(Bureau of Labor Statistics, 1971); and Martha Farnsworth Riche, "Man-hour requirements decline in hospital construction," *Monthly Labor Review,* November 1970, p. 48.

[6] Data were provided for the continental United States and four broad geographic regions. The States included in each region were: *Northeast*—Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont; *North Central*—Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin; *South*—Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia; and *West*—Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Impact of new electronic technology

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The steady stream of technological progress that has characterized our society in America has resulted in higher productivity, elimination of many menial and dangerous jobs, higher wages and shorter hours, and a continuous flow of new products and services which have resulted in a higher standard of living. New industries employing thousands of workers have been formed to manufacture computers, electronic products, and technologies to provide energy and control the environment.

To be sure, innovation in industries such as longshoring, agriculture, and printing, to name a few, has eliminated jobs and required workers to acquire the unfamiliar skills associated with new technology. For some, the adjustment has been painful. But on balance, there is general agreement that the benefits of new technology far outweigh the disadvantages, and that innovation has led to economic progress, new job opportunities, and a more prosperous society.

At this point, early in the decade of the 1980's, there is widespread agreement that the pace of diffusion of technologies which incorporate advanced electronics will be accelerated over the next few years. The experience in the United States suggests that as long as the economy is growing, the introduction of innovations with potential for productivity gains can be compatible with rising employment. When computers were first introduced for office data applications, for example, frequently predictions were made that large numbers of clerical and kindred workers would be displaced and that job opportunities for millions would be curtailed. What actually did happen was quite different. In 1960, clerical workers in the United States numbered about 10 million and accounted for about 15 percent of total employment. By 1980, there were more than 18 million clerical workers and they accounted for about 19 percent of the total. Thus, instead of decreasing as had been predicted, clerical employment increased about 85 percent. And, it is projected to grow significantly to 1990.

Why did clerical employment increase instead of decreasing as predicted? First, normal growth in the volume of clerical work exceeded jobs eliminated by the computer. Second, computers made possible work that was previously impractical because it would have been too costly and too time consuming. Using computers, managers can now prepare reports and analyses that previously were desirable but too costly.

In addition to creating employment by expanding the scope of activities for many industries, the computer required new occupations such as systems analysts, programmers, keypunch operators, console operators, and tape librarians. And new industries were established to manufacture computers and related equipment, creating a variety of occupations and employing thousands.

Technological change can cause job displacement, especially when the industry is concentrated in a particular region or locality. Sometimes the employment impact is direct, as in the case of agriculture. In most cases, however, the effect is less obvious. Output does not advance at the same rate as productivity in all industries or plants, and consequently some industries register employment declines while others register increases. Regardless of the reason, displacements are costly for both the individual and the Nation.

This report examines four major technological changes under way in the United States and discusses prospects for their further diffusion. The four areas are microelectronics, industrial robots, telecommunications, and office automation.

The development of *microprocessors and microcomputers* in the early 1970's, and their widespread diffusion as we enter the 1980's, is a major innovation in electronics. Over the past three decades, the transistor that replaced the bulky vacuum tube was a first step in the development of miniaturized semiconductor integrated circuits which provide more power and reliability in a significantly smaller package. A microprocessor unit contains thousands of electronic components and complex circuits on a silicon chip less than one centimeter square. The unit can be combined with memory and input-output capability to build a microcomputer.

The use of microelectronics has had a significant im-

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pact on American consumers, workers, and manufacturing operations. A vast array of products—calculators, digital watches, video games, TV sets, and microwave ovens, to name a few—incorporate microprocessors and microcomputers. But behind the scenes in American manufacturing plants, production technologies and manufacturing methods are undergoing equally dramatic changes. Microelectronics are being incorporated in systems which control key production equipment, such as industrial robots and numerically-controlled machine tools. Moreover, microelectronic devices increase the processing capability of word processors, computers, data transmission and copying devices, automatic checkout counters, and other such equipment used by banks, insurance companies, and retail and wholesale establishments.

The *industrial robot* is a second major technological innovation capturing current attention. The Robot Institute of America defines a robot as "a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." According to the institute, about 4,000 robots are in use in U.S. establishments, with a large share in automobile manufacturing plants. They perform tasks such as material transfer, die casting, spot welding, spray painting, and limited assembly. Although U.S. industry is increasing its use of robots, Japan leads the world in robot use with more than triple the number of installations in the United States.

There is little information on the impact of robots on productivity and employment. However, evidence suggests that, following installation of robots, productivity is increased, unit labor requirements frequently are lowered, and quality control is improved. At one large manufacturer of refrigerators, for example, a robot sprays paint on refrigerator liners twice as fast as the two-person crew that it replaced.[1] The future impact of robots on productivity and employment will depend on the extent of development and diffusion of new generations of robots that can "see and feel."

Technological changes in *telecommunications* are underway in all major segments of the industry. These innovations are boosting productivity and changing the type of labor required in the two basic processes of telephone communication—call switching and signal transmission. The electronic computer is used extensively in both processes, as well as in other operational tasks and in management and accounting functions.

In call switching, electronic switching systems use high speed computers to handle local and long-distance calls. A growing share of calls is handled by electronic switching systems; total conversion is anticipated by the year 2000. These systems can handle three to four times more calls than electromechanical systems.

Sharp gains in long-distance volume have led to two innovative and important technologies in signal transmission—the millimeter waveguide and fiber optic cables. Both have far greater call-handling capabilities than the existing coaxial cables and microwave relays. The millimeter waveguide is essentially an underground tube through which signal-carrying waves are transmitted. It is designed for use on high density communication routes. Currently, this technology is being tested; future diffusion will depend on call volume growth.

Fiber optic cables for signal transmission are expected to become a major transmission medium in the 1980's. In this technology, glass fiber cables are combined with semiconductor light sources for very high capacity transmission. The fiber cables are compact, resist electrical interference, and interface well with digital switching and transmission techniques.

Other major changes anticipated for the telecommunications industry include further expansion of satellite communication, digital transmission, computerized systems for maintenance and testing, and automation of switching and billing tasks. Experts also foresee nontraditional uses of the communications network for electronic funds transfer in banking, electronic postal service functions, and data systems for the home which will combine communications and data processing capabilities.

Office *data handling and communication* is a fourth area where major technological change has occurred. A large segment of the Nation's work force, including more than 18 million clerical workers, is engaged in producing and processing data. Historically, capital investment in the office has lagged that of other operations, with investment per office worker amounting to less than $2,000, compared with about $25,000 per factory worker.[2]

This "investment gap" may be closed in the years ahead. Investment in office technologies will likely accelerate during the 1980's, as managers turn to modern data handling technologies to reduce labor, material, and related expenses. The largest share of office costs are deemed to be labor-related—a strong incentive for further mechanization.

Specific technologies to be diffused more widely include more powerful electronic computers; advanced model word processors; new equipment and techniques to store, retrieve, and transmit data on microfilm; and electronic mail networks. Increasingly, paper will be replaced by electronic images on a screen which can be transmitted by telecommunication methods.

General impact of innovations

Following are conclusions from the Bureau of Labor Statistics' research on the implications of technological change for the work force.

- While all industries are experiencing technological change, the pace varies among and within industries. Each industry has its own story and it is not always in terms of computer technology and advanced automation. But even conventional changes, such as materials handling mechanization or the installation of larger capacity equipment or machines with faster speeds, are often major developments requiring workers to obtain new skills.
- The size of investment required, the rate of capacity utilization, and institutional arrangements are some of the factors that act as an "economic governor" on the speed of diffusion of technological change and, in turn, possible employment implications.
- Industries with greater application of technological advances generally experience larger increases in productivity (examples, air transportation and telephone communication); industries lagging in application of technological advances generally experience smaller or negative changes in productivity (examples, footwear and wood household furniture).
- The content of jobs and the qualities required of workers are being modified by technological changes. There is less demand for manual dexterity, physical strength for material handling, and for traditional craftsmanship. In contrast, employers are placing more emphasis on formal knowledge, precision, and perceptual aptitudes. As many manual tasks are mechanized, unskilled workers become monitors of very expensive equipment. The reduction in repetitive tasks that are so dissatisfying to the industrial worker may be welcomed, but the isolation and constant monitoring associated with advanced technology can create new stresses.
- Higher educational achievement of workers is becoming essential. The ability to read and write at a functional level is mandatory to interpret operating instructions of complex equipment, and to be retrained for the new skills demanded by changing technology.
- Many new occupations created by new technologies can be filled by retraining employees. Most retraining is accomplished in-plant and includes on-the-job and classroom instruction.
- In general, relatively few employees have been laid off because of technological change. This is due, in part, to the use of various techniques by the private sector to minimize adverse effects to the worker—techniques such as providing advance notice, retraining, and reassigning displaced employees to new jobs. □

FOOTNOTES

[1] "Robots Join the Labor Force," *Business Week,* June 9, 1980, pp. 62–76.

[2] Philip H. Dorn, "The Automated Office—The Road to Disaster?" *Datamation,* Nov. 15, 1978, pp. 154–62.