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ABSTRACT

This paper describes the new technologies most likely to affect the number and types of jobs in the U.S. economy over the next two decades. These work-affecting technologies are presented in the context of the continuing evolution of the U.S. work force into a distinctly new, third era. Chapter I discusses the transformation of the United States from an agrarian nation into an industrial one and the equally momentous transformation from an industrial nation into one variously described as a post-industrial, service, Third Wave, or knowledge-intensive economy. Chapter II describes the emerging technologies that both underlie the transition and promise to give the third era its distinct technological character. Focus of the chapter is on the information technologies, which are the most significant for the immediate future of work and employment in the emerging era and which include the devices, machines, and systems that generate, transmit, manipulate, and are controlled by means of the binary-represented data upon which computers operate. Sections of the chapter look at the information technologies from three perspectives: the computer itself as the paradigm of the information technologies, advanced research and development in computer-based technologies, and specific applications in the workplace. Appendixes include the diamond plot of occupation trends, Toffler's Third-Wave thesis, and lists of references and data sources. (YLB)

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THE TECHNOLOGIES OF THE THIRD ERA OF THE U.S. WORKFORCE

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ABSTRACT

This paper discusses the emerging and developing technologies most likely to affect work in the U.S. during the next two decades. The period is one of continued transistion into a third, distinctly new, post-industrial era. The foremost technologies affecting work during this transition are the closely-related family of information technologies, that is, the devices, machines, and systems which generate, transmit, manipulate, and are controlled by means of the binary-represented data upon which computers operate. It is the information technologies which promise to have the most impact on work and employment not only over the next decade but perhaps for generations to come because of widespread implementation of intelligent machines, for factory, office and service work.

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THE TECHNOLOGIES OF THE THIRD ERA OF THE U.S. WORKFORCE

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INTRODUCTION

This paper describes the new technologies most likely to affect the number and type of jobs in the U.S. economy over the next two decades, that is, from the present until the turn of the twenty first century. These work-affecting technologies are presented in the context of the continuing evolution of the U.S. workforce into a distinctly new, third era.

I. THE THREE ERAS OF THE U.S. WORKFORCE

In the first full century of its existence, the United States underwent a transformation from an agrarian nation into an industrial one. Presently the U.S. is undergoing another, equally momentous transformation from an industrial nation into one variously described as a post-industrial, service, Third Wave, or knowledge-intensive economy [1,2,3,4].

A. The First Two Eras

Figure 1 shows for the U.S. the proportionate distribution of workers among the major industrial sectors of the economy for the period from 1820 to 1995 [5]. Represented explicitly are: Agriculture (including forestry and fishing); Manufacturing (including mining, and Goods Production (which includes all of agriculture, mining, manufacturing and construction taken together). Implicitly represented as the complement to the goods production curve is the remainder of the workforce, those employed in the service sectors.

Figure 1 illustrates the two transitions which demarcate the three eras of the workforce. The first demarcation, already occurring when the historical data picks up at the turn of the nineteenth century, separates the first era of agriculture from the second era of industry.

1. The First Era: Agriculture

Figure 1 illustrates the transition out of the era of agriculture as a dominant economic activity, that transition being represented by decrease in the proportion of U.S. workers required in agricultural production. Down from 85-90% in colonial times [6] and 80% at the turn of the nineteenth century, the proportion of U.S. workers engaged in agriculture is now just over 3% [7].

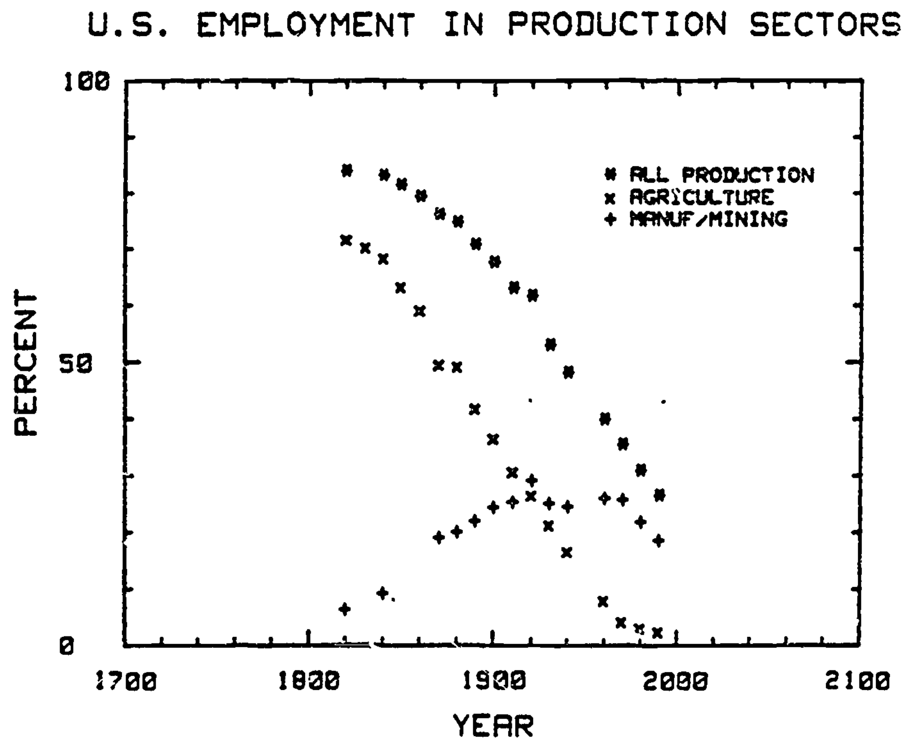

Figure 1. The Fractions of the U.S. Workforce Engaged in (a) Agriculture; (b) Manufacturing and Mining; and (c) Production (including Agriculture, Manufacturing, Mining and Construction) Over the Period 1820 to 1995.

This change, involving first a decrease in the proportion of workers and subsequently a decrease in their absolute numbers, occurred while total agricultural output increased. For example, while the number of agricultural workers declined from its historic high of 12 million in 1900 to its current level of 3.3 million, the Gross Farm Product in constant dollars increased by about 2.5 times [8].

2. The Second Era: Industry

Figure 1 shows also the transistions into and out of the second era, that of industry. The figure illustrates for the manufacturing and mining workforce: (1) the sustained increase during the period from 1830 to 1900; (2) the plateau-like level of 25% around which variations occurred for the period between 1900 and 1980; and (3) after 1980 the on-set of a decline.

The data suggest the probability that manufacturing in particular and goods-production in general are entering an era in which, as for agriculture two centuries before, first the relative number, then the absolute number, of workers engaged steadily decline.

Two questions arise. First, what lies behind the decreases in the proportions of the workforce devoted to agriculture and to industry in their respective eras. Second, what lies beyond, in the third era of the workforce. The following two sections address each of these questions in turn.

3. Machines, Productivity, and the Transistions between the Eras

To suggest a basis for the transition of the U.S. workforce out of the second era, this section of the paper examines long-term trends in: (1) the productivity of labor in agriculture; (2) the aggregate level of farm machinery per farmworker; (3) the productivity of labor in manufacturing; and (4) the aggregate level of industrial equipment per manufacturing worker.

a. Farm Machines, Agricultural Productivity, and the Transition out of the First Era

Figure 2a shows the growth in the productivity of farm workers since 1800, with the most dramatic increases occurring after 1940 [9]. Figure 2b--which shows in constant dollars the relative amount of farm machinery per U.S. farm worker--illustrates the progressive mechanization of farm production: the lower rate in the century from 1840 to 1940 and the rapid increase thereafter [10].

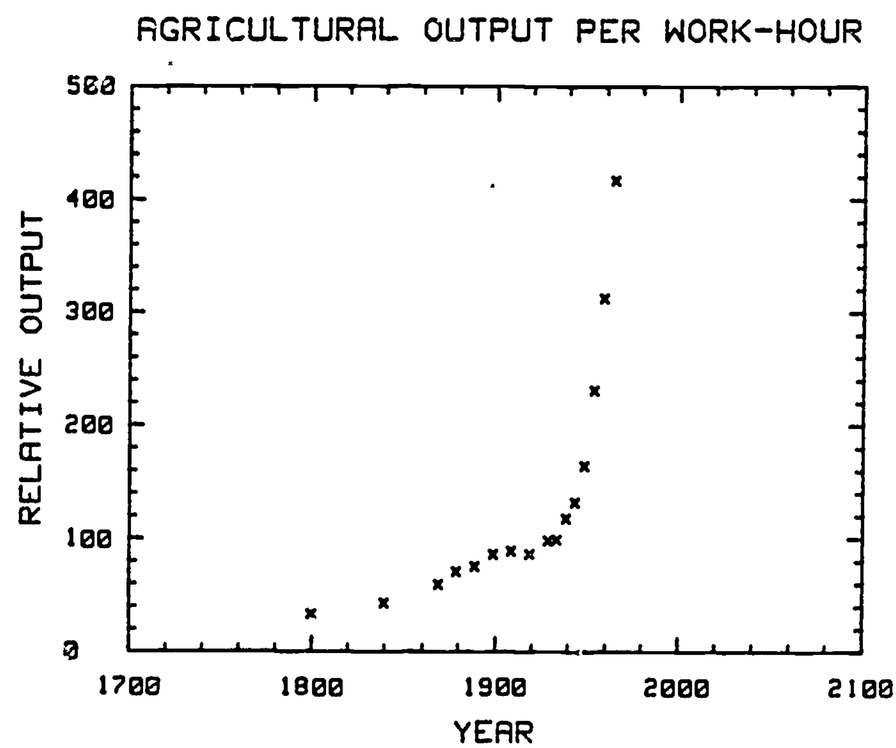

Figure 2a. Output per Work-Hour of U.S. Agricultural Workers Over the Period 1800 to 1980;

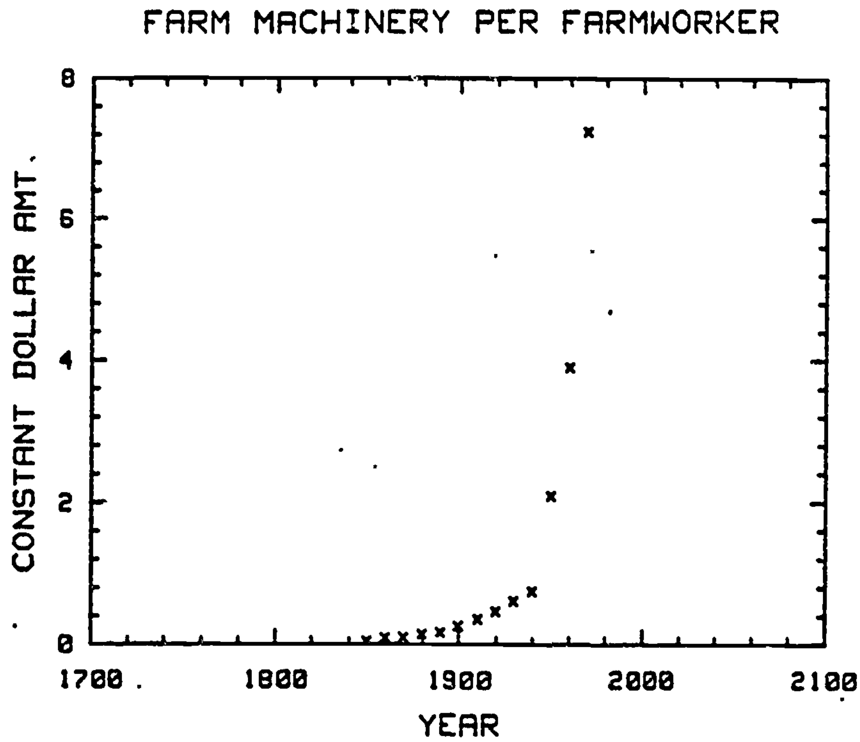

Figure 2b. Constant-Dollar Amount of Machinery per Agricultural Worker Over the Period 1800 to 1980;

Behind the aggregate dollar value of equipment are individual machines, introduced one after another over the total period of continually increasing productivity [11,12]. For example: the cast iron plow introduced in 1797 (when one farm worker could feed somewhat more than 3 people); the first mechanical reapers coming into use in the 1830's; the large, ganged-horse reapers of the 1880's (when one farm worker could feed 6); the steam-driven threshers of the 1900s; the gasoline-engine tractors of the 1920's (when one farm worker could feed 8 people); the self-propelled combine harvesters of the 1940s (when one farm worker could feed 10).

Today, it is the spectrum of tractors, combines, corn-pickers, field-forage harvesters, milking machines and other types of mechanization by which somewhat over 3 million farm workers support more than two hundred twenty million. Figure 2c--which shows the U.S. population of farm harvesters--illustrates the magnitude of the progressive application of machines to farm production. From only a few thousand at the turn of the century, the number of harvesters grew to 2.5 million by the 1970's; by that year farm tractors numbered over 5 million [13].

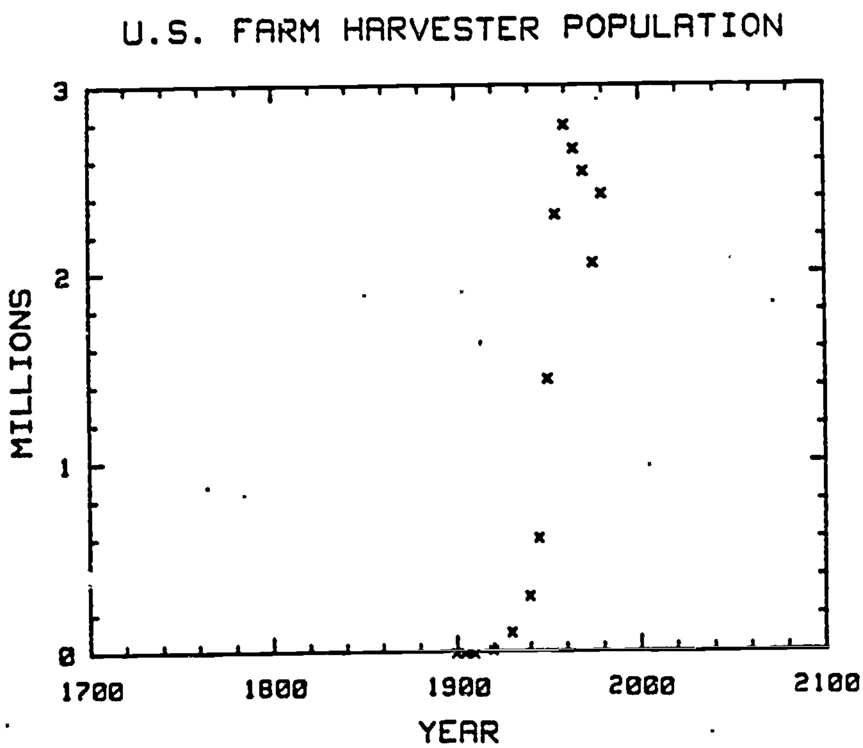

Figure 2c. U.S. Farm Harvester Population from 1900 to 1980.

This dramatic increase in the use of farm machinery has been characterized as the farm machinery revolution accounting for at least 50% of the total agricultural productivity growth [14]. As a result, workers released from subsistence production of food have been made available for producing other goods as well as services. The mechanization of agricultural production in effect closed the era of agriculture and opened the era of industry.

b. Factory Machines, Manufacturing Productivity and the Transistion from the Era of Industry

Figure 3a, which shows labor productivity in manufacturing over the period 1880 to the present, illustrates in terms of relative output per work hour the gains in the productivity of manufacturing workers over that period, especially in the most recent decades [15]. Figure 3b, which shows in terms of constant dollars the relative amount of capital equipment per manufacturing employee for the period 1870 to the present, illustrates the increasing use of machines by manufacturing workers, particularly the acceleration in the last most recent decades [16].

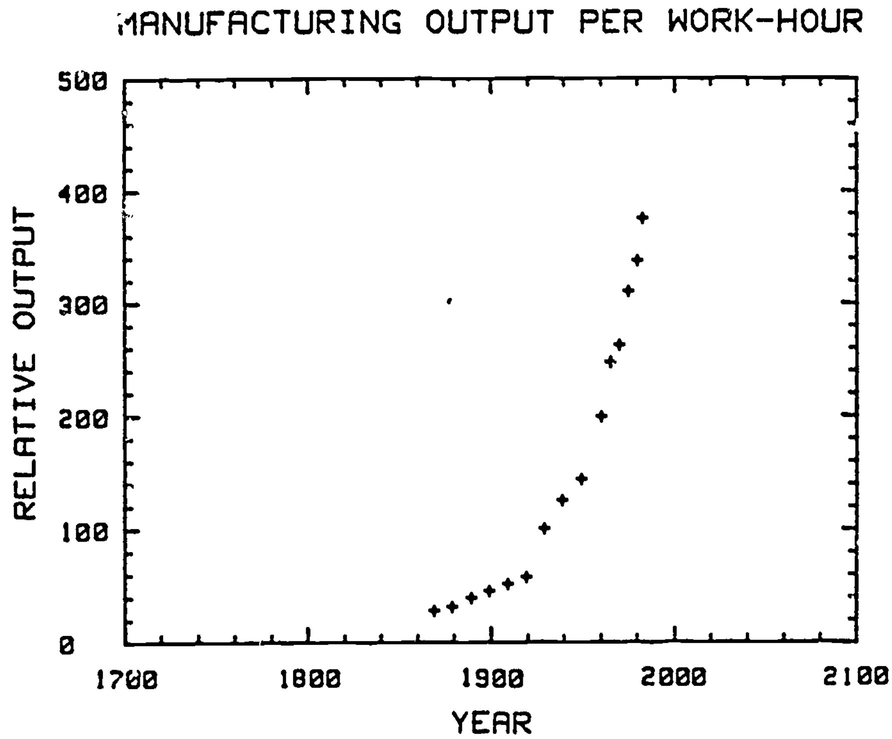

Figure 3a.

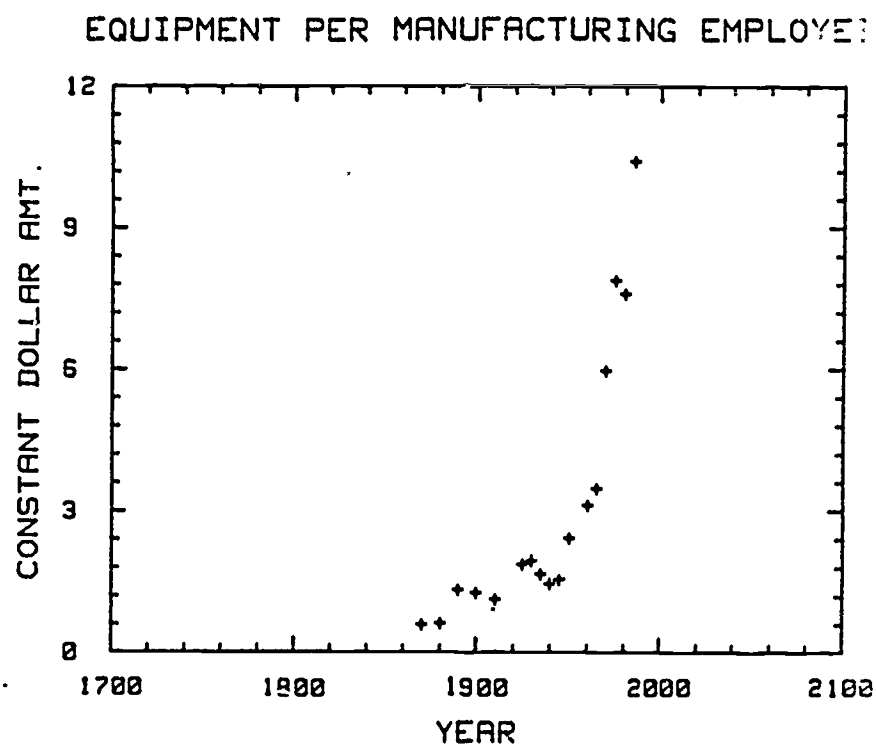

Figure 3b.

Figure 3a. Output per Work-Hour of U.S. Manufacturing Workers Over the Period 1870 to 1980; (3b) Constant-Dollar Amount of Machinery per Manufacturing Worker Over the Period 1800 to 1980.

In manufacturing as in agriculture, behind the aggregate dollar value of the equipment per worker are individual machines. While these machines are too many and too complex to be described here individually, they are part of well-described technological systems, which may be mentioned briefly here. There is:

o The Factory itself--in the 1750s a new system in which workers and machines were concentrated under one roof under the close supervision of employers--based on the introduction of devices such as the spinning jenny and power loom [17];

o The American System of Manufacture--in 1850 a distinctly new system for factory production of, for example, small arms and then-new consumer durables such as the sewing machine--which supplanted handcrafting with machine production based on machine tools, special fixtures and gages [18];

o Mass Production--after the 1913 and the introduction by Henry Ford of the moving assembly line--factories producing sometimes millions of essentially identical products based on interchangeable parts, specialized machines and extreme division of labor [19]; and, most recently,

o Automated Manufacturing--in the current era, factories capable of high volume production with minimal direct-labor cost--based on computer-controlled machines and automated materials handling systems [20].

An example of this current state-of-the-art in automated factories for large scale production is a new U.S. electronic typewriter plant. It is currently described as producing 10 different models of an electronic printer/typewriter at the rate of nearly 1 million per year using 300 production workers and 175 commercially-available robots for a direct labor cost of 3.7%. Of national significance is the fact that this U.S. factory will reportedly produce output with 100% domestic content at least-cost on a world-wide basis [21].

This highly-automated "factory of the present" has already achieved for large-volume production what is envisioned for even small-volume production in the fully-automated "factory of the future": low-to-zero direct labor cost and minimal indirect labor costs by means of advanced machines.

From a research laboratory point of view, hovering on the horizon is the much more advanced automated "factory of the future"--in effect an "operatorless" system capable of flexibly producing small batches of essentially custom products with the efficiency of mass production by means of intelligent, dexterous machines, the successors of today's computers and robots [22].

o o o

The trends shown in this section illustrate for both agriculture and manufacturing the accelerating gains in productivity due to the systematic, large-scale introduction into the workplace of machines of ever-increasing capability.

The effect on the agricultural workforce of what has been called its mechanization is historically clear: that workforce has declined in both relative and absolute terms with the result that agriculture, while still of vital importance, has passed from center stage of the American economy and society.

The effect on the manufacturing workforce of what is being called its automation is beginning to suggest itself: a development which parallels that which previously occurred in agriculture. With industrial production passing from center stage for the U.S. workforce, the question now is what lies ahead in the emerging third era.

B. The Third Era, Its Workforce and Technology

Various economists, sociologists, and popular-press futurists have pointed to this transformation of the U.S. economy from the industrial to some other, latter-day form. Ginsburg and Vojta noted the transistion to a "service economy" in which the service-providing sector overtook the previously dominant goods-producing sector [22]. Daniel Bell described the coming of the "post-industrial society" and a knowledge-intensive third-era economy [23].

Alvin Toffler described as a "Third Wave" this transistion in which a profoundly different post-industrial society encounters and overcomes its predecessor, the industrial one, even as in a second wave the industrial society overcame its predecessor, the agricultural, and in a first wave, the settled-agricultural society overcame the aboriginal hunter-gatherers [24].

Given these various, empirically-based views of the U.S. economy and workforce, it appears useful to view the U.S. as in a transistion to a third, post-industrial era, this era being indicated by a declining proportion of workers engaged in producing physical goods and an increasing proportion engaged in a different form of economically productive activity.

It was Daniel Bell (Appendix B1) who suggested that (1) whereas materials were the strategic resource of the first era and capital that of the second, the strategic resource of the third era is knowledge and that (2) the scientific, technical and professional occupations are the key workers which produce wealth from that strategic resource [25].

Defined in terms of standard labor occupations, technical-professionals comprise one of four groups: Production Workers--including laborers, operatives, precision production and craft workers; Managerial and Administrative Workers--including managers, administrators, proprietors, clerical and sales; Service Workers--the single category of that name which includes, for example, fast-food workers, hospital orderlies, and security guards; and, finally, Technical/Professional Workers--including all professional, technical, and related occupations.

1. The U.S. Workforce in the Third Era

In two different forms, Figures 4a and 4b show the proportion of U.S. workers in each of these four occupational categories for the period 1900 to the present. Figure 4a shows the change in each of the four categories independently against time [26]. Figure 4b shows the data for each decade represented as a single point within an occupational profile diagram described in detail in Appendix A.

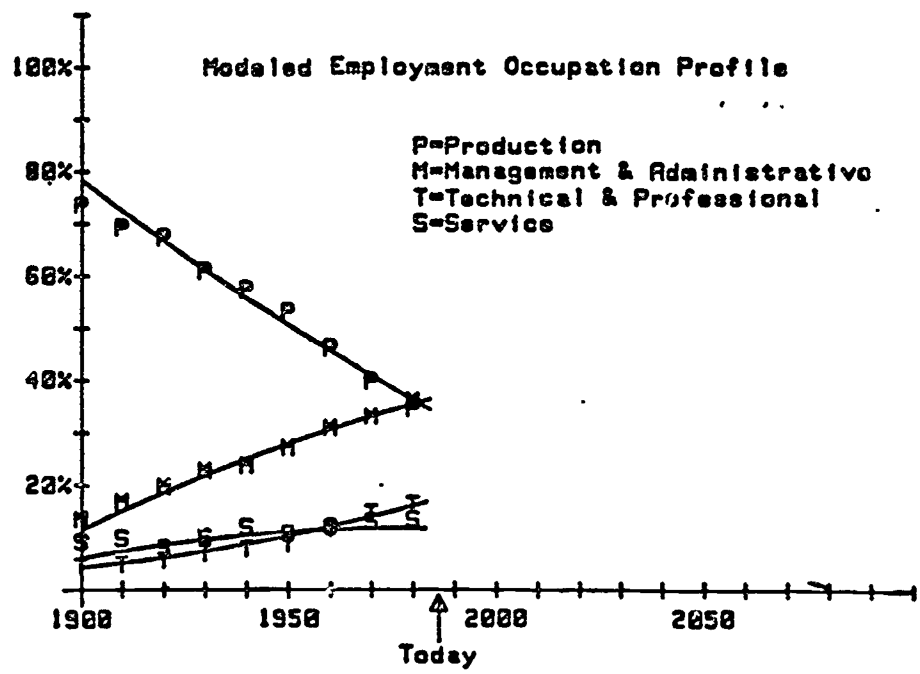

Figure 4a. Occupational Profile of the U.S. Over the Period 1900 to 1985.

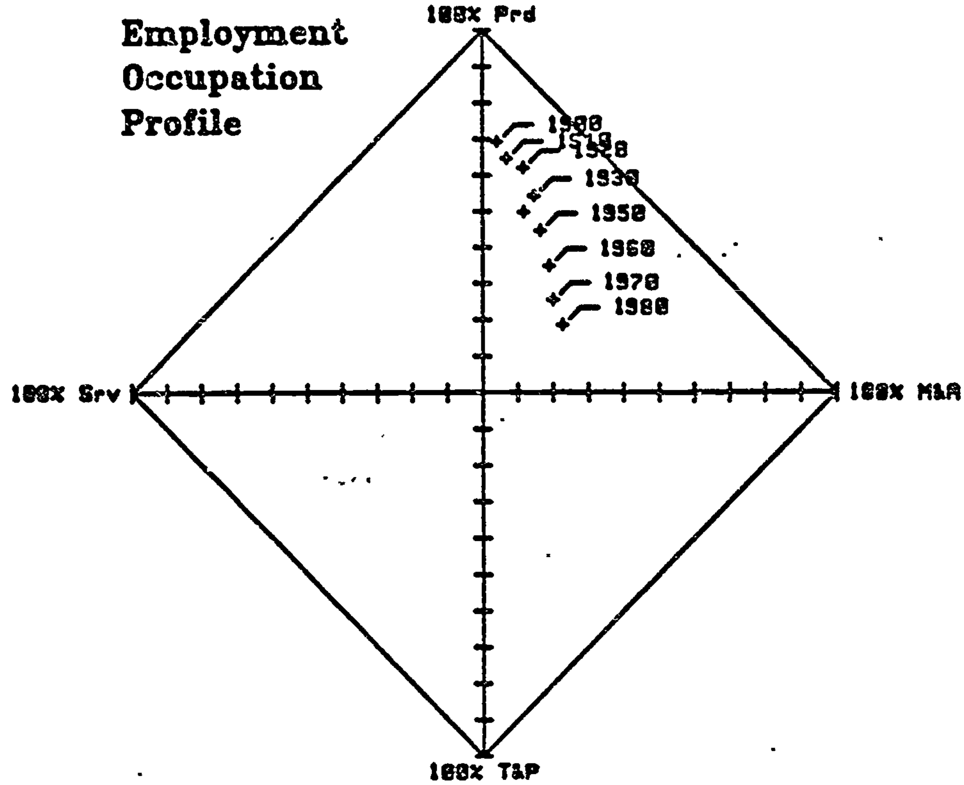

Figure 4b. Diamond Diagram Employment Occupational Profile of the U.S. Workforce over the Period 1900 to 1980.

In terms of the same two forms of representation, Figures 5a and 5b show projections of the historical data for the period 1980 to 2080. For both the past and future, the figures illustrates: (1) the continuing decrease in the relative number of workers directly engaged in physical production; (2) the steady increase in managegment and administrative workers; (3) a flatness in the growth in service occupations; and (4) a steadily increasing growth in the technical and professionals.

Figures 5a and 5b suggest that: (1) in less than a generation, that is, by about 2010, the workforce will cross the point at which there are more technical-professional workers than there are physical production workers; and (2) within the life expectancy of a child born today, the workforce will be approaching a state in which only a very small fraction of the economically active population would appear in either of today's physical production or physical service occupations.

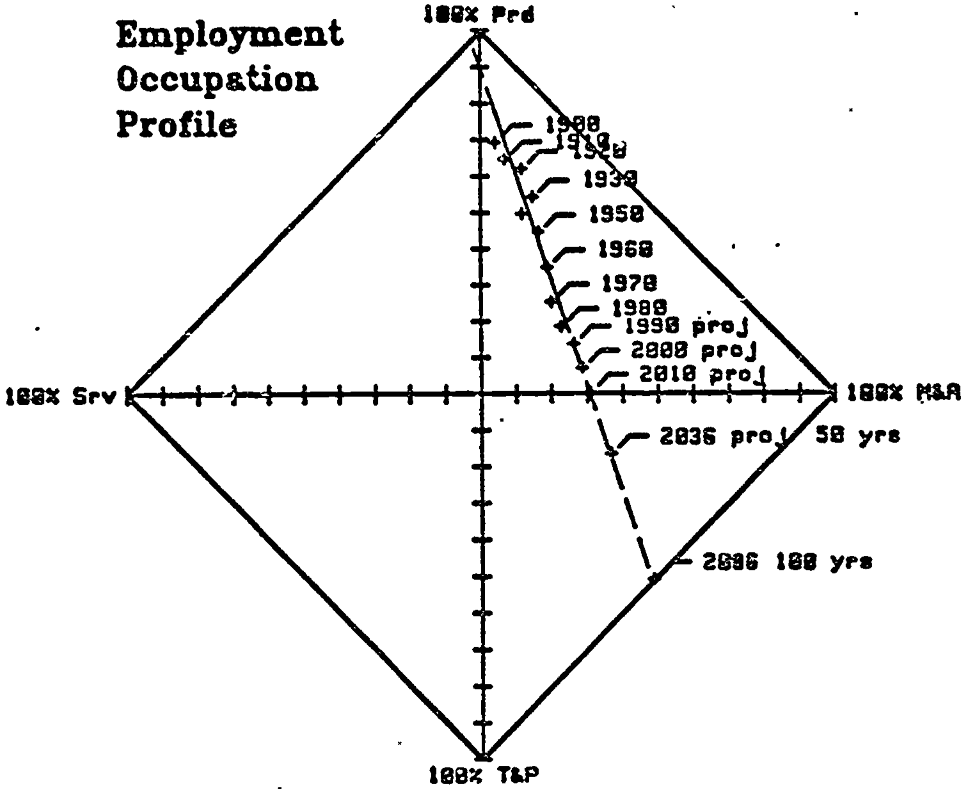

Figure 5a. Extrapolation of the Historical Trajectory of the Diamond-Diagram Employment Occupational Profile of the U.S. Workforce;

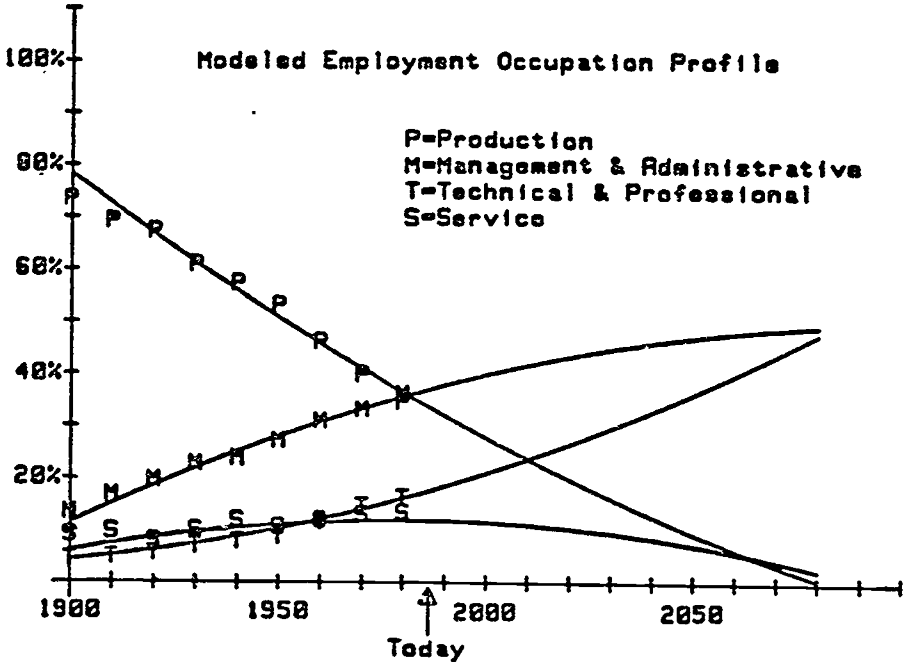

Figure 5b. Occupational Profile of the U.S. of Figure 4a Extrapolated to the End Points of Figure 5a.

While various analyses, including that just presented, suggest the significance of what is in effect a "knowledge industry" as the central economic activity of a third era, current SIC classifications do not provide a simple basis for representing it as a separate sector. For the purposes of this paper, the most knowledge-intensive occupational group will be used as a proxy.

Figure 6 --which shows Figure 1 to which has been added the technical-professional curve of Figure 5a--represents the emergence of the third-era. The figure illustrates--against an implied background of a falling second-era wave represented by the manufacturing of material artifacts--the rise of a third-era wave represented by the production of knowledge.

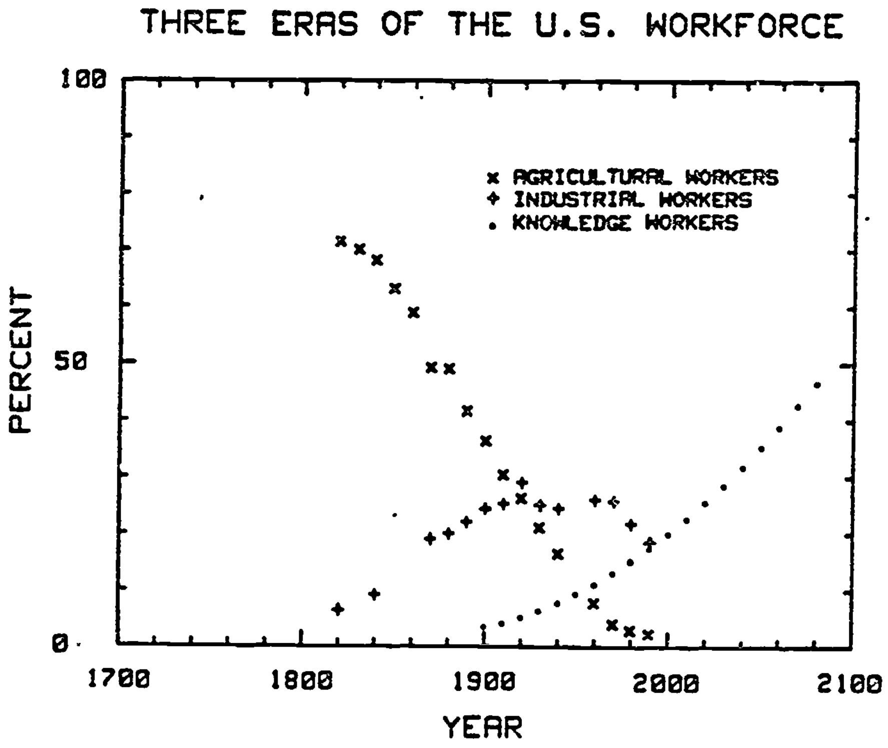

Figure 6. The Three Eras of the U.S. Workforce, Represented by its Agriculture, Industrial and Knowledge (i.e., Technical-Professional) Workers.

2. The U.S. Manufacturing Workforce in the Third Era

Figure 7 shows within the diamond plot the occupational distribution of workers for selected manufacturing sectors [27]. Two features of the figure are worth noting.

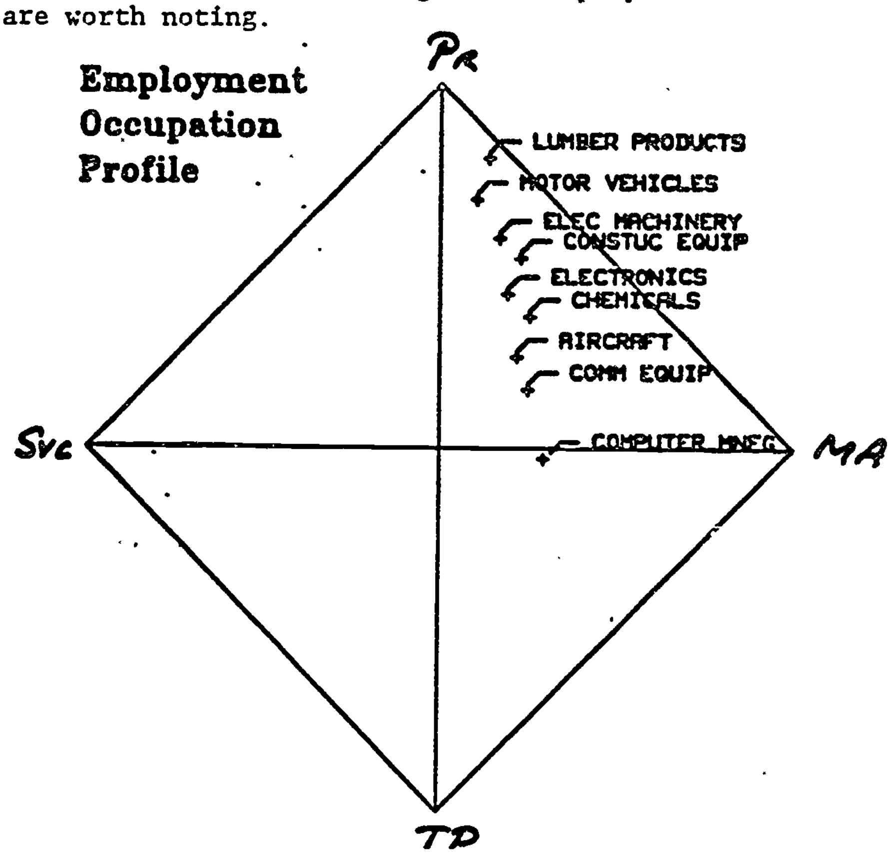

Figure 7. The Diamond-Diagram Employment Occupational Profile of Current Manufacturing Sectors.

First, the various manufacturing industries appear in the figure in an order which quantitatively ranks them by degree of "high tech". By this account, "high tech" industries are those of high knowledge-intensity, this intensity represented by the difference in the proportions of production workers and technical-professionals. By implication, that difference also relates to the amount of knowledge embodied in the product.

Second, the figure when compared to the time evolution of the total workforce suggests a characteristic age for each of the various manufacturing industries. In effect, that age is the year for which the current occupational distribution within the specific industrial sector -- given in Figure 7--equals that of the total workforce--given in Figure 5b. The results of such a comparison appear in the following table.

Table 1. Current Characteristic Ages of Manufacturing Industries

Manufacturing Industry Sector	Corresponding Year of Workforce
o Lumber Mills	Pre-1900
o Motor Vehicles	ca. 1910
Electrical Machinery	ca. 1928
Construction Equipment	ca. 1945
Electronics	ca. 1953
Chemicals	ca. 1960
Aircraft Production	ca. 1970
Communications Equipment	ca. 1985
o Computer Equipment	ca. 2015

As indicated in the table, the characteristic age of the current auto industry is 1910, the period when Henry Ford was establishing what came to be the paradigm of automobile production, the Highland Park assembly plant [19]. Further, the characteriste age of the current electronics industry is about 1953, the time when the transistor was going into commercial production [28]. Finally, the characteristic age of the computing equipment industry is ca. 2015, decades in advance of the total workforce.

As noted in the table, the characteristic ages of the manufacturing sectors fall into three groups relative to the historic data: (i) those such as lumber mills which are outside of and "behind" the historical data; these are, in effect, first era systems of production technologies and products; (ii) those from motor vehicles to communications equipment which are ordered within the era of the historical data; these are, in effect, second era systems; and (iii) those such as computer manufacturing which are definitively outside and "ahead" of the historical data; these are, in effect, third era systems.

Nearly all of the manufacturing industries described have current occupational distributions characteristic of the total workforce in earlier periods. However, as indicated by Appendix Figure C1, there is an established trend to lower proportions of production workers in all of the manufacturing sectors shown, including a start for the "age 1910" auto industry and a continuation for the "age 2015" computer industry [29].

o o o

So far this paper has presented trends in four areas which form the basis for its point of view that emerging technologies underlie a closing of the era of industry and the opening of a new, third era in the history of the U.S. workforce.

o In the manufacturing workforce, there is the trend to permanent reductions in the relative and absolute numbers of industrial workers suggested by the parallels between the agriculture and manufacturing/mining portions of Figure 1;

o In manufacturing productivity and in the capital equipment per employee which underlies it, there are the trends to substantially higher levels, again in parallel with those trends in agriculture, as suggested by the elements of Figures 4 and 5;

o In manufacturing occupations, there are the trends toward greater proportions of technical-professionals and lesser proportions of manual workers as indicated in the individual and composite occupational elements of Figure 33; and, finally,

o In manufacturing technology, there is the trend to more advanced forms of robotics-based automation both in large-scale, mass production organized on a flow-type basis represented by the electronic printer/typewriter factory and in small-scale, batch production organized on a job-shop basis represented by current research.

Taken together, these trends support the notion of manufacturing evolving into a high-technology, high-productivity activity conducted by a compact force of technical/professional workers.

These trends also suggest a technological basis for a major transition which may have already begun, that is, the passage: (1) out of the second era in which labor-intensity represented by manufacturing and its workforce formed the centerpiece of the economy; (2) into the third era in which knowledge-intensity represented by the role of technical-professionals will be an increasing and likely dominant factor in economic activity. The progression of the workforce through various transistions to the point in the year 2010 when more than 50% of it consists of knowledge workers is summarized in Appendix Table B2.

The next section of this paper looks at the new technologies which are most likely to play the dominant role in the current transition to this knowledge-intensive era.

II. THE TECHNOLOGIES OF THE THIRD ERA OF THE U.S. WORKFORCE

Within the context of a workforce undergoing a fundamental transition, this section of the paper describes the emerging technologies which both underlie that transition and promise to give the third era its distinct technological character.

In its narrowest sense, technology may mean an elementary, irreducible machine, device or process. In a broader sense it may mean a system or field based on proven forms of closely related, elementary machines, devices or processes. The term technology is used here to be this latter sense as, for example, robotic, electronic, materials and manufacturing technologies.

The economic significance of a technology depends on the extent of its effects: technologies are considered to be pervasive if they penetrate into and fundamentally change branches of the economy beyond the industry to which they are specific [30]. On the basis of their pervasiveness, it is the information technologies which are most significant for the immediate future of work and employment in the emerging era [30,31].

A. Introduction: The Information Technologies

The information technologies represent the convergence of three major and previously independent technologies: computers, telecommunications and automation. So closely related in terms of the devices by which they operate, the functions which they perform, and their relation to humans at work, the individual information technologies are, in effect, parts of one system.

As a system, the information technologies include (1) all the devices, machines and associated hardware and software systems that (2) generate, transmit, process, and use (3) data, information and knowledge (4) represented at the most irredeucible level in the 0 and 1 bits (5) upon which the central processors of computers perform arithmetic/logical operations.

The following sections look at the information technologies from three perspectives: the computer itself as the paradigm of the information technologies; advanced research and development in computer-based technologies; and specific applications in the workplace.

B. The Core of the Information Technologies: The Computer

In coming to terms with the profusion of information technologies, it is worthwhile to look in detail at the computer, the central device and paradigm of the information technologies. The concept, theory and realization in prototype form of what is now known as the electronic digital computer came together in the decade leading up to 1950: the logic gates of Shannon, the lambda-calculus of Church, various early machines--notably the vacuum-tube Eniac at the Moore School in Pennsylvania--and the conceptualization of von Neumann, who articulated the machine's elements [32].

As a result of continuous development over its lifetime, the computer has been rapidly improved in speed, capability, cost and scope of application. As indicated by Figure 8, in forty years computer speed has increased over a billion time and over the recent decade shown in Figure 9, the cost of computer hardware decreased 90%.

-Increase in Computing Power Over Time

Year	Model	Computational speed (arithmetic operations per second)
1944	Harvard Mark I (electromechanical)	0.4
1946	Eniac	45
1951	Univac I	270
1953	IBM 701	615
1961	IBM 7074	33,700
1963	CDC 3600	156,000
1965	IBM 360/75	1,440,000
1972	CDC Cyber 176	9,100,000
1976	Cray 1	80,000,000
1981	CDC Cyber 205	800,000,000

SOURCES: J. R. Bright, "Technology Forecasting Literature: Emergence and Impact on Technological Innovation," P. Kelly and M. Kranzberg (eds.), *Technological Innovation: A Critical Review of Current Knowledge* (San Francisco: San Francisco Press, 1978), p. 300, "The Digital Age," *Electronics*, Apr. 17, 1980, p. 382; P. J. Schuyten, "The Battle in Supercomputers," *New York Times*, July 22, 1980, p. D1.

Figure 8. Improvements in Computer Speeds Over Its Lifetime.

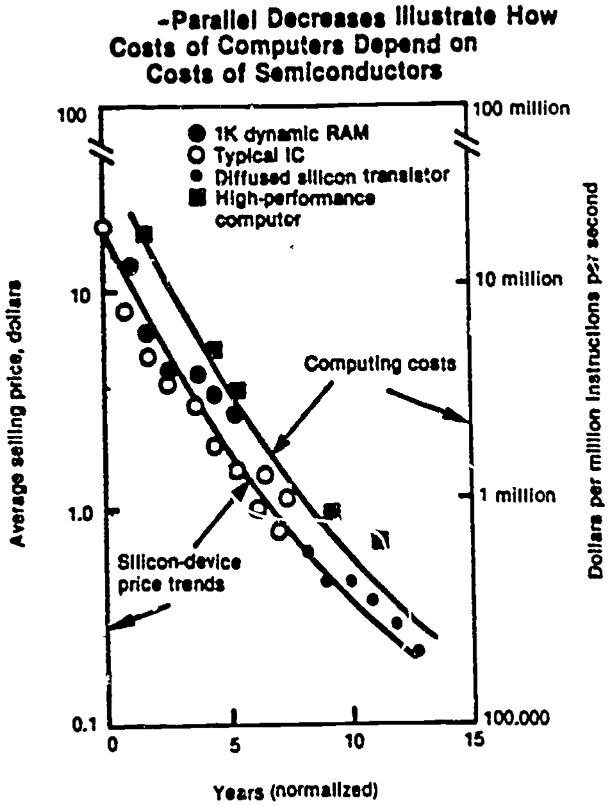

Figure 9. Decreases in Computer Hardware Costs in Recent Decades.

1. The Forms of the Computer

Since it first appeared around 1950 in its paradigmatic form now called the mainframe, the computer has been realized both in successively smaller and successively larger forms, as described in the following table.

Table 2. The Computer Paradigm Realized at Different Scales

Mainframe	The large-size, principal element of central computing facilities; usually room-filling; the historic progenitor which established the paradigm; introduced into the marketplace in 1950s.
Minicomputer	The intermediate, usually desk-size computer; used at first principally by researchers for laboratory equipment control and later, for example, in small businesses; introduced in the 1960's and followed recently by the supermini with greatly increased computational power rivaling, in some cases, that of central facilities.
Microcomputer	A complete computer fabricated on a single integrated circuit microchip, first achieved in the early 1970's; the basis for personal computers and, in microprocessor form, the source of the speed and power of most of today's machines.
Supercomputer	Ultra high speed vector or array type mainframe machines developed for solution of mathematical problems involving large arrays of parameters and variables as in the modelling of atmospheric weather and the analysis of electronic intelligence. Not Fifth Generation machines, which are non-von Neumann logical-inference machines.
Macrocomputer	A neologism to desribes the recent development in which the computer has transcended geographic localization; appearing in, for example, nationwide distributed-computing systems.

2. The Elements of the Computer

The functional elements of the general purpose digital computer are shown in Figure 10. The five elements, which form the paradigm of the digital computer as it is realized in all its overt and covert forms, are: the Input Device, Output Device, Central Processing Unit, Stored-Program Memory, and Data Transmission Channels.

Since the machine's early days, each of the computer's five major elements of the computer has not only been extended in capability but made modular: central processors, memories, input devices, output devices and data channels can each be manufactured, sold and operated separately.

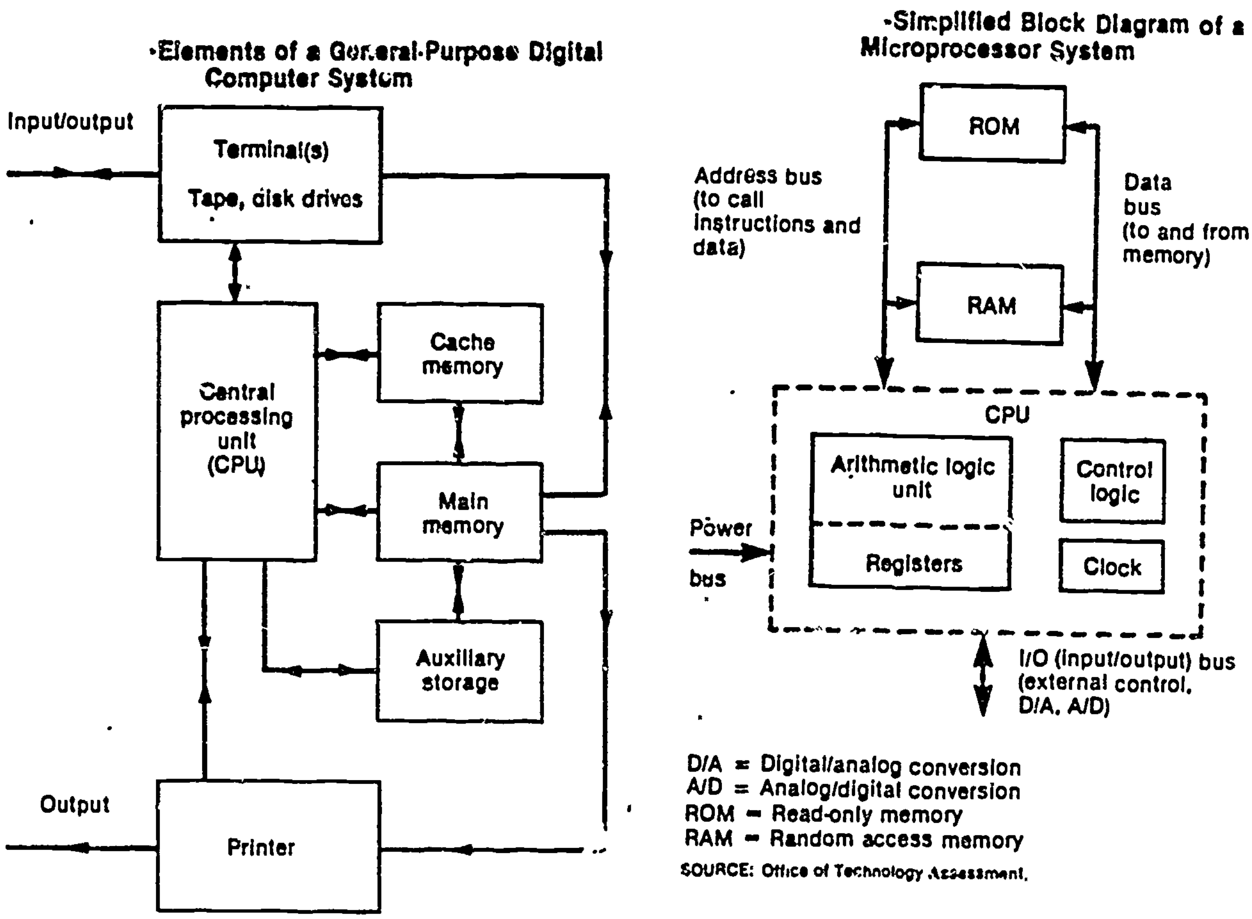

Figure 10. The Functional Elements of the Computer.

a. The Arithmetic/Logic Unit

The first functional element of the computer, the central processing unit (CPU), has at its heart an Arithmetic/Logic Unit (ALU) which performs on data the most fundamental process of computing. This process transforms one string of binary bits into another in the combined algebraic-and-logical operations governed by Boolean algebra. The particular way in which these operations are carried out is by means of logic gates, groups of switching devices organized to perform individual Boolean operations such as AND, NAND and NOR.

ALUs have recently evolved into much more powerful and complex configurations as summarized in the following table. These range from the original type named after John von Neumann who articulated its conceptual and logical structure to the newly-developing forms for parallel processing

Table 3. Evolution of Arithmetic-Logic-Unit Configurations

Elements	Functional Type
Single Serial ALU	Von Neumann
Multiple Serial ALUs	Distributed Processing Von Neumann
Multiple Parallel	Distributed Parallel Processing (non-Von Neumann)

In the classic von Neumann computer, a single ALU performs arithmetic-logical operations, of necessity in a sequential order. In distributed processing systems, separate ALUs perform serial operations as parts of a larger computation. In non-von Neumann computer systems, parallel processing is carried out by means of arrays of ALU's performing operations concurrently.

High-speed, massively parallel processing represents represents one of the key information technologies of the next two decades. During that period, there is every expectation that research into the hardware, software and artificial intelligence aspects of such systems will provide a basis for powerful, commercially available systems.

b. The Memory

The second functional element of the computer, the memory, consists of various devices for storing data. This memory can be very short term for ALU operations based on microcode, intermediate term for CPU operations based on high-level programs, or long term for mass storage of documents external to the system. The following table shows the principal forms of modern computer memory.

Table 4. Principal Modern Forms of Computer Memory

Memory Chip	The semiconductor integrated circuit which because of its small size per memory bit, high speed and low production cost is the principal main memory device; in commodity production as the 64K RAM, it is the main element of microcomputer memory; in development is the 4 megabit chip.
Magnetic Disc	In hard form in systems with moving magnetic read heads, the hard magnetic disc is the dominant storage technology. In floppy form, it is the principal medium for bulk storage for inexpensive personal computers. For central-facility archival storage, magnetic tape is also used.
Optical Disc	An ultra high density medium with data recorded and read out by laser; projected to have a potential capacity to store a gigabyte (10 billion bits) on a standard 12 inch disc; not erasable; limited to write-once, play-only.

c. Programming Control

The third functional element of the computer is the controller, an organized placement of switching devices synchronized by a high-frequency clock which, taken together, allows execution of a programmed sequence of ALU, memory, and data transfer operations. The following table shows types of programming for controlling these varied operations at differ levels of remove.

Table 5. Program-Level Control of Operations on Data

Microcode	Most fundamental level of computer programs with instructions at the bit-level; directly control the flow of electrical current in the switch level of the device; fixed in the permanent memory of the machine; the point at which trade-offs are made between hardware and software in the design of the machine.
Machine Language	Low level of programming in which instructions are written using the symbols which actually represent the instructions in the machine.
Assembly Language	Intermediating program which translates a higher-level symbolic program into an actual sequence of machine language instructions.
Procedural Language	High-abstraction symbolic programmming such as the scientific language Fortran and the business language Cobol; solutions to particular problems must be made explicitly in terms of a series of mathematical/logical operations.
Declarative Language	Highest-abstraction programs currently achieved in languages such as LISP and Prolog; for the solution of problems with only implicit solutions by means of logical inferences; the software tools of research on artifical intelligence and the fifth-generation computer.

d. Input/Output Devices

The fourth functional element of the computer consists of the individual or combination devices by which data is input to and output from the computer. These devices range from direct digital-encoding devices such as analog-to-digital converters to transducers which convert one form of physical signal to an electrical one which is subsequently digitized. The following two tables show the principal types of input and output devices.

Table 6. The Principal Forms of Input Devices

Keyboard	The principal device for input of data to computers; limited to alphanumeric characters at typing speeds; a bottleneck in productivity.
Process Sensors	Any of the analog devices which measure some a property of a physical system, for example, temperature, vibration, rate of flow; usually single, serial output.
Bar Code Reader	Optical device which scans binary coded information in the form of alternating light and dark stripes; used widely in retailing; being introduced into manufacturing and warehousing for inventory control; considered for construction.
Voice Recognition	Earliest form of devices for input of spoken words; commercially available; able to recgnize, for example, up to 1000 words by recording repeated utterances by same speaker and using pattern recognition techniques.
Optical Character Reader	An optical input device sought as an alternative to typist keying in information from existing typed copy; under devlopment; requires machine vision system to recoginize characters of varying font and legibility.
Speech Understanding	Sought-after object of advanced research: machine ability to recognize spoken words of different speakers at conversational rates and vocabularies; the typewriter which takes dictation.
Vision Systems	Optical systems, such as TV, which provide complex, time-varying imagery; area of research and development; principal problems: need to process large volumes of data in parallel in algoritms for extracting only the relevant visual information.

Table 7. The Principal Forms of Output Devices

Printer	The principal output device for hard copy visual records as in document preparation; now available in high-speed forms which operate, for example, on laser sensitization of a drum for transfer to paper in a high-speed xerographic printing process.
CRT Screen	The principal medium for working with alphanumeric information when hard copy is not required, for example, in word processing, programming, and data base examination.
Graphics Displays	The developing area for the presentation of visual pattern information: in the simplest form as graphs, charts, figures; in more complex ways as representational models; and the in the most advanced form for overlays of real-world and computer-generated images as in combat aircraft flight control displays.
Speech Synthesizers	The devices which generate audible words, currently by forming them from combinations of more elemental sounds generated each time; the descendants of Texas Instruments' famous "Speech and Spell".
Controls/Actuators	The devices which provide the computer with the means to control physical systems including generating the goal-directed physical motion of the robot.

e. Data Channels

The fifth functional element of the computer consists of the data channels, the physical paths by which binary-encoded data flows into, within and out of the various processing and memory units within and between computers.

At the device level today, as in 1950 when the transistor was first being developed, direct metal connections are required at the level of the electrical devices which represent data bits. Metallic strips provide electrical connections as for data channels at the device level, copper wire curently provides the data links at the element level, principally through cables. At the systems level, microwave and optical-fiber telecommunication technologies provide long-distance data links.

Table 8. The Physical Paths for Data Transmission

Metallic Strip	The sole means of interconnecting devices at the circuit level, until photons replace electrons for bit-representation within ALUs.
Twisted Pair	Historic form of signal wire; severely limited information-carrying capacity; forms the bulk of the telephone system connections.
Coaxial Cable	Efficient form of electrical conductor for transmitting digital information; principal means of interconnect in network systems.
Microwave	High frequency, line of sight, station to station transmission of radio type signals; used in telephone and satellite systems; subject to inteference and interception.
Optical Fiber	Ultrahigh information-capacity successor to metallic-wire systems; wide bandpass allows multiplexing of many channels; velocity of light reduces delay times; lack of means of coupling into signal increases security from tapping; relative cost of glass versus copper provides material cost savings [34].

In addition to the physical paths which must be present for data to flow from one to another at the level of the devices, there must mechanisms for organizing data flow at the macroscopic, systems level. The following table shows architectures for organizing the channels through which data flows at such systems levels [35].

Table 9. The Extended-System Data Channels

Bus	Bus: A wideband device for interconnecting the internal elements of computer systems that permit multiple devices to transmit information simultaneously.
LAN	Local Area Network: a baseband or broadband system by which independent computers communicate over relatively short distances, usually within one office, department or organization.
WAN	The wide area network: a system for computer-to-computer communication via, for example, telephone, microwave and optical communication channels.

Figure 11 shows a factory-office complex with an information system based on computers linked through electrical cables in a Local Area Network (LAN) [36].

Figure 12 shows for the U.S. as a whole the extent of AT&T's optical fiber telecommunication system which, in addition to having increased capacity for voice communication, allows geographically separated computers to be efficiently linked in Wide Area Networks [37].

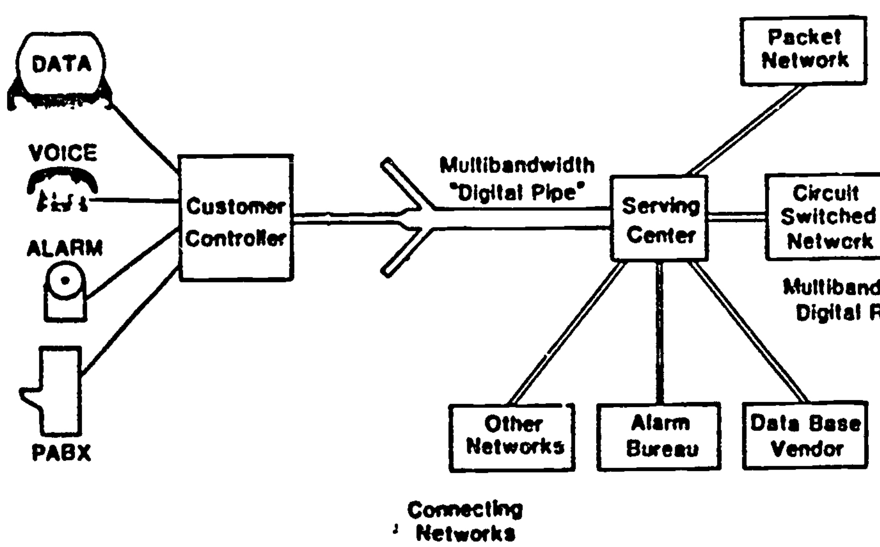

Figure 11. Example of Factory-Wide Local Area Network System.

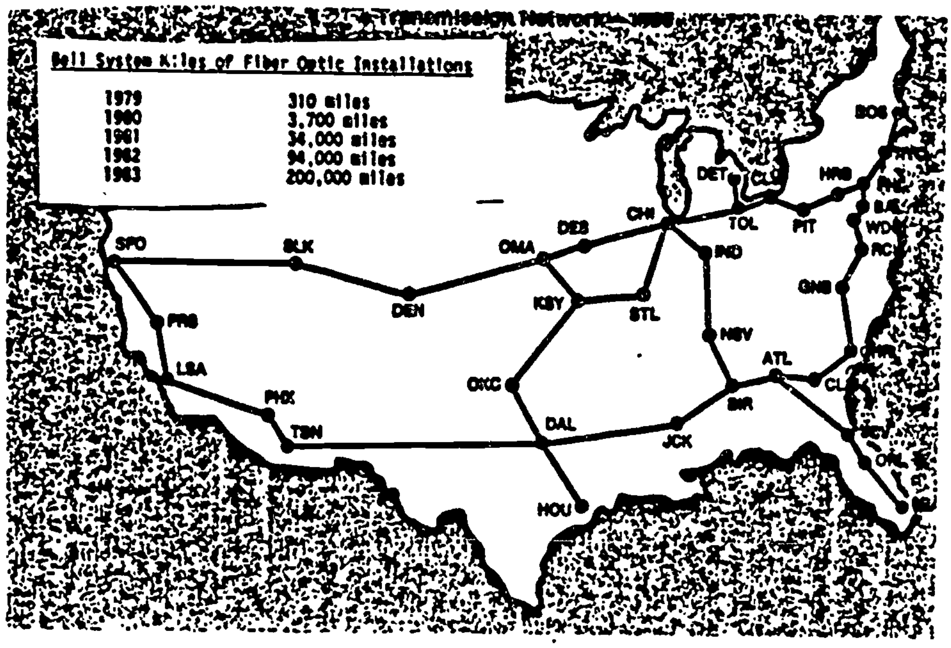

Figure 12. Nation-Wide Optical-Fiber Communication System.

The convergence of telecommunication and computer technologies which optical-fiber systems reflect the the demand pull and technology push for communications with ever-greater data carrying capacities in terms of data rates and data volumes. The following table shows the principal elements of digital telecommunications systems [35].

Table 10. Elements of Digital Telecommunication Systems

Digital Switching	The devices which interconnect any two phones, computers or terminals to provide a physical communications path, either digital circuit-switching which provides a continuously available path or digital packet-switching which multiplexes packets of data from multiple sources over a single line.

Fourth-Generation PABX	The next generation of Private Automatic Branch Exchange, which is the local circuit-switching system installed on a customer's premises. Blending data front-end processors and controllers with digitized voice, they may be thought of as digital PABXs able to handle data or computer front-end processors able to handle voice.
Integrated Services Digital System	A public-access digital transmission network made up of nodes and branches extending over a wide geographical area in which all switching, transmission and processing inside the network is digital and provides a basis for a wide variety of voice, data and image services.

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This section has described the five functional elements of the computer, the device of which they are comprised, and the different forms in which they are manifested. Because of the inherent technical complexity of these systems and devices, it is possible to lose sight of what it is these various devices and systems have in common.

3. Data and Its Representation

From a systems theory point of view, this binary data is the shared part which makes the information tecnologies constituents of an integral whole which is an extended computer. Within the paradigm of the computer as system, the individual information technologies serve as the computer's functional elements. As input, output, memory, processing, and control elements within an extended computer system, the information technologies variously generate, operate upon, transmit, store, and use digital data.

a. The Concept of Data

The term and notion of data originated with the Romans who inscribed on their written letters a "datum" which gave both the time and the place of the letter's writing. Modern technical notions of data are an extension of the Roman concept resting on the information theory of Shannon [38].

According to information theory, a datum locates an event in space and time, as in "it happened here, now." As such, data are the binary-represented events whose occurrences or non-occurrences in a time sequence constitute information. In terms of the most basic computer operations, data is represented in bits and information is represented in bytes.

b. Physical Representation of Data

At the core of the computer are two devices which together allow the physical representation of data. In the simplest terms they are a switch for marking the event and a clock for marking time. In more complex terms, they are high-speed switching transistors--which represent by their electrical on-off states the zeroes and ones which in turn symbolize occurrence and non-occurrence of events--and a high-frequency clock--which generates the time intervals by which the times at which events occur relative to each other are reckoned [39].

c. Limitations on Electrical Representation

The specific device for representing bits has gone from mechanical swithches to a variety of electrical switches, from the vacuum tube and the discrete transistor to the planar transistors arrayed by the thousands on today's integrated-circuits.

However, electrical devices have inherent limitations on speed which need to be overcome: first, in the rate at which a transistor can switch on and off--a limit to the the speed of ALU operations; and, second, in the rate at which electricity travels down wires--a limit to the speed at which data can be transported to, from and within the computer.

d. The Optical Alternative

As a result of limitations on electrical speed, research is currently directed at the development of much faster, hybrid opto-electronic or purely "optronic" devices. Such devices operate optically--that is, with photons of light--rather than electronically--that is, with charges of electricity--to represent the computer's bits [40].

Such optronic devices are being sought in order to achieve totally optical bit representation and ALU operations. While optical-fiber technology allows for transmission of optical information after electrical-to-optical conversion, lack of practical devices for optical bit-representation and switching currently prevents development of the dreamed-of ultra-high-speed all-optical computer.

4. The Intelligent Machines

Automation is generally considered to mean the performance by machines of work usually carried out by people; in this sense, one thinks, for example, of office automation and factory automation. Associated with factory automation are robots, the machines that can perform the phsical labor of lifting materials, welding steel frames, and painting auto bodies. Associated with office automation are computerized systems, the machines that can perform information-handling tasks such as generating invoices, and balancing bookkeeping ledgers.

Emerging from current research and development are two much more advanced types of computer-based machines for carrying out tasks in the workplace with high degrees of effectiveness and autonomy. In effect, they are the "intelligent machines of action" for the advanced automation of physical work and the "intelligent machines of thought" for the advanced automation of mental work.

a. Computerization of Physical Work: Robotics

In the last decade, development has progressed on information-technology machines capable of performing skilled physical work. These machines are capable not merely of crude, repetitive actions but high-variety actions requiring flexbility and dexterity as well.

Machines in the physical workplace have progressed beyond mechanization, that is, the application of by machines of physical power through mechanical links to do heavy, repetitive manual work. It is also progressing beyond automation as the idea was understood in the 1950s and 60s, that is, the application by machines of feed-back to regulate the repetitive action of mechanized devices.

Today's automation involves robotics, that is, the application by machines of real-time computer analysis of sensory input from an environment to choose the most effective of a number of possible mechanical manipulations of that environment to achieve a particular goal.

The following table shows the principal functional elements of robotic systems from a control system point of view.

Table 11. Functional Elements of Advanced Robot Systems

Input Sensors	The sensory devices that provide continuous, real-time inputs on the physical environment in which the robotic system is to operate to carry out its function; for example, vision, touch, force, heat, and motion.
Sensory Processors	The front-end of the control system which must extract from high-volume parallel streams of raw sensory data the salient features related the systems function.

Decision Module	The central element of an advanced robotic control system which compares features of the environment with expectations based on a model and chooses among alternative actions to achieve a goal; the main artificial-intelligence element of the system.
Actuators	The back-end of the control system which converts internal decision information into executable commands to drive specific physical output devices.
Effectors	The output devices that manipulate the physical environment to achieve the goal of the robotic system; ranging from special tools for material-working such as painting and welding; grippers for materials-handling and parts assembly; positioning and locomotion devices from arms, wheels, and legs to aircraft control surfaces, submarine diving planes, and rocket engines; and, finally, weapons.

o At the low end of the robotics scale are simple programmable manipulators which include the insensate "pick-and-place" machines repeating preprogrammed moves which comprise most of today's industrial robots. In this category are the vast majority of the welding, spray-painting, and materials-handling robots appearing in today's factories.

o Intermediate on the robotics scale are the laboratory robots of today, complex sensor-equipped machines operating by means of goal-directed computer control systems capable of taking a wide range of physical actions contingent upon what is sensed in the environment [41,42].

o At the highest end of the robotics scale are the intelligent, articulate androids, the autonomous undersea vehicles, and the battlefield robots that exist in the minds of researchers, the proposals of long-range military planners, and the movies of the day.

b. Computerization of Mental Work: Artificial Intelligence

In the last decade, development has progressed on information-technology machines capable of performing skilled mental work. These machines are capable not merely of simple, repetitive mental tasks such a counting, tabulating and processing data by arithmetic-logical operations but are capable of higher-order intellectual functions as well.

Analogous to the distinctions among mechanization, automation, and robotization as the machines for physical work are distinctions among computers of advanced capabilities as machines for mental work. Being introduced into the lexicon of computer scientists are hardware/software systems differentiated by the highest level of abstraction with which the system can deal.

Table 12. A Hierarchy of Computer System Capabilities

Data Processing	The low end of the scale of capabilities: early-generation systems that operate on data, that is, bit-represented elements such as numbers and characters, in order to sort, count, and tabulate.
Information Processing	The intermediates on the scale: the most recent-generation systems that operate on information, that is, bit-represented relations among data in order to analyze and relate.
Knowledge Processing	The high end of the scale: the just-developing generation of systems that operate on knowledge, that is, bit-represented symbols and concepts as relations among information in order to reason, infer and judge.

As a field of research, artificial intelligence currently operates at the boundary between information processing and rudimentary knowledge processing. Carried out in languages such as LISP and Prolog on hardware specifically designed for them, AI research is aimed at achieving computing systems which can exhibit characteristics of human intelligence including functions such as as planning, learning, and optimization [43]

Expert systems represent the first introduction into the commercial marketplace of products based on research in artificial intelligence. They are software programs which have incorporated within them specific rules governing decision-making in a particular subject area based on the knowledge and experience of a human expert in that field. Knowledge-engineering is the process of obtaining that knowledge from the human expert and representing it within the software program as executable code.

Originally developed for situations where the number of factors and variables that need to be taken into account exceed human capability to handle, expert systems are currently in use, for example, in the engineering design of complex integrated circuits and the medical diagnosis of disease [44]. Also available commercially are expert-system microchips which provide a programming environment for user-developed expert systems for a variety of less sophisticated applications such as machine trouble-shooting and maintenance [45].

Competitive with research within the U.S. on artificial intelligence is work in Japan, particularly in the hardware-oriented work mentioned earlier. In its "fifth-generation" computer project, MITI sponsors research and development of what it calls Knowledge and Information Processing Systems (KIPS), machines so advanced the Japanese choose not to call them computers [46].

In undertaking this task, Japan has reportedly made it a national goal to design, manufacture, use and sell knowledge-information processing machines that not only dominate future computer markets but provide the basis for massive gains in both industrial and service productivity. As such, these machines are intended to form the principal basis for an explicitly third-era, knowledge-based economy intended to supercede the United States, with twice Japan's population, in its share of the world economy [46].

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This section of the paper has briefly described the basic constituents of the information technologies in a conceptual framework based on three premises:

(1) that the computer and its elements are the paradigm of the information technologies;

(2) that binary-represented data is the shared part among the information technologies which makes them elements of an extended computer system; and

(3) that robotics and artificial intelligence are the advanced information technologies which will have the greatest effect on work in the emerging third era.

The following section of the paper examines specific realizations in the workplace of the computer paradigm in its myriad forms.

C. The Information Technologies in the Workplace

Robots welding automobile chasses, personal computers on executives desks, and automated teller machines are among the information technologies that have already appeared in the workplace. As a result of applications such as this, the computer has become this era's engine of change, transforming the places of work and the tasks of workers.

This section of the paper looks at particular information technologies as they are being developed for and implemented in first, the factory; second, the office; and, third, places of service work as well.

1. The Technology of the Factory of the Future

The automated factory of the future is a conceptualization of what the production facilities of manufacturing will come to be over the next few decades as a result of the progressive application of the information technologies [47].

a. The Forms of the Automated Factory

Fully automated factories can be realized in as one of two forms, depending on the volume of production and the variability of parts being manufactured. In either case, there is no direct-cost, "touch" labor involved in production. While people design, build and tend the factory, they do not operate it as such.

1. Hard Automation in Large-Volume Flow Production

Where markets allow production of long runs of essentially identical parts, production can be organized on a flow basis. At present, the transition from manual control to computer control of high-volume, flow-type production is being made by means of hard automation. With hard automation, specially-designed hardware, such as dedicated materials handling systems, and special-purpose software, such as system-specific parts programs, are used in conjunction with low-variability products.

A U.S. electronic typewriter plant exemplifies current state-of-the-art in automated factories for large scale production. This new plant is described as producing 10 different models of an electronic printer/typewriter at the rate of nearly one million per year using 300 production workers and 175 commercially-available robots for a direct labor cost of 3.7%. Reportedly this U.S. factory will soon produce output with 100% domestic content at least-cost on a world-wide basis [48].

While the technology of hard automation for large-volume production already been implemnted, the technology of flexible automation of small batch production is more a matter of research and development.

2. Flexible Automation in Batch Production

Where markets allow only batch production of highly-variable parts, production is organized on a job shop basis. Present job shops accommodate needs for low volume production of high-variety parts by means of general purpose machine tools, part-dependent fixtures, and skilled machinists.

Pressures arising from the globalization of markets, demands for increased product quality at lower costs, and even population demographics [49] are propelling development of the fully automated factory of the future not only for large-volume, flow-type production but small-volume, job-shop production as well.

Table 13 summarizes the characteristics of the production systems which require flexible, as opposed to hard, automation.

Table 13. Aspects of Flexible and Hard Automation

Type of Automation	Hard	Flexible
Volume of Production	High	Low
Variability in Product	Low	High
Mode of Production	Flow	Batch
Characteristic Form	Assembly Line	Job Shop

b. Information and Control in the Automated Factory

As an information system, the fully integrated factory of the future is a computer-integrated-manufacturing enterprise (CIM), one in which all the production process and related managerial functions are represented as computerized data that move freely and are used throughout the production life of the product [50].

Complementary to the information-system view of the technology of the factory of the future, there is the automation/robotics, control-system view. As a control system, the fully automated factory is a robotic production system which, given raw material and design specifications as input, can produce finished product without the direct intervention of people in the production process [51].

The following table shows the operational functions within manufacturing now being brought under computer control as they form the elements of a data-linked, order-to-delivery, computer integrated manufacturing enterprise.

Table 14. Computer Integration from Order to Delivery: Data-Linked Activities within a CIM Enterprise

Customer Order Processing	Entry into the system of customer-specific product specifications; output to the customer the resulting product design, price and delivery information; entry of orders, output of factory order and customer billing; monitoring of delivery and payment.
Product Engineering Design	Design to customer specifications of product which is within the product-family, cost and schedule capabilities of the enterprise.
Production Process Planning	The generation of the detailled plan including the machines, materials, tools, and sequence of operations to be used to achieve the customer-specific product design, price and delivery.
Material Inventory Control	Monitoring of the quantity, the location, and the condition of raw materials, tooling, work-in-progress, and finished product relative to current and future needs.
Shop-Floor Production	Implementation on the shop floor of the process plan for the fabrication, assembly, and inspection/testing of the customer-specific product.
Product Delivery	Packaging, shipping, and delivery of the customer-specific product on the schedule set at order entry with customer feed-back to order-processing and design.

c. The Software Systems of the Factory of the Future

The following table lists the broad, design-to-production manufacturing functions now being implemented in software in order to achieve computer integrated manufacturing in the discrete parts industries. Among these various elements, there has been, and continues to be, overlap as the concepts behind them and the software systems to which they give rise continue to evolve.

Table 15. Software Systems for the Principal Design-to-Production Elements of Computer Aided Manufacturing

Computer Aided Design	Orinally conceived and developed for drafting, CAD systems provide graphic representation and geometric modelling in the design of products.
Compter Aided Engineering	An extension of CAD drafting into engineering design, CAE software provides for performance simulation and functional analysis of CAD-designed products, for example, complex integrated circuits or aircraft assemblies.
Computer Aided Process Planning	For production management of shop floor operations, CAPP systems are used to generate in detail the actions to be carried out in the material processing and support operations in the manufacture of the product.
Computer Aided Manufacture	For shop-floor level control of the materials-processing and materials-handling machines of production systems, CAM software includes that which generates, for example, the NC code which numerically controlled machine tools execute.
CAD/CAM	The software link between the various elements of CAD, CAE, CAPP, and CAM subsystems which allows direct data exchange during all phases of the design-through-production process. May include, for example, Group Technology (GT) systems for automated feature-analysis of parts and their grouping into families for efficient production.

d. The Hardware of the Factory of the Future

CAD, CAE, CAPP and CAD/CAM represent the software systems which deal with information-processing aspects of CIM integration. To achieve the factory of the future, both the information-processing and the materials-processing aspects of physical production must be brought under intelligent machine control. The following table shows the principal shop-floor hardware elements of such a fully automated factory for flexible, small-batch production.

Table 16. The Principal Hardware Elements for Physical Production within a CIM Enterprise for Flexible, Small-Batch Production

Matl Processing Machines	The computer-controllable machines which form, cut, shape and otherwise work and transform raw and semi-finished materials into product, including advanced machine tools, such as multifunction, numerically controlled machining centers.
Industrial Robots	The complex, sensor-equipped, highly-articulated, programmable mechanical manipulators which carry out production functions which require manual dexterity and interaction with a changing environment, beginning with simple tasks such as welding and painting and progressing to more complex ones such as assembly.
Inspection Stations	The systems of devices which examine and test materials and product for conformity to requirements, including, for example, machine vision systems for mechanical parts and automated test equipment (ATE) for electronic instruments.
Sensory Systems	The systems of devices which allow the control system to automatically respond to the changing production environment by providing direct sensory information, for example, through robot vision and tool wear monitoring systems.

Materials-Handling Systems	The computer-controllable systems for handling raw materials, tooling, work-in-progess, and finished product, including Automated Storage and Retrieval Systems (ASRs) which shelve and the Automated Guided Vehicles (AGVs) and related systems which transport them.

As indicated in the figure above, the job-shop form of the factory of the future--for fully automated production of, for example, machined, cleaned, and inspected parts--consists of multi-function machine tools, automated materials handling systems, automated guided vehicles, robots, and sensors integrated into a system under computer control.

e. U.S. and Japanese Programs in Flexible Automation

The strategic economic significance of this automated factory for flexible small-batch production is its capablility for producing small batches of essentially custom products with the efficiency of mass production. As such, flexible automation poses potential for both competitive and comparative advantage.

Japan has clear national goals for the development and implementation of this automated factory for flexible, small batch production [52]. Following a completed seven-year MITI-organized project for research on flexible machining systems [53], MITI has implemented tax policy to specifically support industry development of robotics-based flexible automation, a technology which it characterizes as basic, that is, strategic to future manufacturing-based trade [54].

At the national level in the U.S., the National Bureau of Standards in its Automated Manufacturing Research Facility is addressing questions of dimensional measurements for quality control and interface standards for flexible automation, in particular, for the automated machining of small mechanical parts [55]. As a research form of a very advanced flexible manufacturing system made up of machine tools, robots, automated materials handling systems, and computers from a variety of manufacturers, the AMRF provides a laboratory for research on issues of interface standards as a means to effective integration of flexible machining systems [56].

In the AMRF, an NBS-developed factory system architecture based on real-time hierarchical control is being tested successively at the equipment, workstation, cell, shop and facility levels of control. At present, a modular, integratable system of control has been realized to the cell level for three metal-cutting workstations.

The broad-scope work within the AMRF deals with all aspects of standardization within a fully automated job shop: from neutral data format standards for estabshing CAD-CAM links [57], through robot programming language environments [58], to a standard factory system architecture [59]. The research being carried out at NBS is public-domain, in a cooperative program involving industry, universities, and other Federal agencies.

2. The Technology of the Office of the Future

The office of the future, like the factory of the future, is a technological goal, a vision of what the office will become with implemenation of the advancing information technologies.

a. Information Technologies in Four Types of Offices

The effect of the information technologies on particular offices depends on the type of information that the office processes; following are examples of four types of offices, each have information-intensive activities as a central function.

An Administrative Office	One which processes organizational records, for example, personnel, payroll, purchases, and operating costs as a means of managerial control of an organization; e.g., corporation or public agency.
A Business Office	One which executes market transactions, for example, sales, deposits and funds transfers, as the market action of the enterprise; e.g., in a stock exchange, bank, or insurance company.
A Technical Office	One which produces executable designs and plans as a means to physical production of goods; e.g., an independent architect or engineering department within a firm.
A Professional Office	One which provides expert judgment, advice and actions as a service; e.g., doctors, lawyers, accountants and investment analysts.

For whichever purpose it exists, the primary function of the office is information processing and a primary product the document [35]. The information which the office processes and the documents it produces may appear in many forms, including speech, text, tables, graphics, and pictorial image.

While factory and office differ fundamentally in that the factory processes material and the office processes information, there are direct parallels between the concepts, goals and elements of the information technologies as they are applied to the factory and office as workplaces

b. The Computer Integrated Office

What Computer Integrated Manufacturing (CIM) is to the factory and material-processing, the Integrated Office Information System (IOIS) is to the office and information processing. Within an integrated office information system, all the information which the office receives, generates, and processes into the documents it stores and transmits is represented as computer data which moves freely for use throughout the office system.

Office automation is the means to achieve the technological goal of an IOIS and the office of the future. The elements of office automation are shown in the following table.

Table 17. Some Hardware/Software Components of Office Automation

Word Processors	Microcomputers dedicated to preparation, modification, and printing of alphanumeric character text documents.
PC/Microcomputers	The general-purpose small computers used on an individual basis for data manipulation, word processing, graphics display and local document storage.
Electronic File System	Mass-storage memory system with indexing system for rapid storage and retrieval of documents of any type in digital form.
LAN Connections	The hardware/software systems which allow interconnection of individual terminals, computers, and peripherals through a local area network.
Database Management Systems	The software systems for organizing, accessing, searching, and maintaining the integrity of collections of data.
Office Applications Software	Software for specific office functions such as a Management Information System for an administrative office, a financial analysis expert system for a business office or CAD for a technical office.

c. The Office Workstations

As a place of work, the office of the future will be organized into a network-linked system of integrated, multifunction workstations. The nature of the workstation depends on the tasks to be carried out, for example, document production, professional analysis or communications, as illustrated in the following table.

Table 18. Workstations and Elements of Office Automation Systems

Document Production Workstation	The combination of keyboard for alphanumeric input, CRT for display, local memory, access to mass storage memory, on-line information services, and printers in a single-operator, single-position system as principal means for producing documents.
Professional Workstation	Specialized microcomputer or personal computer system with software systems for computer analysis, graphical display, document generation specific to the profession, for example, for engineering design, manufacturing process planning, scientific research or business market analysis.
Communication Workstation	An integrated communication system with elements to input, output, direct and control all-digital communication through telephone PABX, internal LAN, and external WAN computer network links for voice, data, and image transmission.

The principal function of such a communication workstation, whether a free-standing or distributed entity, is to deal with the spectrum of telecommunication-related communication and information services which originate from or are directed to offices. The range of communication and information services being developed and implemented [60,61,62] include electronic mail, voice mail, teletex, videotex, video-conferencing, facsimile transmission, and on-line information services to be described below.

o o o

In summary, from an information systems point of view, the office of the future will be an integrated office information system. In that system, document-production, professional functions, and communications may be carried out at multifunction workstations linked, first, to each other through local area networks and, second, to outside computer and information systems at large through wide area networks, tele-communication systems, and even dedicated satellite links.

As an information-processing system, the office of the future will be able to receive, generate, process, store, and transmit information from a variety of electronic and non-electronic media to produce documents, for example, in text, graphics, facsimile, voice, moving image and combination forms.

To carry out administrative, business, professional, and technical office functions, the office of the future will be equipped with hardware/software systems which will share the tasks now carried out by office-based workers.

o For managerial-administrative office workers, office automation in the form of computer-based "information systems" will increasingly move beyond data-handling for efficient, paperless operation to automated decision-making for control of administrative and business systems.

o For technical-professional office workers, office automation in the form of computer-based "knowledge systems" will move beyond graphics representation of designs to expert-systems, for example, for computer-analysis of design alternatives and later to artificial-intelligence "inference engines" which not only analyze but generate new concepts, principles and models.

Just as the the information technologies in the form of computers, automation, and communications will profoudly effect work in factories and offices over the coming decades, they will effect service work as well.

3. The Technology of Service Work of the Future

While the U.S. is described as having become a service economy, while the productivity of the service sector is described as being low, and while workers are reportedly being displaced out of high-paying production jobs into low-paying service jobs, the specific meaning of service is elusive.

o Service, according to the dictionary, is what servants do.

o Service jobs, according to labor classifications, include attendants, food servers, guards and warriors.

o Service industries, according to standard industrial classifications, include banking and insurance, transportation and communication, electric and water utilities, wholesale and retail trade, health, and government.

In a technological sense, the task of service sectors, service industries, and service occupations is, in effect, to provide "action-on-demand". In essence, to serve is to act when action is called for. Hence, Mitton's observation that "he also serves who only stands and waits."

In terms of the task-specific ways in which they are affected by the information technologies, there are four broad classes of service, that is, four types of action-on-demand: financial, informational, material and physical.

a. Financial Action-on-Demand

The first of the four types of service tasks, those which provide a financial action for the one served, are the type which are carried out in bank transactions, stock sales, and insurance coverage. The following table represents the principal information technologies specifically related to providing a service of financial action on demand [61].

Table 19. Information Technologies Specific to Financial Service

Electronic Funds Transfer System	The computer and network system which provides for representation of funds and account entry information in digital form for the execution of financial transactions and the direct institution-to-institution movement of funds.
Point of Sale Systems	The network-linked terminals located in individual retail establishments for the execution of sale transactions by EFT.
Automated Teller Machines	The network-linked terminals outside of or away from bank branches which provide account transactions including [illegible] withdrawals.
Smart Card	A credit card implanted with elements of microprocessor and memory chips to execute personal identification, data encryption, message verification and memory control as an authorization and payment method.

b. Informational Action-on-Demand

The second of the four types of service tasks, those which provide a information on demand to the one served, deal with providing data, information, advice and counsel, ranging from on-line flight schedule information to expert professional judgment, for example, in medicine, law, and architectural design. The following table represents the principal information technologies specifically related to providing a service of information on demand [35, 60].

Table 20. Informational Action-on-Demand Technologies

Electronic Mail	Computer terminal-to-terminal transmission over computer nets with storage and display on demand of messages, memos, and documents.
Voice Mail	Telephone set-to-set transmission with storage and access on demand of digitally recorded calls.
Teletex	One-way computer-to-TV transmission over telephone lines of text and graphics information for display on demand on specially-adapted sets.
Videotex	Two-way computer-to-computer transmission over telephone lines of text, graphics, on-line information services, and executable software programs as a telecommunications service.
Videoconference	TV-to-TV two-way transmission of live image, audio and data for remote meetings.
Facsimile	Reader-to-printer transmission of a digital representation of the pictorial image of a document.
On-Line Information	Interactive computer-to-computer terminal search, selection and display of infomation from central data bases, for example, for reservation, bibilographic, stock market, and scientific data services.

c. Material Action-on-Demand

The third of the four types of service tasks, those which provide material goods-on-demand to the one served, deal with the sale and delivery of goods including raw-material, semi-finished and finished goods. The following table represents the principal information technologies specifically related to the service of providing material goods on demand in both wholesale and retail trade [60].

Table 21. Material Action-on-Demand Technologies in Wholesale and Retail Trade

Point of Sale Systems	The network-linked terminals located in individual retail establishments for the execution of sale transactions by electronic funds transfer.
OCR-POS Sales	Optical character recognition systems coupled to point of sale systems for execution of sales transactions involving reading computer-generated Universal Product Code labels on merchandise and payment by means of electronic funds transfer.
Automated Warehousing	Automated material-handling by means of automated storage and retrieval systems, automatic guided vehicles, and UPC bar-coded goods linked to automated office functions including computerized ordering with billing via electronic funds transfer.

d. Physical Action-on-Demand

The last of the four types of service tasks, those which provide a physical action for the one served, are the type which are carried out in hospital surgery, airline transport, and machine repair. The following table represents the principal information technologies specifically related to the physical action-on-demand tasks, that is, service robotics.

Table 22. Information Technology of Physical Action-on-Demand: Service Robots

Hospital Robot	Demonstrated by the Japanese at a world exposition, a hospital-worker robot capable of handling bed-ridden patients [63].
Cleaning Robot	Under commercial development, a mobile vacuum-cleaner robot to do night-cleaning of the central areas in large-scale establishments such as shopping centers [64].
Brain Surgery Robot	Demonstrated at the White House and subsequently used in surgery, a robot to align a guide along a path computer-generated from a three-dimensional x-ray to allow accurate placement of a surgical instrument for brain tumor excision [65].
Sentry Robot	Under development, an autonomous mobile robot for patrolling fences of large-area high-security military installations [66].
Construction Robots	In research and planning, a variety of robot devices for on-site materials-handling, fabrication and assembly of structural elements and application of materials [67].
Space Station Robots	In planning, hybrid teleoperator-robot systems for maintenance and repair of the NASA space stations [68].
Combat Robots	In research and development, a variety of autonomous vehicles, weapons, and other military systems for land, sea, air and space combat, including the Star Wars space-based defense system. [69,70].

In summary, service--that hard-to-define activity which is here taken to be action-on-demand in either financial, informational, goods-provision, or physical forms--is being affected by the information technologies no less than work in factories and offices.

The implication of progressive application of information technologies to office and service work is that they will eventually become as capital-intensive, high-productivity, and wealth-producing as the production of goods has been in the past.

o o o

The prospects of high capital-intensity/high-productivity in all sectors of the economy--in office and service tasks as well as in agricultural and industrial tasks--has major implications for all work, all workers, all employers and the society at large. In conclusion, a few of these implications for work and workers will be mentioned here.

III. CONCLUSION: TOWARD INTELLIGENT MACHINES AT WORK

The objective of this paper has been to identify and describe the new technologies most likely to affect the U.S. workforce over the next two decades. As shown in the first section of this paper, those twenty years will be part of a momentous transistion into a third, distinctly new, post-industrial era.

From the point of view of this paper, the technologies most affecting the workforce during this transition and for generations to come are the information technologies.

This closely-related family of technologies consists of all the machines, devices and systems which generate, transmit, manipulate, or are controlled by the binary-represented data upon which computers operate.

The pervasiveness of the information technologies has already been manifest. In factories, in offices, and whereever service is performed, computers, automated machines and robots are in use.

Whatever economic and technological forces have brought the U.S. workforce to its present relation with these machines appear to be impelling it to an even more advanced state within the discernible future.

In that future, the information technologies will manifest not only growing pervasiveness but substantially increasing power. Wherever people work, they will encounter intelligent machines, both the "intelligent machines of action" and the "intelligent machines of thought". As suggested by the following matrix, next-generation robotic systems will share tasks with the physical production and physical service occupations while next-generation computer systems will share tasks with the management/administrative and technical/professional.

Table 23. Task-Sharing with Intelligent Machines in the Occupations

Physical Production	Physical Service
Sharing tasks with physical production workers will be intelligent machines in the form not only of industrial robots but computer-controlled machine tools, automated materials handling systems, and automated guided vehicles, as they appear first in the factory and then on the less ordered construction site.	Sharing tasks with physical service workers will be intelligent machines in the form of the "service robots", working first in large-scale establishments such as commercial shopping centers doing night-cleaning and later, for example, doing military applications such as base security and even combat.
Managerial-Administrative	**Technical-Professional**
Sharing tasks with managerial-administrative workers will be intelligent machines in the form of "information systems", working. first, for data-handling to achieve fast, paperless operation of administrative systems and, later, for automated decision-making and control within such management systems.	Sharing tasks with technical-professional workers will be intelligent machines in the form of AI systems working, first, for example, as expert-systems for machine-analysis of design alternatives and later, for example, as "inference engines" which not only analyze but generate new ideas, principles and models.

Implementation in the workplace of intelligent machines such as these depends on commercial products which have been hard engineered from the soft systems concepts generated in research.

While the U.S. has a deserved reputation for being ahead in research in robotics and artificial intelligence, areas which are necessary but not sufficient for success in third-era economy, there is ample evidence that Japan is at least even with and arguably ahead in the bottom-line area of the hardware of intelligent machines.

o Just completed is a seven-year MITI-organized project for research on flexible machining systems, which in cell form are automated machine tools which Japanese industry sees as the growth market and arena of competition in machine-tool-based factory automation [52, 53].

o Further, in a newly-implemented tax policy, MITI has directed support to industry for development of robotics-based flexible automation, the higher-level form of machine-tool-based factory automation, the essence of the factory of the future and the basis of future manufacturing [54].

o Finally and potentially most importantly, in its current "fifth-generation" computer project, MITI sponsors development of the hardware of the Knowledge and Infomation Processing Systems (KIPS) which it sees as the basis for revolutionary productivity gains in all areas of its economy [46].

In undertaking these tasks, Japan has made it a national goal to design, manufacture, use and sell intelligent machines as the basis for an explicitly third-era, knowledge-based economy intended to supercede the U.S.--with twice Japan's population--in its share of the world economy [46].

Surely then as the U.S. workforce moves into its third era, it will not be alone in trying to achieve mastery of the technologies of the intelligent machines which underlie it.

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APPENDIX A. THE DIAMOND PLOT OF OCCUPATION TRENDS

Figure A1 shows the form of the diamond plot of the distribution of occupations applicable to any given sector, industry, or firm.

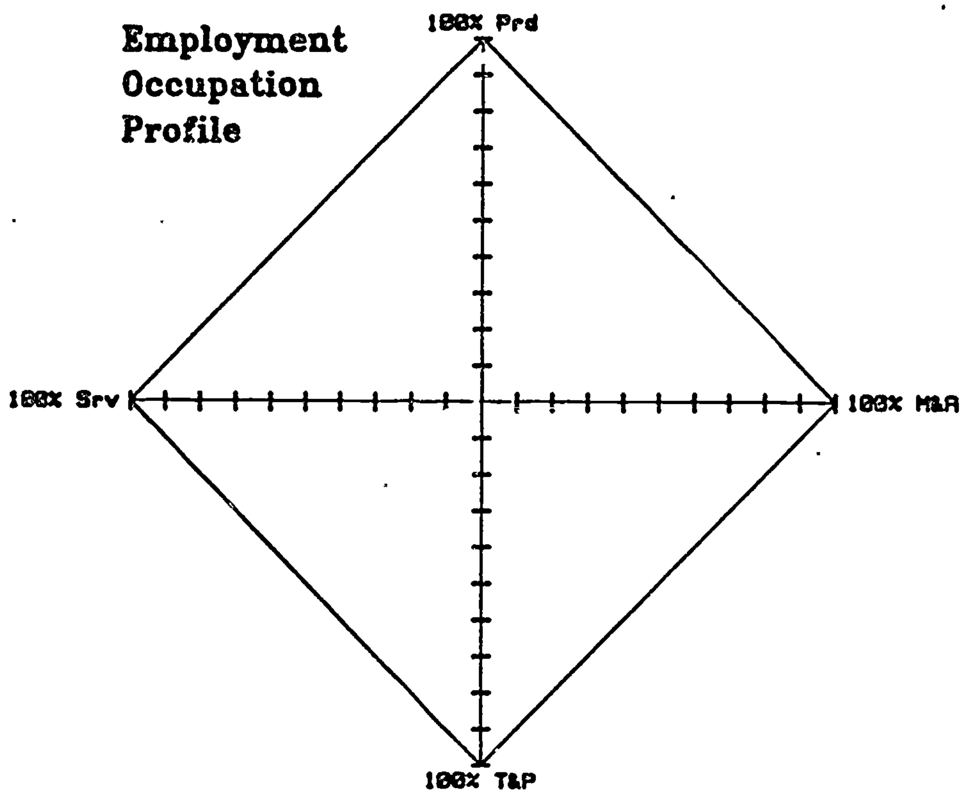


Figure A1. The Employment Occupational Profile Diamond o Production Workers--including laborers, operatives, precision production and craft workers;

o Managerial and Administrative Workers--including proprietors, managers, administrators, clerical and sales;

o Service Workers--the single category of that name; and, finally,

o Technical/Professional Workers--including professional, technical, and related occupations.

Along the vertical axis is plotted (P - T/P), the difference between the percentage of production workers and the percentage of technical/professionals for the given entity. Along the horizontal axis is plotted (M/A - S), the difference between the percentage of managerial/administrative workers and the percentage of service workers.

This type of chart reduces the four numbers representing the percentages in the four categories to two numbers which locate a single point within the diamond. If there are only production workers, the point will fall at the top of the diamond, the vertex labelled an abbreviated "100% Production". If there are only managerial/administrative workers or only technical/professional workers or only service workers, the point will fall at the right, bottom or left vertices respectively. A mix of 25% of each would produce a point at the center.

Figure A2--based on recent data on the the distribution of workers within the four occupational groups--shows the location of various industrial sectors within the diagram.

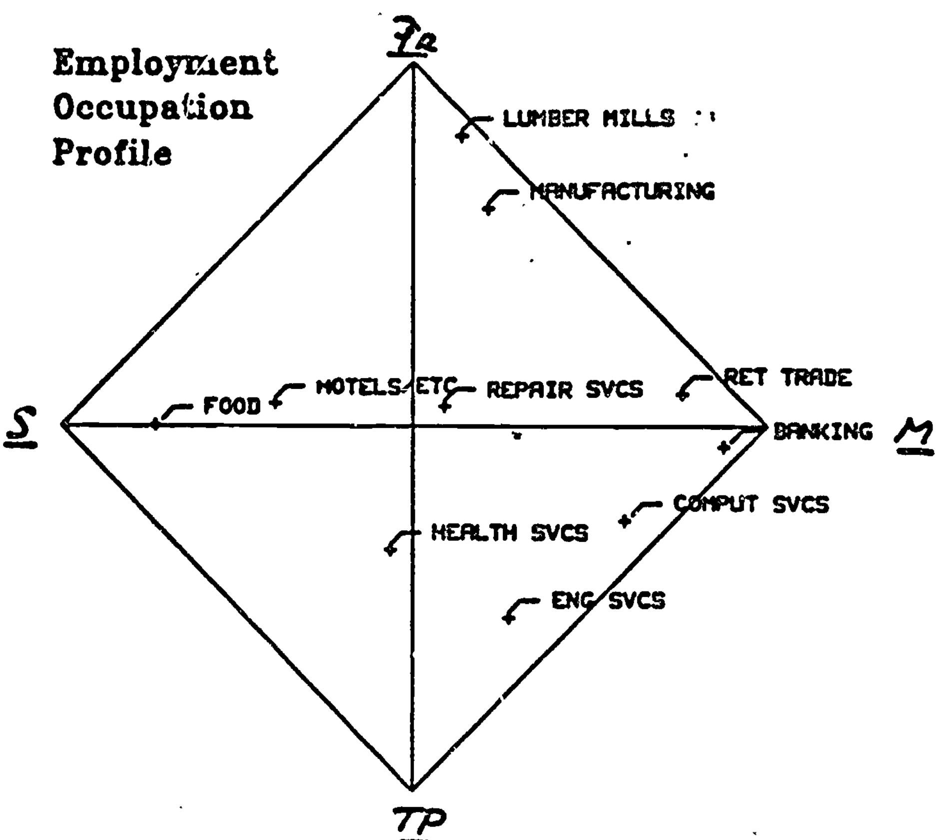


Figure A2. The Employment Occupational Profile of Selected Industrial Sectors.

Relative to the pure forms at the vertices:

o Lumber Mills--at the top--are almost purely "production";
o Banking--at the right--is almost purely "managerial and administrative";

o Food Service--at the left--is almost purely service workers; and

o Engineering Services (including Architectural)--at the lower right --is most highly technical and professional.

The Total Workforce within the Diamond

Figure A3--with Figures A1 and A2 for orientation--shows the occupational distribution of the U.S. workforce over the period 1900 to the present. The figure illustrates the distinct trajectory over which the workforce is evolving.

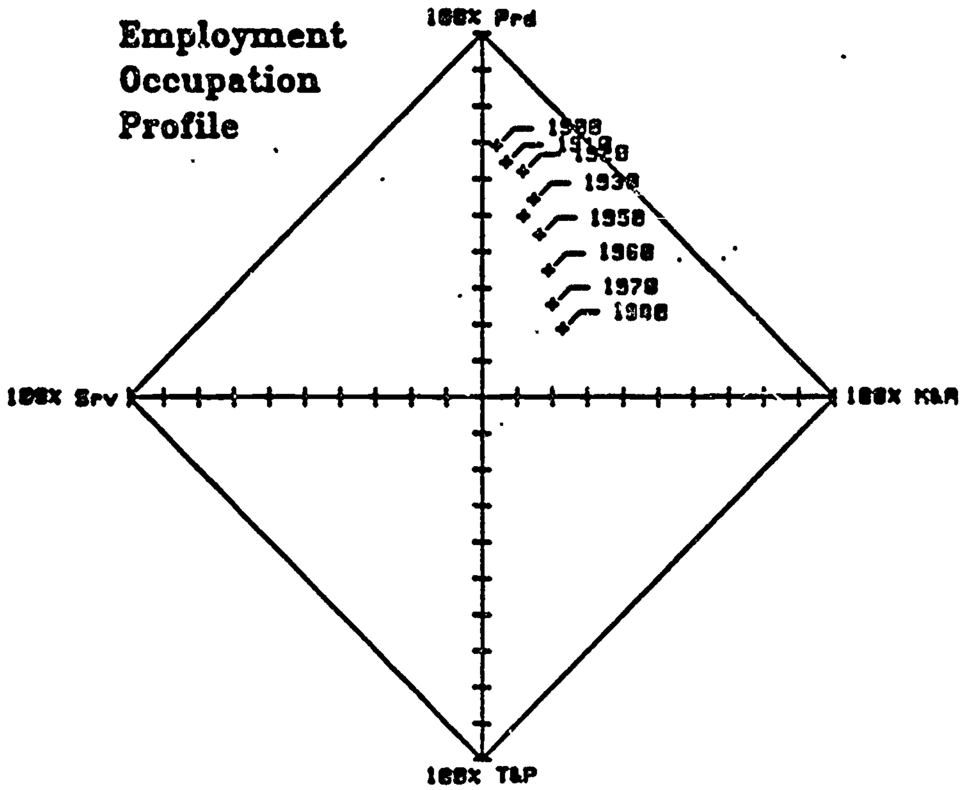


Figure A3. Diamond-Diagram Employment Occupational Profile of the U.S. Workforce over the Period 1900 to 1980.

Figure A4--which represents the addition to Figure A3 of a straight-line fit to the data--shows, first, that the evolution over the 80 year period is along a quite linear path evolving at a relatively uniform rate; second, it suggests a tendency to continue on that path.

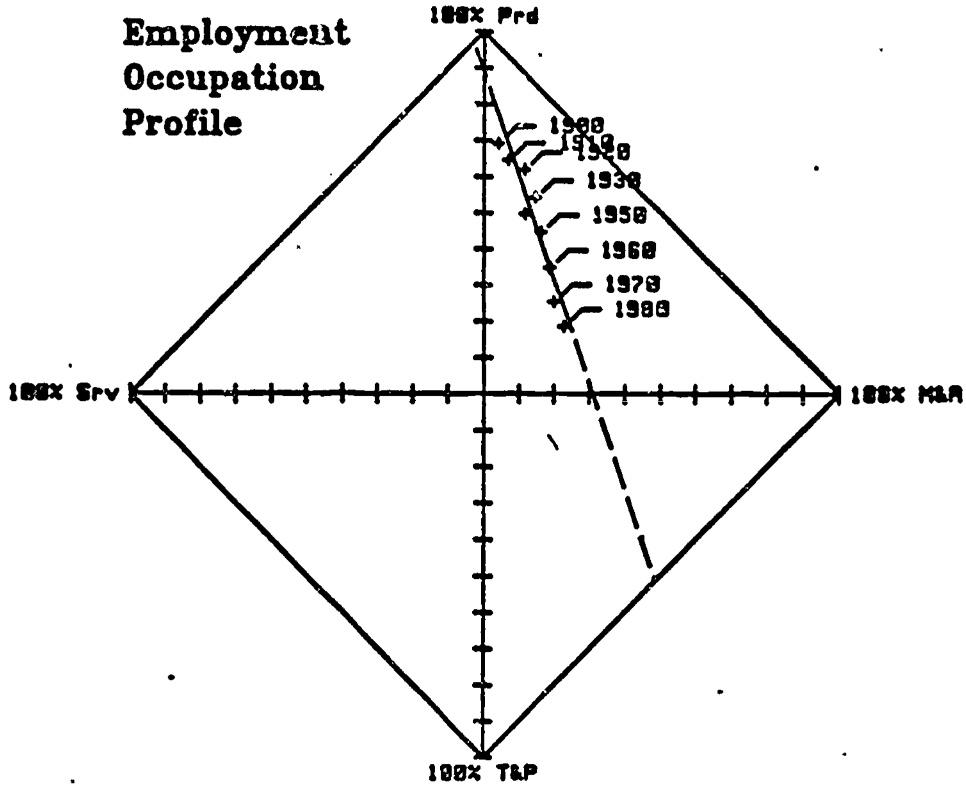


Figure A4. Straight-Line Fit to the Diamond-Diagram Employment Occupational Profile of the U.S. Workforce over the Period 1900 to 1980.

Figure A5--which represents the addition to Figure A3 of reference lines--illustrates two points. First, it shows the crossing in about 1975 from the upper left half of the figure--representing the "blue collar" phsyical production and service domain--into the lower right half of the figure--representing the "white collar" managerial-administrative and technical-professional domain. Second, the figure shows the closeness of the historical trajectory to the line in the diagram which represents the shortest path between the vertex of "100% Production" and one particular point.

The point on the boundary of Figure A5--which represents the terminus of the trajectory along which the U.S. workforce appears to be moving--corresponds to an economically active workforce made up of "50% Technical-Professional and 50% Managerial-Administrative". By implication, that point also represents zero per cent physical production and zero per cent physical service workers.

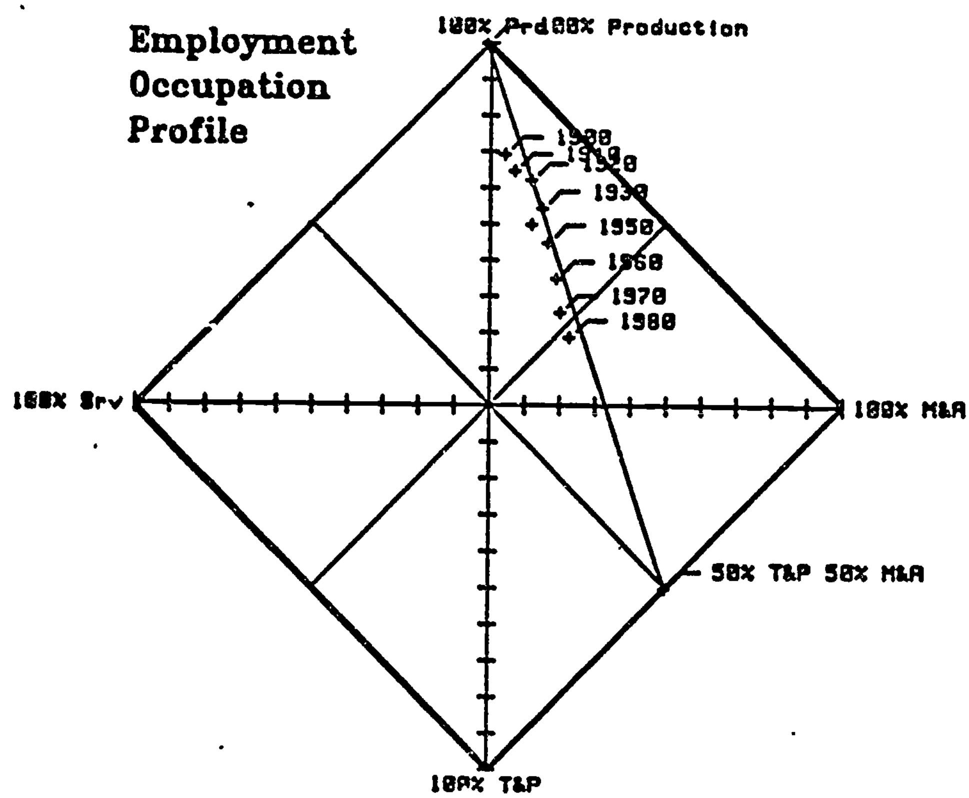
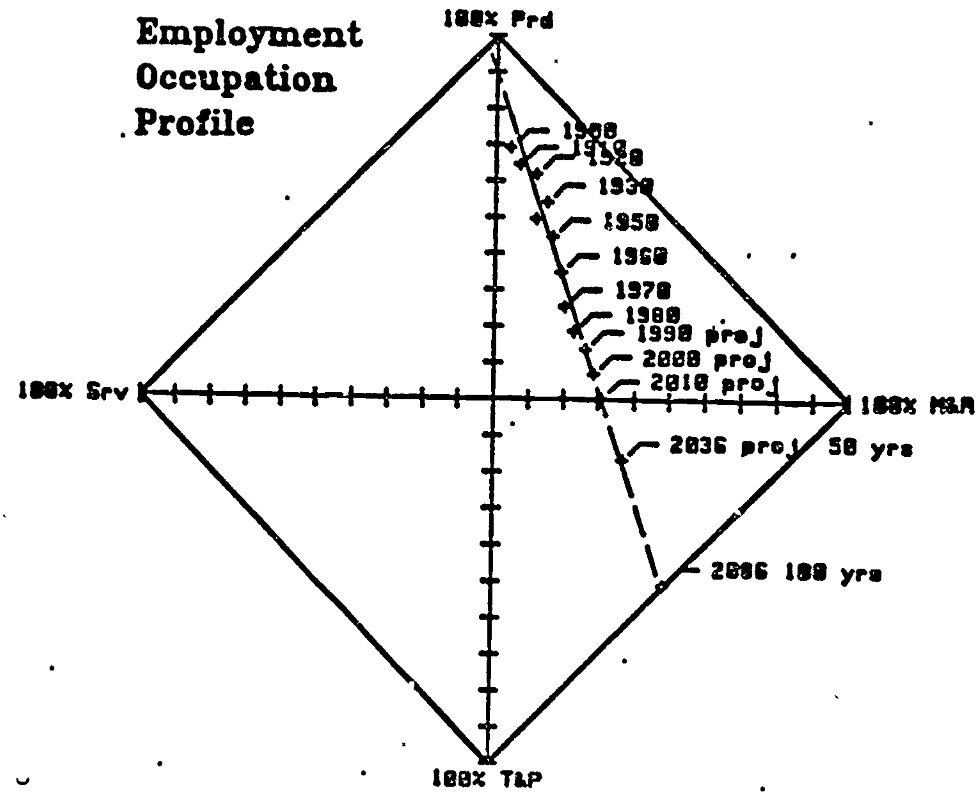


Figure A5. Grid Imposed on the Diamond-Diagram Employment Occupational Profile of the U.S. Workforce over the Period 1900 to 1980.

Figure A6--which shows some extrapolated dates based on the average rate of movement over the past eighty years--gives some estimate of when the workforce might reach significant points along this trajectory should the established trend continue. For example, in less than a generation, that is, by about 2010, the workforce will cross the point at which there are more technical-professional workers than there are physical production workers. Similarly, within the life expectancy of a child born today, the workforce will be approaching a state in which only a very small fraction of the economically active population would appear in either of today's physical production or physical service occupations.



APPENDIX B. TRANSISTION YEARS IN THE ERAS OF THE U.S. WORKFORCE

Approx Yr	Particular Transistion in Workforce	
< 1776	90% in agriculture (level of historical high)	(1)
~ 1860	50% in sectors outside agriculture	(2)
~ 1900	peak 12 million in agriculture (historical high)	(3)
~ 1920	peak 30% in manufacturing (historical high)	(4)
~ 1935	50% in sectors outside production	(5)
~ 1955	50% in occupations outside production	(6)
	(peaks in manufacturing share of national income and share of production workers: 32 % and 27%)	(7)
~ 1975	50% in occupations outside manual	(8)
~ 1979	peak 27 million goods production (historical high)	(9)
~ 2010	50% in knowledge-information occupations	(10)

(1) Text Ref 6 (2) Figure 1 (3) Appendix E (4) Figure 1
(5) Figure 11 (6) Figure 4a (7) Figure D9 (8) Figure *a2
(9) BoL EEI 3/85 (10) Figure 29

MODES	PRE-INDUSTRIAL	INDUSTRIAL	POST-INDUSTRIAL
MODE OF PRODUCTION	Extractive	Fabrication	Processing; Recycling
ECONOMIC SECTOR	Primary *Agriculture* *Mining* *Fishing* *Timber* *Oil and Gas*	Secondary *Goods-Producing* *Manufacturing* *Durables* *Non-durables* *Heavy Construction*	Services Tertiary: *Transportation*, *Utilities* Quaternary: *Trade*, *Finance*, *Insurance*, *Real Estate* Quinary: *Health*, *Education*, *Research*, *Government*, *Recreation*
TRANSFORMING RESOURCE	Natural Power *Wind, Water, Draft animals, Human muscle*	Created Energy *Electricity—oil, gas, coal* *Nuclear power*	Information[1] *Computer and data-transmission systems*
STRATEGIC RESOURCE	Raw Materials	Financial Capital	Knowledge[2]
TECHNOLOGY	Craft	Machine Technology	Intellectual Technology
SKILL BASE	Artisan, Manual worker, Farmer	Engineer, Semi-skilled worker	Scientist, Technical and Professional occupations
METHODOLOGY	Common Sense, Trial and error, Experience	Empiricism, Experimentation	Abstract Theory: *models, simulations, decision theory, systems analysis*
TIME PERSPECTIVE	Orientation to the past	Ad hoc adaptiveness, experimentation	Future orientation: forecasting and planning
DESIGN	Game Against Nature	Game Against Fabricated Nature	Game Between Persons
AXIAL PRINCIPLE	Traditionalism	Economic Growth	Codification of Theoretical Knowledge

Figure B1. Daniel Bell's Schema on the Post-Industrial Society.

APPENDIX C. THE PROPORTION OF MANUFACTURING WORKERS ENGAGED IN PRODUCTION

The figure shows the ratio of production workers to all employees to total employment over the past decade for individual manufacturing sectors (as well as for manufacturing as a whole).

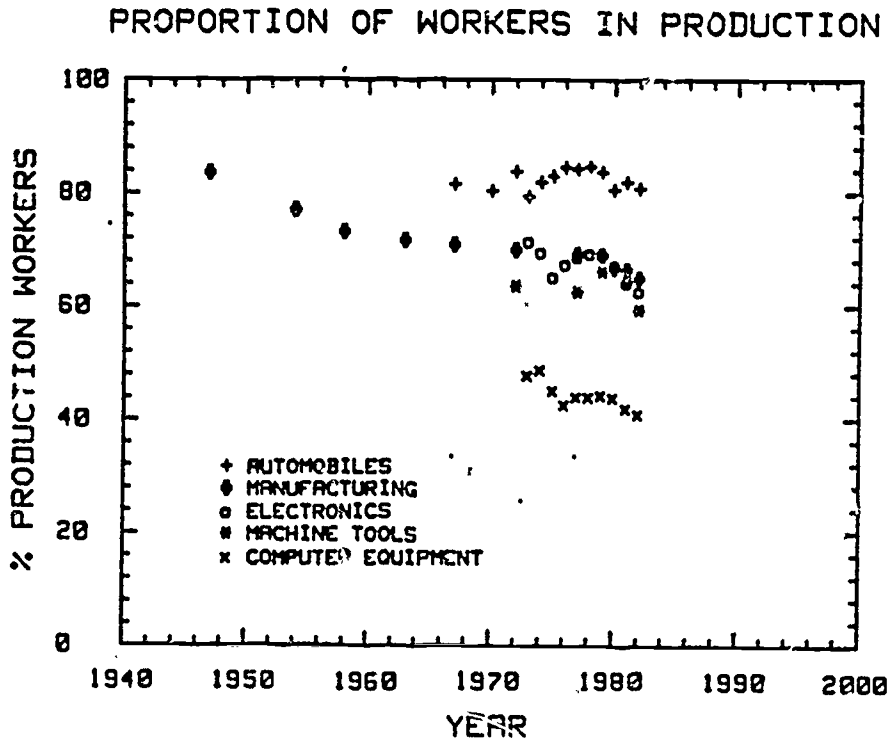


Figure C1. The Ratio of Production Workers to All Employees in Selected Manufacturing Industries over the Period 1970-1980.

Appendix D. Toffler's Third-Wave Thesis

Alvin Toffler described as a "Third Wave" this transistion in which a profoundly different post-industrial society encounters and overcomes its predecessor, the industrial one, even as in a second wave the industrial society overcame its predecessor, the agricultural, and in a first wave, the settled-agricultural society overcame the aboriginal hunter-gatherers [.]

Figures D1 through D5--respectively for Britain, Germany, France, the United States, and Japan--illustrate the third-wave phenomenon noted: for each country the wave-like rise of industry and fall of agriculture in terms of proportion of workers.

LABORFORCE IN PRODUCTION: BRITAIN

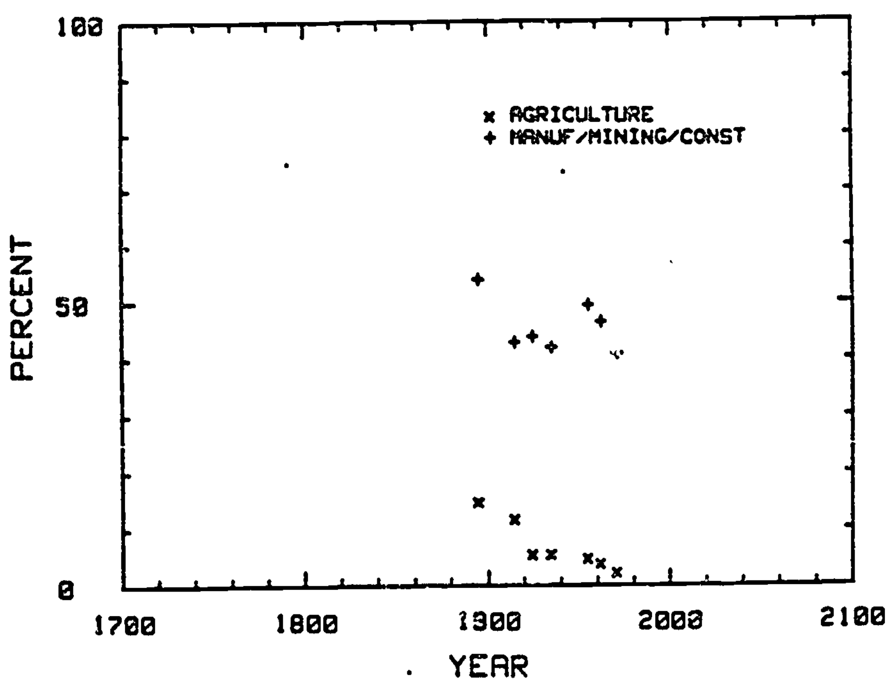


Figure D1. Britain: The Distribution of its Workforce in Agriculture and Manufacturing/Mining/Construction.

LABORFORCE IN PRODUCTION: GERMANY

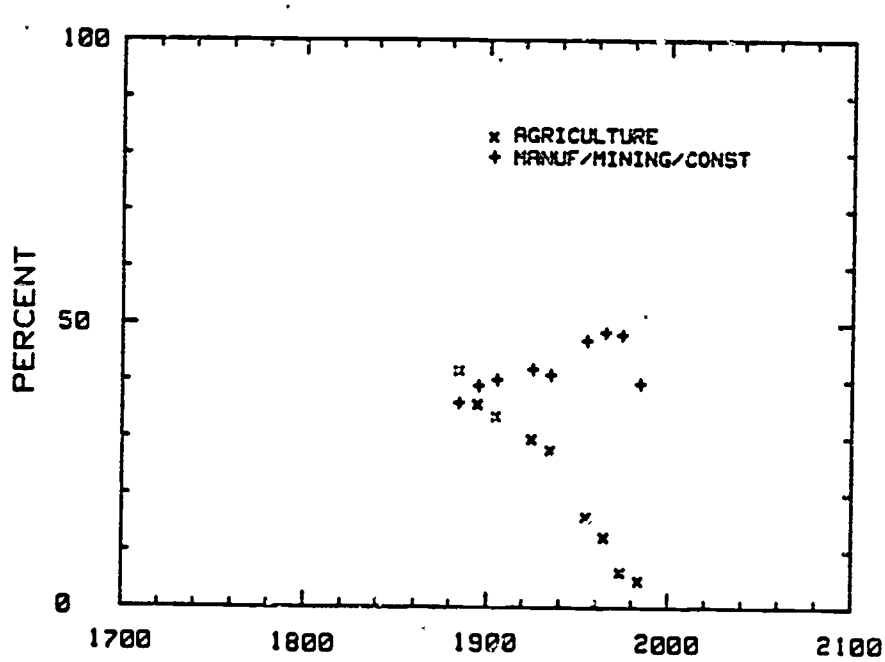


Figure D2. Germany: The Distribution of its Workforce in Agric and Manufacturing/Mining/Construction.

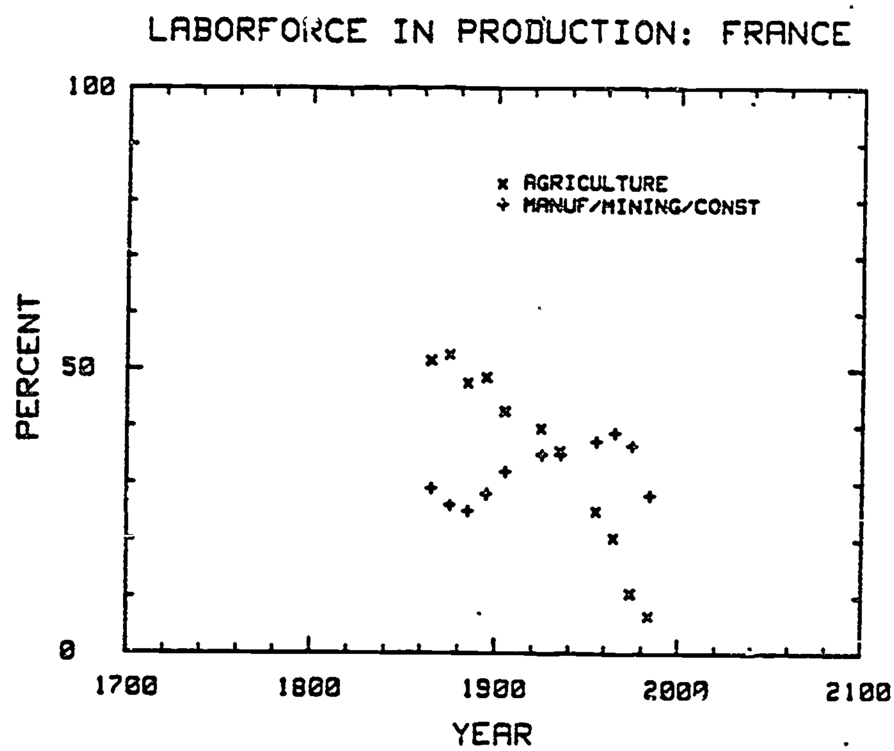


Figure D3. France: The Distribution of its Workforce in Agriculture and Manufacturing/Mining/Construction

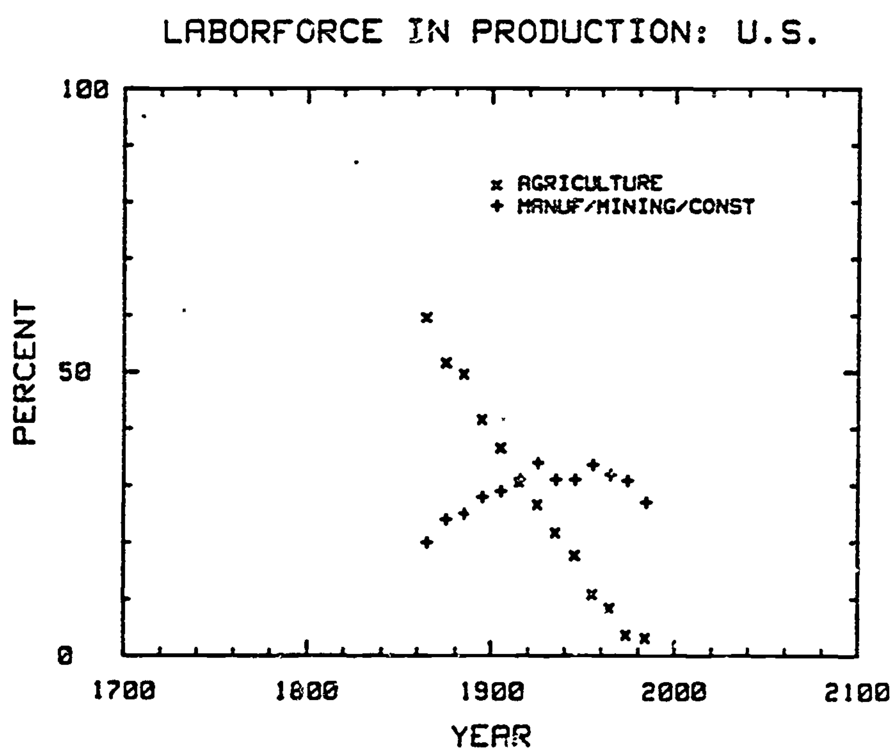


Figure D4. United States: The Distribution of its Workforce in Agriculture and Manufacturing/Mining/Construction.

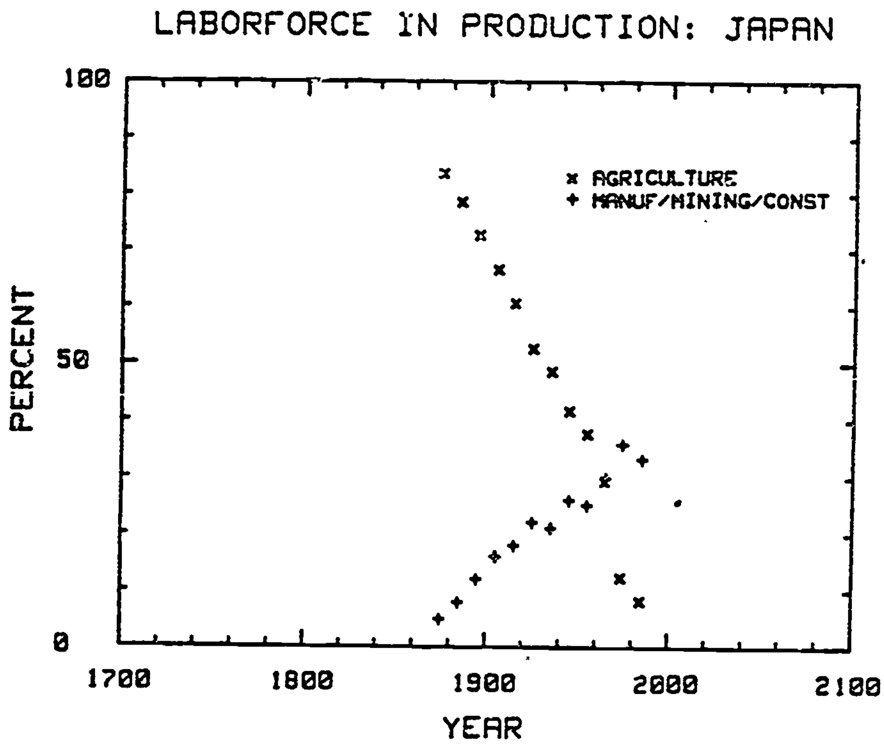


Figure D5. Japan: Distribution of its Workforce in Agriculture and Manufacturing/Mining/Construction.

Also according to the "third wave" thesis, the second wave occurred successively in Britain, the first to experience the "Industrial Revolution", then at progressively later times in other industrializing countries, such as the United States and later Japan.

Figures D6 and D7--which show together respectively the agriculture and manufacturing portions of Figures D1, D4 and D5--clearly illustrate the succession--Britain, United States, Japan--in the rise of industry and fall of agriculture.

These two figures illustrate a number of other points. First, the relative acceleration of industrialization as it occurred in successively in the respective countries. Second, the shortening of the period during which the industry sector remains at a peak/plateau. Third, a possible acceleration in the rates at which the industry wave falls. And, fourth, a kind of convergence with the United States leading in the rise of the "third wave" (indicated by the relative fall of industry). Worth noting also is the relative smoothness in the evolution of the United States in such transistions compared, for example, to the ups and downs of Britain's manufacturing employment.

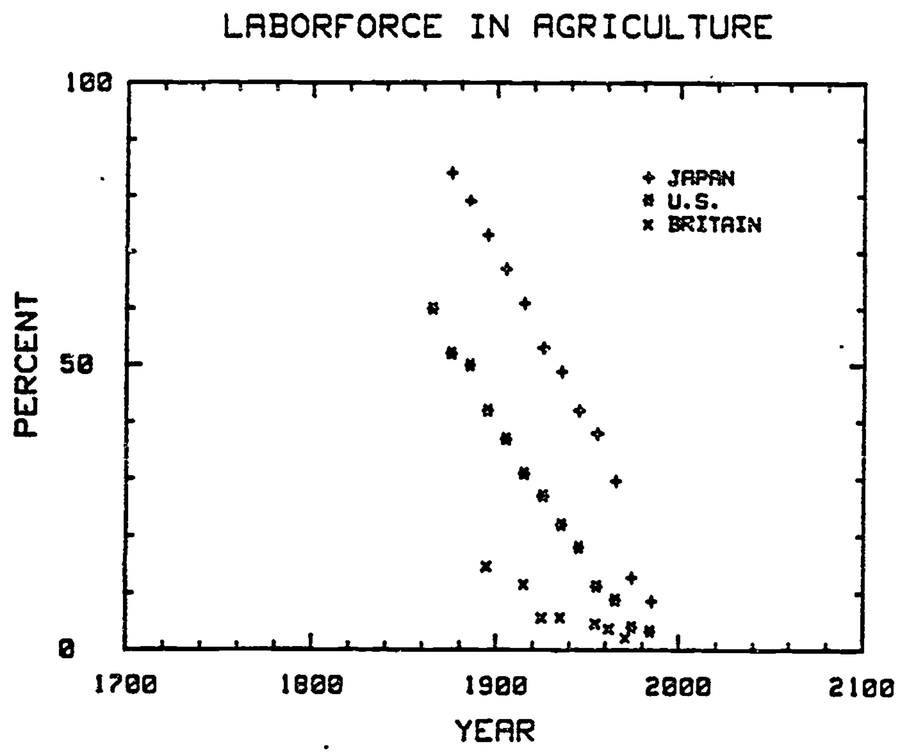


Figure D6. Comparison of Britain, the United States, and Japan in the Fraction of Workforce in Agriculture.

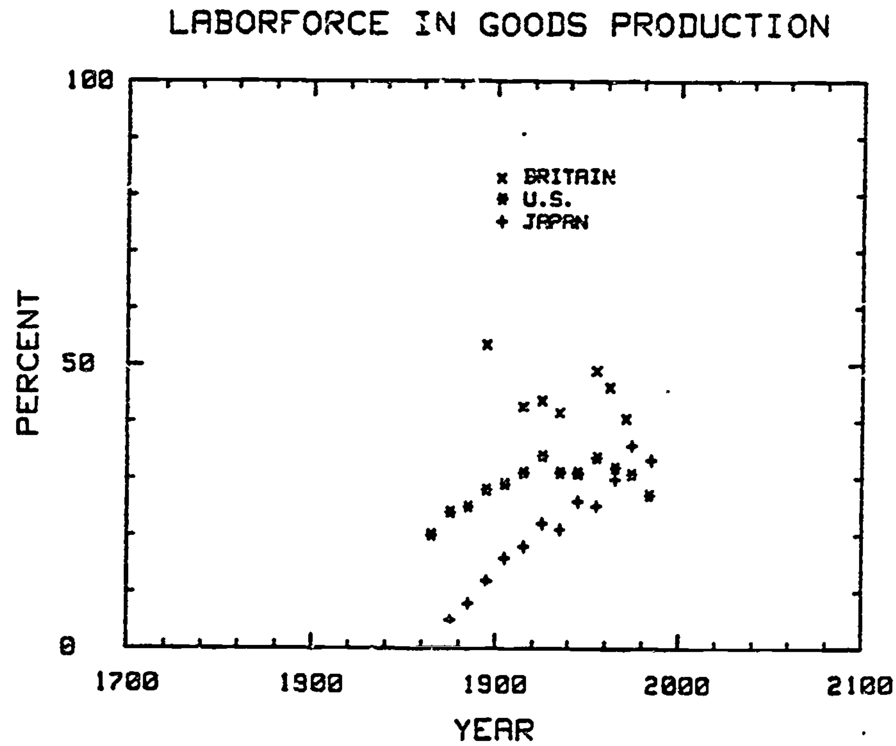


Figure D7. Comparison of Britain, the United States, and Japan in the Fraction of Workforce in Manufacturing, Mining, and Construction.

Figures D8 and D9--which show the proportion of the U.S. national income derived from agriculture and from manufacturing--also support the notion of cresting waves in those two eras.

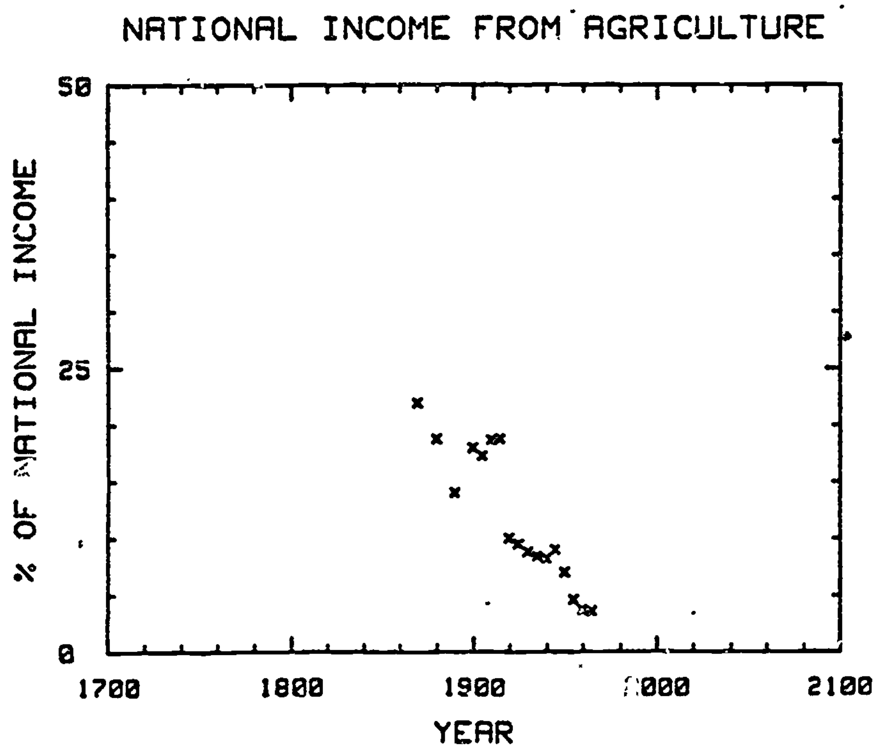


Figure D8. The Fraction of the U.S. National Income from Agriculture over the Period 1870 and 1970.

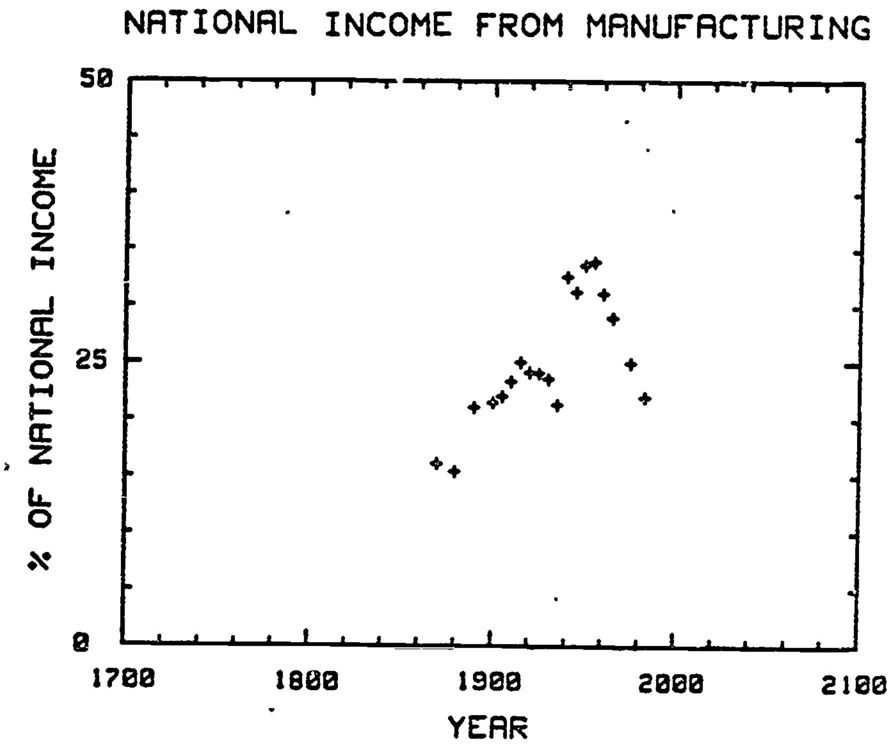


Figure D9. The Fraction of the U.S. National Income from Manufacturing over the Period 1870 to 1970.

APPENDIX E. SOURCES OF DATA FOR FIGURES

Figure 1. U.S. Employment in Production: The Proportions of U.S. Workers Engaged in (a) Agriculture; (b) Manufacturing and Mining; and (c) All Production Sectors (Agriculture, Manufacturing/Mining and Construction) over the Period 1820 to 1995.

HSt Series D152-166 1820-1940
MLR Nov 1985 1950-1995

Figure 2a. U.S. Agricultural Productivity: The Relative Output per Work-Hour of U.S. Agricultural Workers over the Period 1800 to 1965.

LTG Series A167 for 1869 to 1965
HSt Series K445-485 for estimate of farm productivity for 1800 and 1840 based on that in food grains

Figure 2b. Capital Equipment per U.S. Farmworker: The Relative, Constant-Dollar Amount of Machinery per Agricultural Worker over the period 1800 to 1980.

HSt Series K1-16 Current Dollar Equipment 1850-1970
HSt Series E35 Machinery Price Index as deflator

Figure 3a. U.S. Manufacturing Productivity: The Relative Output per Work-Hour of U.S. Manufacturing Workers over the Period 1870 to 1980.

LTG Series A165 for 1869 to 1965
StA post-1965

Figure 3b. Capital Equipment per U.S. Manufacturing Worker: The Relative, Constant-Dollar Amount of Machinery per Manufacturing Worker over the period 1800 to 1980.

HSt Series P107-122 Current Dollar Equipment 1863-1970
HSt Series E35 Price Index/Machinery deflator
StAb for post-1970

Figure 4a. The Occupational Profile of the U.S. over the Period 1900 to 1985 in terms of the Proportion of Workers in Four Broad Occupational Categories: Production, Managerial/Administrative (incl. Clerical and Sales), Technical/Professional and Service.

HSt Series D182-232 for 1900-1970
EEI (Jan 1981) for 1980

Figures A1 through A5:
Comparison of the Proportions of Workforces in Agriculture and Manufacturing/Mining/Construction for Various Countries over Time: Britain, Germany, France, the U.S. and Japan.

LTG for pre-1965 and ILO for post-1965; some incommensurable data in overlapping periods, esp. Japan

Figures D8 and D9: The Proportion of the U.S. National Income from Agriculture and Manufacturing over the Period 1870 to 1970.

LTG Part III table 4 for 1870-1965
StA Series No. 1336 for 1958-1983.

Appearing in "Technology and Structural Unemployment: Re-Employing Displaced Adults", U.S.Congressional Office of Technology Assessment, Washington, D.C.

Figure A2. The Employment Occupational Profile of Selected Industrial Sectors

OEB of 1984 and 1982

Appearing in "Technology and Structural Unemployment: Reemploying Displaced Adults", U.S. Congressional Office of Technology Assessment, Washington, D.C.

HLS of 1980

Figure C1. The Ratio of Production Workers to All Employees in Selected Manufacturing Industries over the Period 1970-1980.

StA	No. 1392	Motor Vehicles	1967-1982
	No. 1384	Machine Tools	1972-1982
	No. 1389	Computing Eqp	1973-1982
	No. 1390	Electronics	1973-1982
	No. 1407	Manufactures	1947-1972
	No. 1337	Manufactures	1954-1982

Data Sources

(HSt) Historical Statistics of the United States: Colonial Times to 1970, Bicenntenial Edition, U.S. Department of Commerce, Bureau of Census, Washington, D.C., Oct. 1966.

(StAb) "Statistical Abstracts of the United States", U.S. Department of Commerce, Bureau of Census, Washington, D.C., 1985.

(LTG) "Long-Term Economic Growth 1860-1965: A Statistical Compendium", Series ES4-No.1, U.S. Department of Commerce, Bureau of Census, Washington, D.C., Oct. 1966.

(MLR) Monthly Labor Review, U.S. Department of Labor, Bureau of Labor Statistics, November, 1985.

(ILO) Year Book of Labor Statistics, International Labor Office, Geneva, 1985.

(HLS) Handbook of Labor Statistics, U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2070, Dec 1980.

(EEI) "Employment, Earnings and Income: 1909-1984", Vol. 1, U.S. Department of Labor, Bureau of Labor Statistics.

(OEB) "Occupational Employment" Bulletins, U.S. Department of Labor, Bureau of Labor Statistics: "OE in Transportation, Communications, Utilities and Trade", Bulletin 2220, Dec 1984; "OE in Mining, Construction, Finance and Services", Bulletin 2186, Feb 1984; "OE in Manufacturing Industries", Bulletin 2133, Sept 1982.

Appearing in Table 9 of "Technology and Structural Unemployment: Reemploying Displaced Adults", U.S. Congressional Office of Technology Assessment, Washington, D.C.