) cylindrical parts production	▲ ●			■	
b) sheet metal parts production	▲ ●			■	
c) 3-D mechanical assembly	▲			● ■	
d) electronics assembly	▲ ●		■		
5) Standardization of interfaces between wide range of computerized devices in an integrated factory			▲	●	■
6) Computerized factories which could run on a day-to-day basis with only a few people in management, design functions					▲

[a]Microcomputer-based workstations for CAD are now being marketed, but in the judgment of technical experts consulted by OTA, they are either not powerful enough and/or not inexpensive enough to be useful in a wide variety of applications.

[b]Almost all FMSs currently running are used to machine prismatic parts (e.g., engine blocks), which are those whose outer shape consists primarily of flat surfaces. The projections in this entry refer to FMS for quite different applications: a) machining of cylindrical parts, such as rotors and driveshafts (or "parts of rotation" in machining jargon, since they are generally made on lathes); b) stamping and bending of sheet metal parts, such as car body panels; c) assembly (as opposed to fabrication of individual parts) of three-dimensional products, such as motors; and d) assembly of electronic devices, such as circuit boards. While machines currently exist for automatic insertion of electronic parts into circuit-boards, an electronics FMS would integrate the insertion devices with soldering and testing equipment.

▲ – solution in laboratories.
● – first commercial applications.
■ – solution widely and easily available (requiring minimal custom engineering for each application).

SOURCE: OTA analysis and compilation of data from technology experts.

has peculiar characteristics which call for different levels of automation. For some factories it has been possible to run machine tools at night with only one person in a control room. **For at least the next 10 to 15 years, discrete manufacturing factories operating without production workers (i.e., with only a few managers, designers, and troubleshooters) will be only a remote possibility.**

Employment Effects

Programmable automation is not likely to generate significant net national unemployment in the near term, but its use may exacerbate regional unemployment problems, especially in the East North Central and Middle Atlantic areas where metalworking industries are concentrated.

The level of automation in manufacturing is one of many factors that influence industrial employment. In particular, **it should be recognized that employment in an industry is a strong function of the volume of production.** Technology is a secondary influence that governs the mix of people, equipment, and materials needed to produce a given amount of product. Hence, although PA is labor-saving, the aggregate number of jobs in an economy must be examined in the context of overall economic conditions. These conditions include short-term business cycles as well as long-term shifts in the strengths and structures of different industries, plus levels of imports and exports. Thus, the favorable effects of PA on industrial competitiveness may help to increase demand for labor or to avert job losses that could occur in its absence.

Evaluating the employment effects of PA poses serious analytical problems. There are shortcomings in current approaches for this analysis, and **data available support only inferences as to the general directions of likely occupational and industry employment change.**

Employment change will depend on a series of complex effects on jobs. Those effects will be realized as changes in the tasks that people will do, changes in the requirements for skill, and changes in the ways managers aggregate tasks into jobs and assign them to people trained for different occupations. The scope of change may be neither obvious nor immediate, because PA will often be accompanied by significant transformations of manufacturing organization, production processes, and/or product design. The more extensive such transformations, the broader the set of people affected by the introduction of PA, and the harder it is to attribute employment effects to PA, per se.

Change in skill requirements will often reflect a shift from manual to mental work. In many cases, PA will lower the time required for people to become proficient at a task, and it may lower the amount of judgment needed. At the same time, it may lead to a requirement for general knowledge of several tasks, broadening the mix of skills needed. For example, it is likely that PA maintenance personnel will need to know how to solve mechanical, electrical, and electronic problems rather than one class of problems alone.

The fewer the tasks comprising a job, the more likely it is that programmable automation can eliminate the need for a given job. For example, spot welders who only do spot welding, are more likely to be displaced by spot-welding robots than if they do other tasks as well. However, PA offers new potential for combining diverse tasks into jobs instead of fragmenting work into narrowly defined jobs, as has historically been associated with mechanization. It raises the prospect of a tradeoff between larger numbers of narrowly defined jobs and smaller numbers of more broadly defined jobs.

A major influence on employment is the supply of labor, which will grow more slowly during the next decade or so, in large part because of slower growth of the population and an increase in the average age. The supply of younger workers will decline, diminishing competition for entry-level jobs, while the proportion and number of prime-age workers (25 to 54 years) will grow.

From early indications, it appears that PA will cause the following broad, long-term trends in occupations:

- **demand for engineers and computer scientists, technicians, and mechanics, repairers, and installers on the whole will rise**—although specific occupations (e.g., drafters) will face diminishing opportunities;
- **demand for craftworkers (excluding mechanics), operatives, and laborers—especially the least skilled doing the most routine work—will fall;**
- **demand for clerical personnel will fall; and**
- **demand for upper-level managers and technical sales and service personnel will rise,** although lower- and middle-management opportunities among users of PA may fall.

Table 2 lists 1980 levels of employment for occupations most likely to experience changes in demand. Taken together, these effects suggest major shifts in the occupational mix of manufacturing industries, especially metalworking. **Overall, the salaried or white-collar work force will constitute a larger proportion of manufacturing employment,** although it is not clear how much their ranks will grow in absolute terms. PA producers especially are likely to employ relatively few production personnel; their situation may signal future patterns among other firms and industries. Consequently, **there will be few opportunities for people displaced from other manufacturing industries to move into jobs among producers of automated equipment and systems.**

In many ways, the shifts in occupations will not be straightforward. Some skills may only be required temporarily, after technology has been introduced but before further automation is achieved. For example, when automated equipment is used in isolated applications,

Table 2.—1980 Employment for All Manufacturing Industries, Selected PA-Sensitive Occupations

	Number	Percent	Long-term direction of change
Engineers	579,677	2.85	+
Electrical	173,647	0.85	+
Industrial	71,442	0.35	+
Mechanical	122,328	0.60	+
Engineering and science technicians	439,852	2.16	+
Drafters	116,423	0.57	−
NC tool programers	9,371	0.05	−
Computer programers	58,622	0.29	−
Computer systems analysts	42,404	0.21	+
Adult education teachers	5,165	0.03	+
Managers, officials, and proprietors	1,195,743	5.87	[illegible]
Clerical workers	2,297,379	11.28	−
Production clerks	139,947	0.69	−
Craft and related workers	3,768,395	18.51	−
Electricians	126,001	0.62	+
Maintenance mechanics and repairers	391,524	1.92	+
Machinists, tool and die makers	356,435	1.75	−
Inspectors and testers	538,275	2.64	−
Operatives	8,845,318	43.44	−
Assemblers	1,661,150	8.16	−
Metalworking operatives	1,470,169	7.22	−
Welders and flamecutters	400,629	1.97	−
Production painters	106,178	0.52	−
Industrial truck operators	269,105	1.32	−
Nonfarm laborers	1,576,576	7.74	−
Helpers, trades	100,752	0.49	−
Stockhandlers, order fillers	104,208	0.51	−
Work distributors	16,895	0.08	−
Conveyor operators	31,469	0.15	−

NOTE: Data pertain to wage and salary workers.

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990 Alternatives," unpublished data.

there may be many needs for programing. But, the integration of design with process planning and production systems reduces the need for programing, as does the development of standard, easy-to-use software packages. These "short-term" phenomena may persist for many years, making it hard to plan for long-term employment change.

The effects of PA on compensation patterns are ambiguous, partly because numerous other changes are occurring in the economy. Over the past decade, there appears to have been an erosion of medium-wage jobs, and clustering of jobs at both high- and low-wage levels. Analysts attribute this in part to the proliferation of low-wage service jobs, and in part to growing separation of administrative and production functions in manufacturing. PA will likely stem the latter trend by helping to integrate administrative and production activities. Other developments, such as slower growth in the labor force participation of women (who filled the bulk of the new, low-paying service jobs created in the past decade), may also serve to alter past trends.

Finally, compensation patterns will depend on the length of the average work week. Whenever it appears that there may not be enough jobs, or enough well-paying jobs, to occupy job-seekers, it is often proposed that average work hours be reduced to allow more people to hold jobs. However, the average work week cannot necessarily be reduced without lowering the real wages per employee.

In light of the attention given to the Japanese, who use PA extensively and who have expanded production, it is instructive to see how their work force has been affected. Japanese companies have displaced labor, but displacement has often been masked by shifting relationships between manufacturers and suppliers, and by selective layoffs that affect primarily female, middle-aged, and older personnel.

Work Environment

Application of computers to the manufacturing workplace offers a range of options for organizing work in ways that will enhance the workplace. PA, in particular, 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. **Although historically U.S. manufacturers have tended to place a lower priority on work environment issues, there is a growing awareness among manufacturers that attention to the work environment ultimately has payoffs in productivity.** Work environment issues may become more important to the public, meanwhile, as changing employment patterns reduce the opportunities for personnel to move out of unsatisfactory manufacturing jobs into others.

The various forms of PA have both positive and negative effects on the safety and health of workers. **The introduction of programmable automation will create new situations, or perpetuate old ones, that have negative psychological effects on the work force.** Two of the principal effects are boredom and stress. 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. In sites visited for OTA work environment case studies, it was evident that both FMSs and NC machine tools can cause boredom when there is no immediate need for operator intervention and application of problem-solving skills. In addition, skilled NC operators who did not write programs reported that operating an NC machine was significantly less challenging than operating a conventional machine.

Work-related stress is a significant feature of computer-automated workplaces. Stress is associated with working on very complicated, expensive, and highly integrated systems, and with lack of autono-

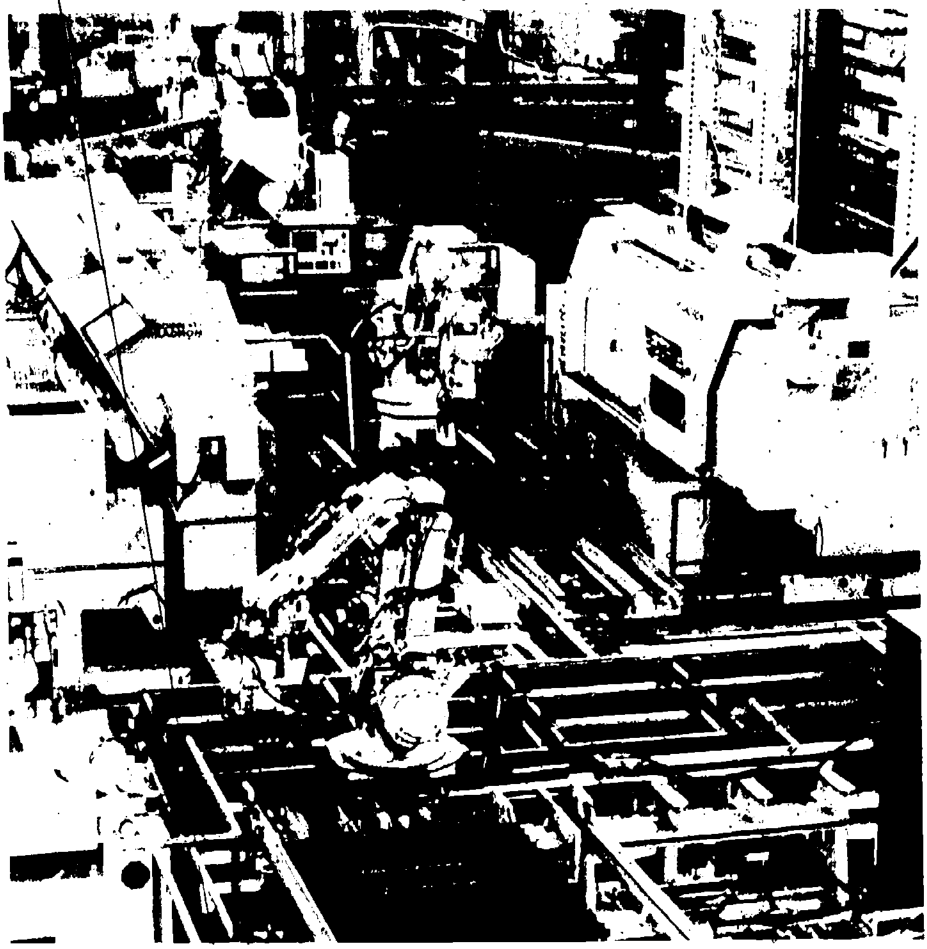

Photo credit Cincinnati Milacron Corp

A "machining cell," consisting of computerized robots and machine tools, manufactures printing press parts

my at work, extending in some cases to computerized monitoring by management. The combination of the complexity of the system and the pressure to minimize downtime because of the high cost of lost production adds up to substantial stress for some maintenance workers. Although each situation is different, excessive boredom and/or stress can often degrade the productivity of individual workers.

On the other hand, the introduction of programmable automation tends to have a favorable impact on the physical surroundings of work. For instance, robots are amenable to hazardous tasks in environments that are unpleasant and unhealthy for workers. However, certain precautions are necessary to avoid potential new safety hazards. In response to concerns about robot safety, groups in the United States, Western Europe, and Japan are providing guidelines for the safe use of robots.

Since the introduction of PA will increase the number of workers using video display terminals (VDTs) and reduce the number operating production machinery, the concerns that are currently being raised about potential VDT hazards apply to a whole new set of workers, including CAD operators. Although there is no evidence that VDTs emit unsafe levels of radiation or that VDT use is hazardous to vision, increased stress levels due to prolonged use of VDTs have been reported, and further study of the long-term effects of VDT use is necessary.

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 less subject to the subtleties of individual personalities. The relief of such symptoms as boredom and stress is more difficult, because they are not well understood and are often complicated by other factors not related to the workplace. **Depending on how tasks are arranged and jobs designed, programmable automation has the potential to decrease the amount of autonomy, control, and challenge available to the worker, or it can increase variety and decisionmaking opportunities.**

Management's strategies and motivations for introducing programmable automation are key in determining its impacts. In addition, the nature of labor-management relations will affect the implementation of new technology and its consequences for the work environment. In work environments that are becoming more and more automated, management is likely to seek increasing flexibility in deploying workers. This will be reflected in collective bargaining demands from management for changing work rules, in return for union demands for such employee benefits as job security. Formal labor-management cooperation in solving workplace problems has been growing in the United States. Where successful, these participative arrangements are likely to have a positive influence on the effects of new technology in the workplace, especially in the areas of job design, changing skills, and training.

In Europe and Japan, mechanisms for dealing with workplace concerns have generally been applied to the introduction of new technology. In many cases, laws specify how such introduction is to be handled. For example, the laws of West Germany, Norway, and Sweden provide for worker involvement in technological change, 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 those of the United States, especially in the area of labor-management relations. These differences limit the transferability of foreign practices.

Education, Training, and Retraining Issues

Programmable automation is one of a number of forces that will reshape instructional services in the United States in the years ahead and create new demands for high-quality education, training, and retraining programs, as well as career guidance, job counseling, and placement services.

A prerequisite of PA-related instruction of all types is a strong foundation of basic skills—particularly reading, science, and math. The high level of functional illiteracy in the United States population is a major barrier to development of PA-related skills. Basic skills deficiencies have already surfaced as a problem in retraining some displaced manufacturing workers for jobs working with PA.

Analytical and problem-solving skills are increasing in importance for some skilled trades personnel and technicians, as well as other occupational groups common to automated facilities. Many who work with PA find themselves using conceptual skills more than motor skills. However, it is uncertain to what extent PA will require a substantial increase in the aggregate level of problem-solving and conceptual skill. As noted earlier, choices for implementing the technology can result in wide variations in worker input and control, and consequently a range of skill requirements.

Development of multiple skills and the "cross-training" of workers to perform a variety of functions on the shop floor are emerging instructional requirements for automated facilities, although not reflected as yet in many established instructional programs. Beyond acquiring a familiarity with PA, engineers in automated facilities need to develop an understanding of the entire design-to-manufacturing process and of how computerized equipment may be integrated with other machines and people for maximum efficiency and productivity. Continued industry pressure for more effective technical managers may well lead to greater emphasis on the development of management skills in industrial engineering and computer science education programs.

There is an immediate need for retraining and job counseling programs geared to the unique needs of displaced workers. In the past, many programs for displaced workers have failed to assess their existing competencies and provide opportunities to strengthen basic skills. As a result, participation rates have been low and dropout rates high in such retraining programs.

Ongoing changes in workplace skill requirements attributable to programmable automation and other factors point to the need for effective education and career guidance services for youth and adults. Individuals need access to current, reliable labor market information in order to make informed career choices and to pursue appropriate avenues of occupational preparation. The potential for frequent job change within the same economic sector or across sectors suggests that the numbers of adults seeking job counseling and placement assistance will increase dramatically in the years ahead. At present, there are few programs that provide these kinds of education and career guidance services to youth and adults on an ongoing basis.

While some institutions and organizations are providing PA instruction that addresses current skills requirements of computer-automated facilities, there are as yet no standard approaches to curriculum. A com-

mon characteristic of successful programmable automation instructional programs examined by OTA was close cooperation and collaboration among educators, industry, labor, and government in assessing needs, developing curricula, and other activities.

On the whole, the U.S. instructional system may not now be able to accommodate the potential demand for PA-related skills, which may in turn affect the rate of growth in PA applications. Shortages of technical instructors, state-of-the-art equipment and other resources are major problems for all segments of the instructional system, including industry-based education and training.

Programmable Automation Industries

While PA industries vary in size, there appear to be several hundred vendors in all. PA firms range from small companies supplying products to meet specialized market niches, to automation "supermarket" firms that offer multiple forms of PA. Many PA vendors are so-called turnkey firms, which package components made by different companies with software and other features into standard or customized systems. Small, innovative firms have played a key role as PA producers.

CAD, NC, robots, and other PA equipment and systems are sold by industries that are more or less separate. NC is the oldest and largest industry, dating from the 1950's. While CAD and robots were available by the 1960's, significant markets for them did not emerge until the 1970's. Markets for other PA products also began to flourish in the 1970's.

Although they grew slowly during the 1960's and early 1970's, **programmable automation markets grew rapidly in recent years and are expected to continue to do so.** Hence, it is hard to describe firms and industries in enduring terms. Moreover, as individual companies expand their product offerings and move to offer complementary products, a market for CIM may emerge. No one yet sells "CIM" as a total product, and some in industry contend that users are still pioneering the concept.

PA firms will affect the economy through their relationships with other industries as well as through their role as employers. Much of their economic impact will be realized indirectly, since their principal customers are other businesses that may use PA to improve their own performance. **Programmable automation industries are likely to become increasingly important to the industrial base and national security of the United States, because of increasing dependence on programmable automation both to enhance manufacturing productivity overall and to manufacture defense equipment.**

Competition among PA firms tends to center on software and customer services rather than on hardware features. This reflects growth in sales of PA systems (as opposed to single pieces of equipment). Indeed, PA vendors often rely on outside sources of hardware. They are offering a growing number of pre- and post-sale services, including applications engineering, training, maintenance, and software updates.

Programmable automation industries are characterized by high levels of interchange between firms. Licensing, outsourcing, mergers and acquisition, limited equity investments, and joint ventures are common, and often occur between firms from different countries. In this regard, PA industries are similar to the overall information-processing and electronics products industries. It is likely that vertical integration will continue to be limited and cooperative arrangements will continue to be made because new products are increasingly complex, product changes occur rapidly, and product development costs are growing. In the long term, however, international cross-fertilization may abate in favor of direct foreign investment.

In the near term, the growth of domestic producers of PA depends on whether domestic economic conditions are favorable to investment, and on the ability of U.S. managers to justify the necessary investments. Anticipated reductions in PA costs and growing understanding among managers of the potential benefits and costs of PA are likely to make companies increasingly receptive to PA. **In the long term, competition from foreign firms in domestic and foreign markets may constrain the growth and size of programmable automation industries.** Companies from many countries, often supported by foreign governments, have been involved in PA development and production since the 1960's, and many countries consider PA industries important features of their economies.

Research and Development

Both industry and government fund a broad range of research and development (R&D) in programmable automation. This work is undertaken in industry, university, and government laboratories.

Total Federal funding of automation R&D in fiscal year 1984 is budgeted at approximately $80 million, through four primary Government agencies—the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the National Bureau of Standards (NBS) (see table 3). R&D at both DOD and NASA is strongly mission-oriented (directed toward a particular agency goal), and it has limited applicability to commercial manufacturing. More generic or basic work is conducted through NSF and NBS.

DOD's Manufacturing Technology Program budgeted approximately $56 million in 1984 for work on automation technologies that could save money in defense manufacturing. Two other agencies within DOD, the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR), budgeted approximately $8 mil-

Table 3.—Federal Funding of Research and Development in Programmable Automation, Fiscal Year 1984 (dollars in millions)

Military agencies:	
Manufacturing Technology (ManTech) Program	$56.00
Defense Advanced Research Projects Agency (DARPA)	3.50
Office of Naval Research (ONR)	4.10
Military subtotal	$63.60
Civilian agencies:	
National Bureau of Standards (NBS)	$3.85
National Aeronautics and Space Administration (NASA)	5.90
National Science Foundation (NSF)	6.90-9.20
Civilian subtotal	$16.65-18.95
Total Federal funding	$80.25-82.55

SOURCE: Office of Technology Assessment

lion for research in PA technologies for ultimate use in both defense manufacturing and battlefield applications. **Though DOD work in programmable automation is not intended to be widely applicable to commercial manufacturing, DOD sets themes for technology development in programmable automation. It serves as an informal coordination point for Government agencies and defense industries.**

NASA's automation research concentrates on robotic tools for use in space. The research program is small and focused on technologies that are very sophisticated by commercial standards, though there are occasional spinoffs to commercial manufacturing.

NSF plays a small but important role in funding basic research in PA. The Production Research Program at NSF focuses on automation technologies, while at least a dozen other programs within NSF fund automation-related research to some degree. Total funding for 1984 is estimated to be about $7 million to $9 million.

NBS has a rather unique role in automation R&D in that it is the Government's primary in-house laboratory for such work. NBS pursues automation R&D in standards (e.g., standardization of programing languages and standardization of interfaces between computerized tools), metrology (measurement of parts using computerized devices), and schemes for integrated manufacturing. **NBS' Automated Manufacturing Research Facility, funded largely through DOD, is perhaps the only full-scale testing facility for CIM in the United States.**

Estimates of CAD, robotics, and machine tool industry funding of automation R&D range from $264 million to $400 million in 1983, and they grow rapidly in the future as the industries expand. There is evidence of increased cooperation between industries and universities in the conduct of automation R&D. In particular, university-industry centers for R&D in programmable automation are proliferating.

The United States continues to be a world leader in many areas of R&D, including computer-aided design, software in general, and virtually all

areas of basic research. Japan has developed substantial sophistication in many areas of robotics R&D, while Japan and West Germany are both strong in machine tool research. Both Japan and Western European countries also do significant research regarding manufacturing integration problems. Western European countries, notably Sweden and West Germany, conduct substantial research in work environment issues, while these issues receive only minimal attention in the United States.

International Policy Comparisons

All of the major industrialized nations support the development and use of PA to some extent. However, the lack of accurate, up-to-date information about the details of foreign government programs makes speculation about their effectiveness extremely risky.

Historical differences in national characteristics have strongly affected PA use internationally. For both Japan and Western European countries, these characteristics include a greater concern for cost reduction—presumably due to greater dependence on export markets, and to higher energy, materials, and capital costs than those in the United States prior to the 1970's. These factors have led to greater concern abroad for manufacturing processes with less materials waste, better product design, and low-cost production. The fact that the United States now faces similar constraints and a more competitive international environment is motivating U.S. manufacturers to focus more closely on manufacturing processes.

Government involvement in automation in **Japan** is substantial, but it is less monolithic than many believe. The influence of Japan's Ministry of International Trade and Industry (MITI) on Japanese industry is ebbing, although MITI continues to develop long-term plans for technological development and to target certain areas of technology for particular attention, such as robotics and microelectronics. Private industry expenditures comprise a greater percentage of total R&D spending in Japan than in any other country, in part due to the near absence of Japanese Government R&D in defense. The Government has, however, played a substantial role in encouraging application of new technologies in small and medium-sized firms, and in facilitating cooperative efforts among PA producers and users.

Like the United States, the **West German** Government has no systematic industrial policy. It has played a large role in encouraging private industry investment, however, and has allocated large sums to semiautonomous research institutes and consortia which perform R&D related to manufacturing. In addition, the Government has established an Advanced Manufacturing Technologies Program to promote the riskier forms of innovation in this sector. Though the use of automation technologies in West Germany is not as extensive as in the United States or Japan, the West Germans have characteristically good government-labor-management relations which facilitate the introduction of new technology.

Sweden and **Norway** have recently begun to devote resources to PA in order to bolster economic growth. These countries are strong in robotics, work environment research, and education and training programs.

The **French** Government has a firm commitment to faster development and diffusion of PA, linking Government support to broad-based plans for restructuring French industries. Despite the availability of Government funds and loans, however, industry has not participated in Government programs to the extent anticipated.

Although the **British** Government is less involved in domestic industry than the Japanese or French, the United Kingdom has developed a set of "schemes" to promote investments in PA. These include loans and grants for consultants to help develop automation, and various mechanisms for support of industry and university R&D.

Italy has no overall industrial policy, although it promotes private investment in its underdeveloped southern regions. In addition, Italy is rapidly becoming a major producer of robots, and leading Italian firms have pioneered new applications.

Canada and **the Netherlands** have begun to promote PA to further economic growth. They have fledgling R&D programs and mechanisms for encouraging application of PA.

Implications for Federal Policy

The overarching policy question that emerges from this assessment is, "Should there be a national strategy for the development and use of programmable automation?" The opportunities and problems posed by PA are interconnected. Successful policy regarding PA must therefore mesh actions in several areas, something that can only be achieved through a multifaceted strategy. Further, the current uses and impacts of PA are a fraction of what they are expected to be in the long term. Thus, there is an opportunity for anticipatory Federal policy.

The principal issues which motivate interest in new policymaking include the relative immaturity of the technologies and lack of experience in their application; the fact that other countries are stimulating development and use of PA; the risk of unemployment growth as a result of PA use, both regionally and nationally; the risk of adverse effects on the psychological aspects of the work environment; and the ramifications of PA for education, training, and retraining.

A policy strategy for PA would have to balance the interests of a large and diverse group of stakeholders:

- The **developers and producers** of PA are primarily concerned with funding and facilities for R&D, as well as general economic policies which affect markets for the technologies.

- The users of PA focus on competition in their product markets. While they tend to resist government intervention in production and personnel areas, they call for improvements in tax and trade laws and other policies which influence the business climate.
- **Members of the labor force** care about whether they can get and keep jobs, what kind of jobs are open to them, and their relations with management. While approximately 20 percent of the labor force is represented by labor organizations, the bulk of the working population has no focused way to articulate its concerns.
- **Communities and State and local governments** are particularly concerned about economic development and maintaining their employment base.
- **Educators and trainers** are concerned about the funding, equipment, and facilities available to them, as well as making curricula responsive to new technologies and skill needs.
- Finally, the **Federal Government** has broad interests in the development and application of PA, including its use for building defense equipment, as well as its effect on productivity, economic growth, employment, and occupational safety and health.

Policy Strategies

If the Federal Government chooses to coordinate activities in areas of technology development and use, employment, work environment, and instruction, it can pursue one of four basic strategies:

1. **laissez-faire—a continuation of current policies;**
2. **technology-oriented—emphasis on programmable automation development and use;**
3. **human resource-oriented—upfront attention to education and training, work environment, and job creation; or**
4. **both technology- and human resource-oriented.**

The principal uncertainties clouding projections are the rate of advance of the technologies, and the relative success of efforts abroad to develop and apply PA and to increase sales penetration in domestic and foreign markets. The state of the economy is also a major and uncertain influence.

The principal arguments for a **laissez-faire strategy** are that additional Federal involvement may not be necessary for effective use of PA, and that it may be too early in the application of PA to assess appropriate Federal actions. The disadvantages of this strategy are the risk that other countries may adopt and benefit from PA faster than the United States, and the risk of losing an opportunity to adopt policies that could not only maximize the effective use of PA but also minimize negative social consequences.

A **technology-oriented strategy**—bolstering R&D as well as encouraging applications of the technologies—could help avert a decline in industrial output and employment caused by competitive losses to foreign industries. Other advantages of such a strategy are that it would help ensure U.S. technological superiority, and it could bolster national security by maintaining a sound industrial base. However, even if greater use of PA were a decisive competitive aid to U.S. firms, a strictly technology-oriented strategy could aggravate unemployment and work environment problems, as well as strain the capacities of education and training systems. The postponed costs of a technology-oriented strategy, particularly for assisting displaced workers, may offset some of the potential economic benefits of such a plan.

A **human resource-oriented strategy** would involve upfront investment in evaluating skill requirements, tailoring education, training, and retraining programs, and conducting research in relevant work environment and educational impacts of PA. Such a strategy could stabilize or diminish future adjustment assistance spending, and could prevent work environment problems. While human resource development can facilitate the use of PA and otherwise improve productivity, its effects on industrial output levels may be less evident than the effects of technology-oriented policy. The major disadvantage of a primarily human resource-oriented strategy is that it might not improve productivity or competitiveness enough to offset trends in other countries. As in the laissez-faire strategy, the United States would run the risk of a further erosion in industrial output levels and loss of technological superiority.

A **combined technology- and human resource-oriented strategy** could ensure technology development and increased competitiveness while minimizing social fallout. It would recognize the complementary contributions of equipment and of people in production, and help assure that human impacts are explicitly considered in PA development and use. The disadvantages of such a combined approach include the administrative and legal burdens of coordinating a wide range of Federal activities.

Specific Policy Options

Technology Development and Diffusion

Existing Federal policy toward manufacturing technology is piecemeal at best. In the area of R&D, four agencies with distinctly different mandates fund automation research, although only a small portion of this work has general applicability for commercial manufacturing. Only in the area of defense procurement is there a concerted Federal effort to coordinate product and process technology development and application.

Option: Fund Research and Development.—Congress could act to increase PA R&D by influencing both the overall level of funding and its distribution to various agencies and research topics. The current environment for PA R&D is relatively healthy. However, funding for more long-term, generic research in nonmilitary application areas is relatively thin. Since the bulk of federally sponsored R&D is centered on military applications, Congress may wish to raise funding specifically for generic research, primarily through the National Science Foundation and National Bureau of Standards. Congress may also wish to increase funding for standards and human factors research, which could facilitate the application of programmable automation across a wide range of industries.

Option: Facilitate Standard-setting.—In addition to bolstering R&D in standards, Congress may wish to consider legislation to facilitate standard-setting as a means of increasing the ease of use of the technologies and encouraging their application. The principal disadvantage of standard-setting is the risk that more rapid adoption of standards may provide short-term benefits for users but hinder future innovations which could be inconsistent with the standards.

Congress might consider legislation which would clarify the legal position of standard-setting groups. Currently, groups which oversee the intricate process of developing standards, such as professional and trade associations, can be held responsible for antitrust violations which specific standards may pose. In addition, Congress could consider mandating a more active role for the Federal Government in coordinating and promoting standard-setting efforts. A potential disadvantage of this option is that it would increase Federal involvement in PA markets.

Option: Encourage Use of the Technologies.—The appropriate rate for adoption of PA is a subject of contention. It depends on the rates of adoption among our trading partners, the extent of delay between invention and adoption of new technology, and the ability of the labor force and industries to adjust. There is probably a degree to which PA adoption can be facilitated by Federal efforts without incurring excess costs. Beyond some indefinite point, however, encouragement of the use of PA may lead to ill-considered applications and excessive problems for employees and communities.

Federal options for facilitating application of PA primarily involve removing barriers. These options include assistance in providing capital for the purchase or lease of automation equipment, and providing information about PA to manufacturers.

Measures to encourage adoption of PA, however, are only a partial and short-term solution to manufacturing problems. **A longer-term solution involves redressing the historical U.S. inattention to manufacturing processes, organization, and management.** Though there is some evidence that the private sector has begun to address this need, Congress could play an important role in fostering the development of engineering curricula in universities which combine manufacturing, design, and human resource management activities; as well as encouraging research in manufacturing engineering topics. Further, Congress could establish some form of "manufacturing institute," per-

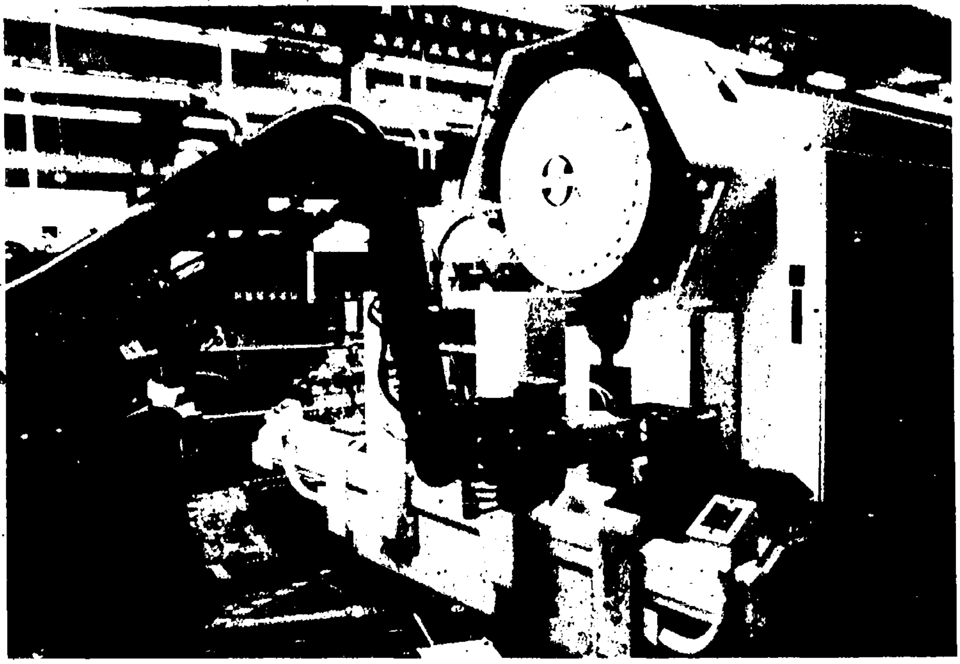

Photo credit: National Bureau of Standards

A robot loads a computerized machining center at the National Bureau of Standards' Automated Manufacturing Research Facility

haps building on the research centers already at NBS or at universities, to provide a focus for manufacturing technology, organization, and management issues. Such an institute could serve as an information clearinghouse for manufacturers, as well as a think tank with rotating fellowships for people from all parts of the manufacturing sector.

Employment

The United States has had major Federal programs for employment since the Depression era. Excluding education and training programs (see later in this chapter), existing Federal employment policy covers four broad categories: 1) the development and distribution of labor-market information, 2) income maintenance for the unemployed, 3) labor standards, and 4) job creation. Compared with policies in most European countries and Japan, U.S. labor market policy is reactive and uncoordinated, and it is not linked to other, industry-oriented programs for structural adjustment in the national economy.

Option: Maintain the Status Quo.—Existing Federal programs provide relatively limited Federal involvement in employment change. Though some might argue that this level of involvement is appropriate, the existing set of programs and institutions have several drawbacks. In the last two decades, Federal employment policy has come to focus on short-term programs for aiding disadvantaged groups of people (low-income or chronically unemployed or underemployed). In particular, current programs are ill-equipped to deal with long-term shifts in labor demand arising from technological and economic changes, growing uncertainty in skill requirements, and extended unemployment among groups other than the disadvantaged. Similarly, they are not designed to deal with large regional disparities in unemployment, a problem that PA will likely aggravate in the near term.

Option: Establish Programs for Job Creation.—Job creation programs can help decrease unemployment, as well as stimulate economic growth and help build the skills of the work force. The principal problem in developing a job creation program is to avoid paying for jobs that employers would have created anyway, and to avoid merely shifting employment from one industry to another, either of which would diminish net job growth.

Job creation programs range from the most general (i.e., expansionary macroeconomic policy) to specific measures to stimulate hiring, including tax credits, incentives for domestic production, change in average work hours, and increased production of public goods and services. In particular, the latter two types of job creation programs might be considered in the face of persistent labor surpluses. Although reducing average work hours can spread work among a larger group of people, individual employees may experience real wage losses. The actual costs and benefits of reducing work hours depend on how such a program is structured.

Similarly, stimulating production of so-called public goods and services would also create jobs. Production of public goods and services does not have to be met by expanded public sector employment. As in the case of defense procurement, public investment can stimulate private sector employment. "Public goods and services" can include a multitude of activities—from highway building to child care. The principal disadvantage of public goods programs historically has been the diversion of resources from private goods production.

Option: Expand Programs for Labor-Market Information.—PA offers the prospect of radical and ongoing changes in the deployment of labor among manufacturing firms. Monitoring of employment patterns by expanded collection and analysis of occupational employment data would provide a means of measuring the rate, extent, and direction of change. Expanded data collection by the Department of Labor and the Bureau of the Census would improve their ability to describe and forecast employment trends, and it would improve the information they disseminate to educators, counselors, and individuals. It would also provide data for comparing staffing patterns among firms—information that would be useful to managers, labor organizations, and educators. The primary argument against such efforts to expand labor-market information is rooted in the desire to reduce paperwork required of businesses, and to limit Government statistics to those that are specifically needed by Federal agencies.

Option: Expand Adjustment Assistance Programs.—Expanded programs for income maintenance or relocation assistance may be necessary to ease adjustment problems caused by PA and a variety of other factors. Although the debate over aid to displaced workers tends to focus on external aid, actions by employers themselves may also serve to ease employment shifts. Congress might consider legislation to encourage advance notice of technological change, which allows workers to plan for change, evaluate training needs, and seek new work. Employers often resist advance notice requirements, however, arguing that technological change is a management prerogative. Another measure that Congress might consider for employer actions would be financial incentives to relocate personnel either within or outside the firm.

Work Environment

OTA's analysis suggests that the area where PA itself may motivate the greatest departure from past Federal policy is work environment. Because PA will eventually affect the work environment of most manufacturing personnel, especially in metalworking manufacturing, and because it poses potential new problems pertaining to the psychological aspects of the work environment, this technology raises questions about the adequacy of existing mechanisms for studying, monitoring, and regulating workplace conditions.

Option: No Increased Federal Role.—Although no single policy instrument specifically addresses the impacts of PA on the work environment, various mechanisms are already in place at the Federal, State, and local levels that cover workplace concerns in general, particularly in the areas of health and safety. Further, a few efforts have begun in both the private and public sectors to plan for the workplace effects of the introduction to new technology. Finally, it may be too early in the development and application of PA to devise an appropriate Federal role. All the above concerns might argue for retaining the status quo.

However, work environment issues are similar in some ways to other problems, such as pollution, which are not easily solved by the private sector on its own. With current estimates of union membership in the United States totaling about one-fifth of all workers, there is a large segment of the population that will not have a focused way to articulate work environment concerns. Finally, there is a great deal to be learned about the effects of PA on the workplace, and such research must begin immediately in order to help improve the workplace as adoption of PA accelerates.

Option: Increase Oversight and Monitoring.—Congress could increase the emphasis placed on the workplace effects of computerized manufacturing automation through its oversight and monitoring activities. Considerable oversight has been provided on these issues by a number of congressional committees over the past several years.

In addition to its own oversight activities, Congress could designate monitoring responsibilities to the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). While such oversight could inform Congress and the public about workplace concerns and cover a wide range of settings, it might result in a piecemeal effort with little or no coordination of activities or sharing of information.

Option: Increase Support for Work Environment Research.—Congress could support research, through such agencies as NIOSH, NSF, and the Department of Labor, on both the short- and long-term social impacts of PA on the workplace. Potential areas for research might include the physical and psychological effects of PA, management strategies and policies in introducing and using PA, worker participation, identification of hazards and how to control them, changes in work content and organization, and changes in organizational structure, among others. Research would be particularly valuable for identifying techniques to measure nonphysical problems in the workplace. Demonstration projects, seminars, and experiments would enhance understanding of the effects of PA and the extent to which it can be shaped to improve the work environment.

Current research on the social impacts of PA on the manufacturing work environment is modest in scope and support, reflecting the limited amount of interest and funding available for this purpose. By contrast, study of the impacts of new technology on the workplace is more common in Japan and Western Europe, where the subject has historically received more attention across sectors.

Option: Set New Standards.— New safety and health standards may be required to address problems associated with the use of PA. Reliable information would be needed on the numbers of people at risk, the nature of the risks, and the potential costs and benefits of establishing and enforcing new regulations.

Option: Promulgate Omnibus Work Environment Legislation.—Other aspects of the introduction of new technology into the workplace, beyond safety and health concerns, suggest that a broader approach to work environment policy may be desirable. These aspects include the potential for excessive surveillance of workers and the disparity in worker and management understanding of both the choices available in adopting PA and theie workplace ramifications. In addition, a broader approach would ensure that the interests of all workers would be protected.

A number of European countries have taken an omnibus approach to workplace concerns. In Norway and Sweden, for instance, work environment legislation has been in effect since 1977. One purpose of this legislation is to protect workers' mental as well as physical health in the workplace, particularly in the context of technology change; another is to give employees an opportunity to influence the design of the work environment.

Education, Training, and Retraining

The Federal role in education has traditionally been that of supplementing or enhancing State and local activities. In recent years there has been a movement toward lessening direct Federal involvement. In contrast, the Federal role in training and retraining efforts—particularly for the economically disadvantaged—has been dominant since the mid-1960's. In keeping with the trend toward decentralization, the recently enacted Job Training Partnership Act (JTPA) shifts responsibility for administration and regulation of federally funded training and retraining activities to the States.

Option: No Increased Federal Role.—As in other areas affected by PA, it may be too early to assess the appropriate Federal role in education, training, and retraining related to PA. However, if the Federal Government chose not to modify its existing programs, it would forgo potential roles unlikely to be assumed by other levels of government or the private sector, such as assisting in the coordination of instructional activities, ensuring that adequate labor market and occupational forecasts are developed, and ensuring that information derived from such forecasts is actively disseminated to individuals, educators, and trainers.

Option: Increase Support for Facilities, Equipment, and Qualified Instructors.—Congress could consider options such as tax incentives for the purchase of state-of-the-art equipment for training, and funding to establish selected educational facilities and maintain them for use in periods of intense demand for PA instruction. Congress is currently considering legislation to encourage interest in math and science teaching, engineering education, and other forms of technical instruction. While these measures could remove many of the barriers to the establishment of PA instructional programs, they might also stimulate too much interest in PA instruction at the expense of other types of education and training.

Option: Encourage Curriculum Development.—Congress could enact a grant program to fund the development of curricula geared to the development of PA-related skills. Encouraging comprehensive curriculum design and the establishment of voluntary guidelines for curriculum content at various levels would guarantee some degree of standardization to both enrollees and employers.

Option: Encourage Renewed Emphasis on Basic Skills and Problem-Solving Skills.—Congress could choose to encourage at all levels of instruction a renewed emphasis on strong, basic skills in reading, math, and science. Special emphasis could be placed on the development of individual problem-solving skills, since these are important prerequisites to training for careers in computerized manufacturing, as well as for nonmanufacturing occupations.

This option could make the labor supply more resilient in the long term by raising the overall skill level. It could also create a foundation of skills that could be enhanced over time through the development of job-related skills, including those associated with PA. Finally, this approach would not feed the process of "skills obsolescence" by tying individual instruction too closely to specific technologies.

Option: Encourage Individual Participation in PA-Related Instruction.—Possible measures already being considered by Congress to make individual participation in instruction more economical include individual tax incentives (e.g., deductions for spending on training for a new occupation); the designation of training as an allowable expense under the Unemployment Insurance System; and the establishment of individual education or training accounts. Incentives to individuals would be particularly valuable in instances where employers do not provide PA-related instruction to their employees beyond the level of introductory training.

Option: Encourage Industry-Based Instruction.—Few users of PA equipment currently have or plan to establish in-house instructional programs. Congress could choose to encourage users of programmable equipment to establish or enhance in-house technical training programs through the creation of tax incentives that help defray the costs of instructors, equipment, expansion of instructional facilities, and curriculum development.

Option: Intensify Research Efforts.—Congress could choose to increase Federal sponsorship of research to identify changing skills requirements within manufacturing occupations, and to provide for broad-based dissemination of the findings to better equip educators and trainers for curriculum development. Congress could also use a research program to encourage the development of instructional standards that are in keeping with PA skills requirements.

General Information

Information on the operation of OTA, the nature and status of ongoing assessments, or a list of available publications may be obtained by writing or calling:

Congressional Relations and Public Affairs Office
Office of Technology Assessment
U.S. Congress
Washington, D.C. 20510
(202) 226-2115

Publications Available

OTA Annual Report.—Details OTA's activities and summarizes reports published during the preceding year.

List of Publications.—Catalogs by subject area all of OTA's published reports with instructions on how to order them.

Press Releases.—Announces publication of reports, staff appointments, and other newsworthy activities.

OTA Brochure.—"What OTA Is, What OTA Does, How OTA Works."

Assessment Activities.—Contains brief descriptions of assessments under way and recently published reports.

Contacts Within OTA

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