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REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Manufacturing Technology -- A Changing Challenge To Improved Productivity

With new technology, the United States can increase the productivity of industries that produce goods in small lots. Many foreign industrial nations have ways of diffusing technological advances throughout their manufacturing bases. We can learn from these foreign efforts to enhance manufacturing productivity.

The United States needs to make manufacturing productivity a national priority to remain internationally competitive and to maintain strong industries.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This is GAO's study of how the United States compares to other nations in applying modern manufacturing technology by discrete parts, batch process manufacturers. These manufacturers constitute over 35 percent of the manufacturing firms in the United States, and they manufacture most of the items procured by the Federal Government.

This study of manufacturing technology was undertaken because to varying degrees, there are sufficient indications that the private sector is having difficulty maintaining its productivity in dealing with rapid changes in manufacturing technology. Moreover, the Federal Government is the largest single purchaser of manufactured goods and if indeed technology and productivity falter then the cost of these goods will increase accordingly. GAO wanted to provide a document which would encourage discussion and debate on the subject, recognizing that the issue is a very complex one and is interrelated with other problems, such as inflation, capital formation, and international competitiveness.

We were also aware of the interest of several committees of the Congress in the subjects of increased productivity, competitiveness of the United States in world markets, price stability, and economic growth, and the role of the National Center for Productivity and Quality of Working Life in resolving these problems.

The report should be useful to the Congress, the executive branch, and to the private manufacturing sector in identifying policy and actions relating to national manufacturing productivity, scientific research and development, and technology diffusion.

Our review was made pursuant to the Budget and Accounting Act of 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget; the Secretary of Commerce; the Chairman, National Center for Productivity and Quality of Working Life; and other interested agencies.

Comptroller General
of the United States

Contents

ABBREVIATIONS

APT	automatically programed tool
ARC	Automation Research Council
BOM	Bill of Materials
CAM-I	Computer-Aided Manufacturing-International, Inc.
CIM	computer-integrated manufacturing
CMPM	computer-managed parts manufacturing systems
CNC	computer numerical control
DNC	direct numerical control
DOD	Department of Defense
ERDA	Energy Research and Development Administration
FRG	Federal Republic of Germany
GAO	General Accounting Office
GNP	gross national product
JPC	Japan Productivity Center
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NC	numerical control
NSF	National Science Foundation
NTIS	National Technical Information Service
OECD	Organization for Economic Cooperation and Development
SBA	Small Business Administration

REPORT TO THE CONGRESS
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MANUFACTURING TECHNOLOGY--
A CHANGING CHALLENGE
TO IMPROVED PRODUCTIVITY

D I G E S T

THE EMERGING PROBLEM

The United States is the World's largest producer of manufactured products and for many years generated most of its raw materials, produced its own manufacturing tools and consumed most of the products it manufactured--historically, exporting less than 7 percent of its gross national product.

But, the United States is running out of raw materials--oil is one--and must increasingly import them at higher costs to operate its factories. These increased imports must be paid for by increased exports; and, the increased exports must come either from improved productivity or from reduced domestic consumption.

If from the latter, the costs of the available goods will substantially increase to the American consumer and to Federal, State and local governments.

Meanwhile, the successes of foreign competitors in using sophisticated manufacturing technology to produce consumer goods are evident.

--Americans are buying a large quantity and variety of quality foreign products.

--Foreign markets that the United States has traditionally enjoyed are diminishing.

--In 1971 the U.S. balance of trade turned unfavorable for the first time since 1893 and again showed a deficit in 1972 and 1974.

A significant amount of these goods are made in small lots or batches by industries known as discrete parts, batch process manufacturers. In the United States these manufacturers represent over 35 percent of the manufacturing base and contribute 36 percent of manufacturing's share of the gross national product.

The technology involved in small batch manuufacturing has been undergoing profound changes because of the numerically controlled machine tool (developed in the 1950s) and the increased use of computers to control manufacturing processes. Furthermore, foreign competitors seem to be surpassing us in using this new technology to improve their industrial productivity.

In the 30 years since the end of World War II, other industrialized nations have had rates of improved industrial productivity consistently higher than those of the United States.

While a rapid productivity increase rate could have been expected for a while in some of the industrialized nations due to rebuilding industrial bases, the effects of the war do not account for the sustained productivity improvement rate for the extended 30 year period. Economists who have studied the matter generally agree that productivity improvements due to reconstruction activities were completed mostly in the 1950s.

Following World War II, the European countries and Japan, largely at U.S. insistence established formal productivity centers that focused on management and marketing techniques and problems in the service sectors of the economies.

Additionally, and without U.S. encouragement, informal productivity centers were established in the areas of manufacturing, science and technology. These were joint cooperative efforts organized from the Government, labor, industry (including industrial associations and institutions) and university communities.

The consistently increasing productivity rates of these industrialized countries can be attributed, at least in part, to the productivity centers.

In the area of advanced manufacturing technology, the United States generally is using more than other countries. But it is highly concentrated in aerospace, electronics, and other firms producing defense-related products, and without added impetus it does not show promise of diffusing to small- or medium-sized firms.

However, the general level of technical capability seems about equal in all industrial nations.

Looking to the future, it appears that foreign competitiors have an advantage of being able to exploit, develop, and diffuse manufacturing technology faster than the United States. Although this kind of international technological competition is healthy and stimulates each country to the common goal of improving world wide living standards, the U.S. needs to take a positive stance to improve its own diffusion of manufacturing technology so as to enhance productivity and remain competitive.

Normally, the Government would not be interested in an issue of this magnitude unless:

--private industry was neglecting or generally unaware of the issue,

--actions being taken by private industry were not in the best interests of our economy, or

--private industry was not advancing fast enough to sustain our socieconomic way of life.

Although there are no outright indications of neglect, a broad cross-section of U.S. manufacturers generally do not know how advanced manufacturing technology affects them. And, those applications of technology contemplated or under way do not seem to be progressing fast enough to sustain us. Consequently, GAO became interested in the evaluation of manufacturing technology and its impact on productivity.

GAO now believes that in order to remain internationally competitive and to maintain a strong industrial base, actions must be initiated to make manufacturing productivity a national priority.

GAO recommends that as a top priority effort the National Center for Productivity and Quality of Working Life develop a national policy and appropriate means for achieving balanced productivity growth in the industrial/manufacturing base. Further, GAO recommends that the National Center, in carrying out this recommendation, seek the cooperation and assistance of the Department of Commerce and other appropriate agencies. In addition, GAO recommends that the Department of Commerce strengthen its efforts to support and develop productivity enhancing technology related to manufacturing.

The combination of the existing expertise of the National Center and the Department of Commerce in close coordination with other public and private organizations, would facilitate early initiatives with a minimum startup time. Moreover the Department of Commerce could, thereby, provide the much needed focal point to coordinate all the disparate Government and private work in developing, standardizing and diffusing manufacturing technology. This is discussed in more detail in chapter 8.

CHAPTER 1

BACKGROUND

The Federal Government spends billions of dollars each year for U.S.-manufactured products. Inflation is constantly raising the unit costs of the products at a time when there are mounting pressures to limit Government spending. It therefore becomes increasingly important that manufacturers supplying the U.S. Government use the most cost effective manufacturing methods in producing products.

We initiated a review of manufacturing technology applied to meeting the Government's civil and national defense needs because of the GAO and Federal interest in

--procuring these goods and services at the lowest practical cost,

--applying techniques to improve the productivity of federally operated industrial facilities,

--furthering the objectives of the Congress and the executive branch in establishing the National Commission on Productivity and Work Quality, and more recently the National Center for Productivity and Quality of Working Life,

--applying and using the National Science Foundation grant program as it relates to manufacturing technology, and

--providing a document which would encourage discussion and debate on the subject, recognizing that the issue is a very complex one and is related to other problems, such as growth of capital formation and high inflation in plant and equipment costs.

We were also aware of the interest of several committees of the Congress in the subject of increased productivity, competitiveness of the United States in world markets, price stability, and economic growth.

Several matters surfaced early in the survey which persuaded us to expand the project to a survey of manufacturing technology generally. First, there were over four million different items in the Federal supply system. Virtually everything produced in the United States is procured, in one form or another, by the Federal Government. There were over 25,000 contractors producing items or services for the Department of Defense alone.

Second, a large number of items procured by the Government--for instance materials-handling equipment and Army tanks--are products of industries which produce in small lots or batches. These are known as discrete parts, batch process manufacturers.

Third, there was a declining U.S. balance-of-trade position which in 1971 turned unfavorable for the first time since 1893 and again showed a deficit balance in 1972 and 1974. An important negative factor was the rate of increase in the imports of high-technology products which have consistently been among our major exports. Except for agricultural products, many imports and exports were products of either U.S. or foreign discrete parts, batch process manufacturers--the same type which account for the manufacture of a large proportion of the products procured by the Government.

Fourth, the U.S. rate of increase in productivity in manufacturing was among the lowest in the world.

And fifth, we were told that the technology of manufacturing discrete products in small batches was undergoing profound changes because of the development in the 1950s of the numerically controlled machine tool (see p. 26) and the burgeoning application of computers to the manufacturing environment, including computer control and operation of the machinery of manufacturing. There were suggestions that our foreign competitors were moving ahead of the United States in applying the new technology to this large segment of manufacturing industries.

The Government's interest in issues of this type would also be stimulated by indications that the private sector was: (1) neglecting or was generally unaware of the issue, (2) taking actions which were not in the best interests of our economy, or (3) their initiatives were not moving fast enough to sustain our socioeconomic way of life.

To varying degrees there are sufficient indications that the private sector is having difficulty in dealing with rapid changes in manufacturing technology which would warrant the Government's interest. For example, although there are no outright indications of neglect, there are clear indications that a broad cross-section of our manufacturing base is generally unaware of the impact of advancing manufacturing technology. Moreover, even though many actions now underway or contemplated by selected elements of our manufacturer base are in our national interests, their progress may not be fast enough to insure sustaining and advancing our socioeconomic way of life. Based on these observations and coupled with our current state of economic growth we concluded that a survey of U.S. and foreign manufacturing generally would satisfy our specific interests in manufacturing (especially as it relates to Government procurements) and, at the same time provide some useful insights into problems of U.S. productivity, relative levels of manufacturing technology and competition in foreign trade.

In making our study, we surveyed a sample of metalworking companies and held discussions with over 200 U.S. industrial, academic, governmental, and financial organizations. We also visited a smaller number of similar organizations in the United Kingdom, West Germany, France, Italy, Norway, Denmark, and Sweden. Although we did not visit Japan, we discussed the subject with representatives of the Washington, D.C., office of the Japan Productivity Center and conferred with a number of knowledgeable individuals with a firsthand knowledge of manufacturing activities in Japan.

We also surveyed the literature on matters of productivity and technology and utilized previous GAO studies involving technology and foreign trade. We did not attempt to study all of the literature in depth, nor do we feel we have studied all of the literature.

The study of such a broad field involving such a wide range of disciplines, companies, countries, individuals, facts, assumptions, and possibilities for the future requires subjective evaluations and appraisals by the study participants. No one small group engaged in such a broad study can lay claim to having considered all pertinent and available information, opinions, and perceptions. Indeed one of our primary conclusions is that the subject matter studied is so important, broad, and dynamic as to merit continuing attention in the United States by some responsible, qualified, and properly staffed organization either in the public or the private sectors or some combination thereof.

We believe our study has been sufficiently comprehensive to identify some serious productivity problems in the United States, to provide information and create some controversy, and to suggest potential courses of action to policymakers in the executive and legislative branches--and in the private sector, that are now engaged in the emerging national interest and debate on productivity in the United States.

Several cautions to the reader seem appropriate. The matters discussed--economic or technical--concerning this study are relevant, in general, only when construed within the context of a relatively long timespan, such as 10 to 20 years. The computer-integrated manufacturing systems discussed herein probably will not reach full development until 1985 or beyond in the country or countries providing the most favorable environment for their development. Therefore, viewing the matters in terms of business or economic conditions at a particular point or for a brief period could yield distorted perspectives.

Although our study focuses primarily on discrete parts, batch-processing industries engaged in various forms of metal working--principally metal cutting--the principles, problems, and potential for improved growth through computer-integrated manufacturing apply equally to other areas of manufacturing, such as plastics, glass and metal forming. The opportunities for improved productivity through automation in the service sector of our economy are also great. The Committee on Automation Opportunities in the Service Areas of the Federal Council for Science and Technology issued in June of 1975 the results of a 4-year study of the opportunities for productivity improvement in the service sector. 1/ The Committee's findings and recommendations are very similar to ours, and excerpts from the study are contained in appendix III.

Also the reader should be aware that our study does not discuss if computer-integrated manufacturing should be brought about. The development and component applications of computer-integrated manufacturing are already taking place. The question, therefore, is not whether but how quickly and effectively the development process will be completed and which national entities will move most quickly and effectively. It is primarily these questions to which our study addresses itself.

Finally, although our study emphasizes the importance of the emerging computer-integrated manufacturing technology, technology does not stand by itself. Investment capital, employee-management attitudes and relationships, institutional characteristics--public and private--monetary policy, raw material endowment,and other factors are all woven together in intricate mosaics, which are different for all countries. It is the interaction of all of these factors that make up a nation's productivity. To encompass all of the factors in a single report would be impracticable. We discuss or refer to many of these other factors to highlight manufacturing technology and our problems in realizing the full potential of the new manufacturing technology.

In developing this report, GAO was fortunate to have had expert advice and assistance from a wide variety of experts in government, the private sector, and academia in the U.S. and abroad.

In January of 1976, we had a one day conference of experts on various aspects of manufacturing from Government, industry, labor, and academia to review a draft of our report.

Overall we have received a panorama of viewpoints ranging from expressions that all is well with U.S. industry and no action is necessary, to the direst of concerns that the U.S. is already falling behind. On balance, however, the affected government agencies and private organizations are in general agreement with our findings.

We gratefully acknowledge the assistance of these people and their contributions to our work.

Nevertheless, the observations, judgments, and suggestions in the report are those of GAO and do not necessarily reflect the views of any of those who so generously assisted in the study.

CHAPTER 2

INTRODUCTION

To assess the importance of manufacturing technology, the GAO staff surveyed programs in the United States and selected foreign countries concerned with advancing the state of the art of manufacturing technology, particularly the use of computers in the manufacturing environment.

In our analysis, we considered the growing interdependence of world economies and the fact that such a review could not be limited only to factors internal to the United States. All industrial nations compete for increasingly scarce resources of manufacturing as well as for markets for their end products, and high rates of productivity are necessary to minimize manufacturing costs and maximize a country's competitive position. Importantly, the rates of productivity growth in the United States since World War II have been the lowest of 11 major industrial nations.

Table 1 shows how the annual rates of manufacturing productivity growth have increased at a dramatically higher rate in other industrial nations since 1960.

TABLE 1

Productivity Gains

Average Annual Increase in Output Per Man-Hour

In Manufacturing, 1960-1973

Japan	10.5%
Netherlands	7.5
Sweden	7.1
Belgium	6.5
Italy	6.4
France	6.0
West Germany	5.8
Switzerland	5.3
Canada	4.3
United Kingdom	4.0
United States	3.4

Source: U.S. Department of Labor

There is extensive literature on economic growth in the United States centering on broad analyses of applications of land, labor, and capital. And there have been general discussions of factors contributing to productivity such as education and technological advances. There have been fewer studies addressing the quantitative importance of each single factor or analyzing the possible underlying reasons for the low rate of U.S. productivity growth in relation to other countries.

In the following paragraphs, we draw heavily on a study report of the National Science Foundation and the work of Edward F. Denison of the Brookings Institution because (1) they are authorative works, (2) they raise important questions concerning the need or effectiveness of overt efforts to improve national productivity, (3) they bear strongly on some of the points we make, and (4) they form a prior broad study basis for some of the more specific observations we have made regarding the more specific discrete parts, batch process industries and the emerging technology of computer-integrated manufacturing.

NATIONAL SCIENCE FOUNDATION STUDY

The National Science Foundation study examines public policy questions concerning productivity growth. Part of the examination was directed to relative rates of growth of the United States and other industrialized countries.

In their study Piekarz and Thomas 2/ began their comparison of the United States productivity performance with that of foreign countries by making three observations.

First observation

U.S. output for each employed person appears to be, and probably has been throughout this century, higher than that of any other nation.

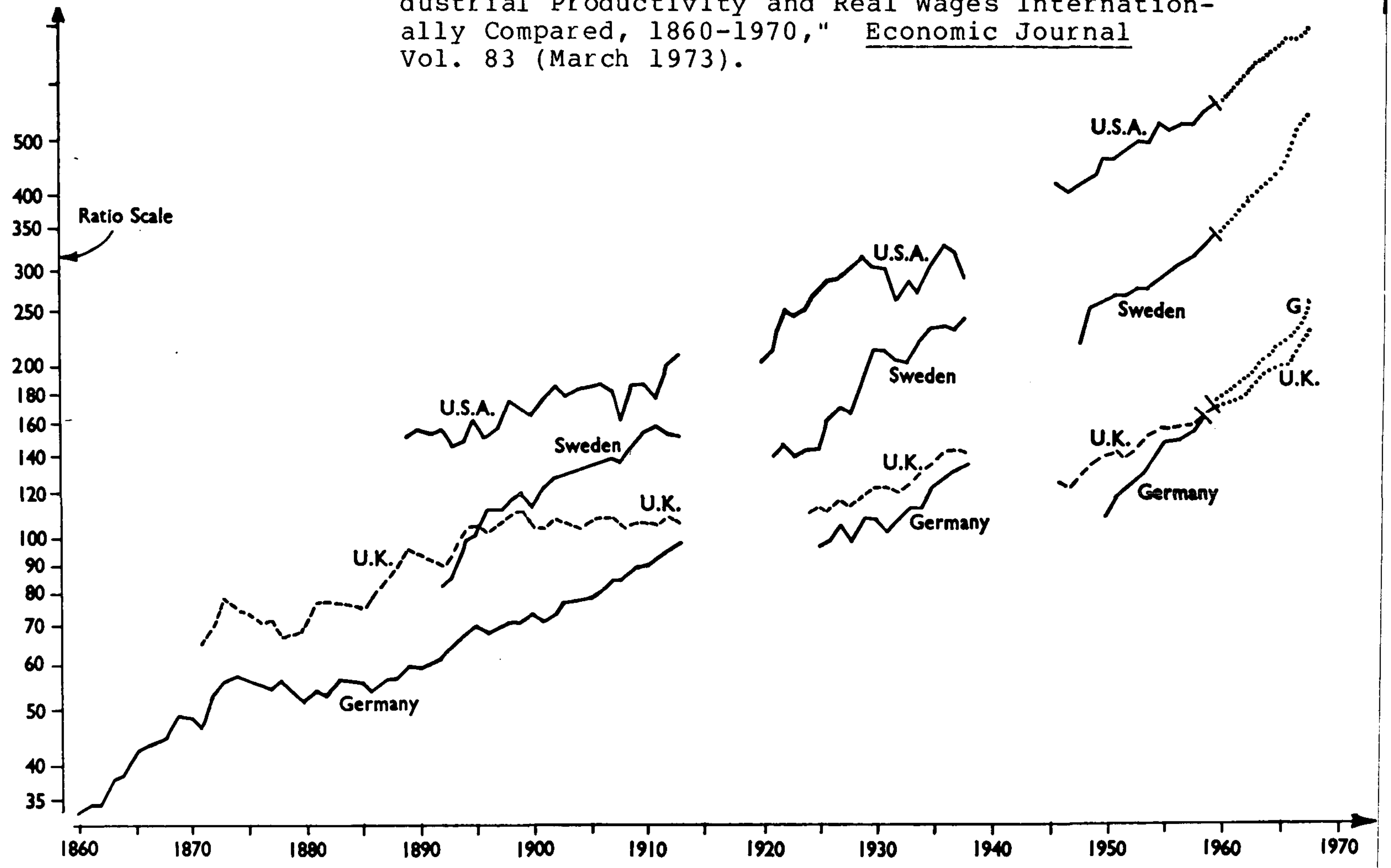
Chart 1 shows that the U.S. ratio of industrial output for each person employed in industry has exceeded the ratios for the United Kingdom, Germany, and Sweden from 1860 to 1970.

Table 2 shows that the U.S. gross domestic product for each person employed ranked first among the major industrial nations in 1971 as well as in 1961 and 1951. However, a simple comparison of the rate of growth between 1961 and 1971 reveals that it substantially lagged behind the other nations.

CHART 1

Note: Data is from 1860-1960.

Source: E. H. Philips Brown, "Levels and Movements of Industrial Productivity and Real Wages Internationally Compared, 1860-1970," <u>Economic Journal</u> Vol. 83 (March 1973).



Industrial productivity (output per person occupied in industry) in 4 countries. Indexes, all relative to the average level of productivity in U.K. 1890–99 = 100.

TABLE 2

Gross Domestic Product per Person Employed for the United States and Nine Other Industrial Nations, 1951, 1961, and 1971 (note a)

	1951		1961		1971		
	Gross domestic product per person	As percent of U.S.	Gross domestic product per person	As percent of U.S.	Gross domestic product per person	As percent of U.S.	Rate of growth 1961 - 1971 (note b)
	(thousands)		(thousands)		(thousand)		
United States	$5.45	1.00	$7.99	1.00	$13.42	1.00	68%
Canada	3.85	.71	6.59	.82	11.61	.87	76
Japan	NA	NA	1.18	.15	4.41	.33	274
Finland	NA	NA	2.60	.33	5.27	.39	103
France	NA	NA	3.55	.44	7.90	.59	123
Germany	1.36	.25	3.25	.41	8.01	.60	146
Italy	.87	.16	1.92	.24	5.35	.40	179
Norway	2.56	.47	3.44	.43	NA	NA	NA
Sweden	NA	NA	4.15	.52	9.26	.69	123
United Kingdom	1.73	.32	3.10	.39	5.55	.41	79

Source: OECD, Manpower Statistics and OECD, National Accounts of OECD Countries, 1950 to 1968 and 1960 to 1971, Table 1 - Domestic Product and Expenditure for all included countries.

a/The 1971 data reflects the misalignment of currencies.

b/Computations made by GAO.

Second observation

The annual rate of U.S. productivity growth, averaged over the past century, seems to have approximated the experience of other industrial nations.

Piekarz and Thomas use table 3 to show that the average annual rate of growth of GNP per capita of the United States over the period 1870 to 1965 compares favorably with most other industrial nations. The observation is also supported by chart 1 and an analysis by Kuznets 3/ of the average annual rate of change of national output per unit of labor input, and output per unit of labor plus capital input of selected countries.

Third observation

Since the post-World War II reconstruction, U.S. productivity growth has compared less favorably with that of other countries than it did up to that point.

Piekarz and Thomas state that:

> "Among the other industrial nations for the years 1955 through 1968, average annual growth of output per employed person in the economy as a whole, the industrial sector, and service activities exceeded the U.S. rate by about 50 percent. Only in agriculture has the U.S. experience been comparable. This performance for most of the other industrial countries represents an acceleration from their previous productivity growth."

Table 4 shows how the United States compares to other western industrialized nations in the rates of growth from 1955 to 1968 for the total economy and the agriculture, industry and service sectors.

Piekarz and Thomas found that evidence is lacking to determine whether the seemingly higher rate of productivity growth of other countries as compared to the United States is permanent. They found evidence in Denison's work 4/ and others, as we did, that foreign countries have, for example, a higher rate of investment in production plant and equipment. However, they note that the United States compares favorably in upgrading labor skills and technology development.

But they conclude that:

> "There is no way to determine whether during the next decade or two the gap in overall

TABLE 3

Long-Term Average Annual Rate of Growth of GNP per Head of 14 Countries, 1870 to 1965

Average annual compound rate

Australia	0.9%	Japan	2.2%
Belgium	1.5	Netherlands	1.1
Canada	1.8	Norway	1.8
Denmark	1.9	Sweden	2.1
France	1.6	Switzerland	1.7
Germany	1.8	United Kingdom	1.2
Italy	1.3	United States	2.0

Source: Angus Maddison, Economic Growth in Japan and the U.S.S.R. (London: George Allen and Unwin, Ltd., 1969), pp. XXI.

TABLE 4

Average Annual Growth of Output Per Employed Person for 13 Industrial Countries 1955 to 1968

	Annual Rate of Growth			
	Total economy	Agriculture	Industry	Services
United States	2.5%	5.4%	2.9%	1.7%
Other major countries (unweighted average)	4.0	6.1	4.6	2.2
Canada	1.9	4.8	3.8	-0.1
France a/	5.1	6.1	5.3	3.4
Germany a/	4.4	6.1	5.0	2.5
Italy	6.0	7.8	5.8	3.7
United Kingdom	2.4	5.8	2.9	1.4
Other European countries (unweighted average)	3.9	4.8	4.2	2.6
Austria	4.5	5.1	4.4	3.1
Belgium	3.5	5.8	4.4	2.3
Denmark a/	3.7	4.3	3.0	3.0
Finland a/	3.9	4.6	4.1	1.5
Ireland a/	3.3	3.3	3.4	2.2
Netherlands	4.0	6.2	4.8	2.8
Norway	4.1	2.5	3.9	3.4
Sweden a/	4.1	6.5	5.6	2.3
All countries (except U.S.) (unweighted average)	3.9	5.3	4.3	2.4

Source: Organization for Economic Cooperation and Development, The Growth of Output 1960-1980, Retrospect, Prospect and Problems of Policy, December 1970, p. 35.

a/Covers a shorter time period.

technological capabilities between the United States and the more advanced of the other industrialized nations will contract, widen, or remain about the same."

Our studies do not yield any more conclusive results concerning relative, future national growth rates than those of Piekarz and Thomas. However, table 4 shows that only in agriculture does the United States compare favorably in growth rates with other nations. When combined with our other findings, this forms a basis for postulating about the future of the discrete parts, batch-processing segment of manufacturing industry. In the United States only agriculture has well-defined national programs and an institutional structure for technology enhancement, diffusion, financing, marketing and productivity improvement.* In the service sector similar structures and programs may be developing.** In the industrial sector there are a number of Government programs directed to specific areas of manufacturing, but there is no cohesive national program.

In July 1975 the Joint Economic Committee, Subcommittee on Economic Growth, held hearings on the lack of a national technology policy and its impact on the economy. In announcing the hearings, Senator Lloyd Bentsen said:

"* * * as of today, the United States has no national policy for encouraging the type of technological innovation that is needed to maintain a healthy, growing economy. * * * no new system has been developed or adapted to meet the new set of emerging priorities: economic growth, environmental soundness, export competitiveness and social welfare."

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*In the broad sense, the activities of the U.S. Department of Agriculture, the State Agriculture departments, and the agricultural colleges constitute U.S. "productivity centers" for agriculture.

**For example, the health care research and delivery work of the Department of Health, Education, and Welfare which is strongly funded and the work of the Government's Joint Financial Management Improvement Program which measures productivity in the Federal Government sector. See also the results of a study of productivity improvement opportunities in the service sector by the Federal Council for Science and Technology 1/ and the work of the National Commission on Productivity and the Quality of Work Life.

By contrast, the foreign countries we studied have well-developed national programs for industrial development and, through their productivity centers, a structure for service sector productivity improvement. The establishment of national structures--formal and informal--for productivity improvement in foreign countries took place from late in the 1940s to early in the 1950s.

This was followed by sustained improvements in productivity growth rates. Thus, there is a presumptive cause-effect relationship between the creation and maintenance of structured national productivity efforts and sustained productivity growth in the foreign countries. (A more detailed discussion of foreign productivity centers may be found in chapter 6.) This, compared with sustained high rates of productivity improvements in American agriculture--the only sector in the United States with a fully developed national productivity effort--suggests that formal national productivity programs can influence the rate of growth of national productivity.

DENISON'S WORK

Denison has pioneered in identifying the determinants of changes in output and measuring of changes in them, and, as a means of understanding economic growth, he has estimated the effect on output of changes in each. In his earlier work 5/ Denison identified 31 change determinants. He finds that changes in the following categories were chiefly responsible for long-term growth. 6/ The categories are (1) the number of employed persons and their demographic composition, (2) working hours, including the proportion of part-time workers, (3) the education of employed persons, (4) the size of the capital stock, (5) the state of knowledge, (6) the proportion of labor allocated to inefficient uses, (7) the size of markets, and (8) the strength and pattern of short-term demand pressures. Advances in knowledge were the biggest single source of growth, and lengthier education of the labor force also appeared as a major source of growth. (Our study focuses primarily on advances in knowledge, but we did some survey work on education. (See ch. 7.)

In Denison's work 6/, advances in knowledge include technological knowledge; i.e., knowledge concerning the physical properties of things and how to make, combine, or use them in a physical sense. It also includes managerial knowledge; i.e., knowledge of business organization and of management techniques construed in the broadest sense. Advances in knowledge comprise knowledge originating in the United States and abroad and knowledge obtained in any way: by organized research, by individual research workers and inventors, and by simple observation and experience.

Denison goes so far as to state 4/ that in the very long run changes in the state of the arts (i.e., advance of knowledge) and gains from economies of scale are the fundamental sources of growth in output per unit of input.

In this report we recognize the high quality of American managerial knowledge by observing that foreign productivity centers have had missions of acquiring and disseminating American managerial know-how and in compensating for the lack, in their own countries, of well-developed schools of business and of organizations such as the American Management Association. (See ch. 6.) Denison makes the same point and concludes, along with many others, that American management technology is the best developed of the industrialized nations.

Our study, therefore, concentrated primarily on technological knowledge because of its importance to national growth and because of the emerging new technology of computer-integrated manufacturing, which can impact on such a large sector of American manufacturing.

Denison also makes the point 4/ that any scientific discovery, theory, or knowledge of any new materials, machines, techniques, procedures, and practices that arise anywhere in the world quickly spreads to all industrialized countries. By accelerating its own contribution to advances of knowledge, one industrialized country cannot expect to gain more than a temporary advantage over the others with respect to knowledge available for use.

The experts with whom we discussed this matter in the United States and abroad agreed that knowledge can spread quickly among countries.

There is an important difference, however, in the acquisition of technological information by the United States and other industrialized countries. One of the major problems we encountered in attempting to assess the level of development of computer-integrated manufacturing in foreign countries was the virtual dearth of information in the United States on foreign developments. Foreign publications and research works on manufacturing technology were not routinely scanned, translated, or published in the United States. Only a relative handful of private industry professionals routinely visited foreign countries for firsthand appraisals of foreign technology. (By this we mean manufacturing generally. We found many individual American companies which were well aware of the manufacturing processes used by foreign competitors in the same product line.) We could find only a few academicians who had a firsthand knowledge of foreign developments, and, while we found some Federal Government officials who had firsthand knowledge of specialty areas of foreign technology and some who had hearsay knowledge of foreign developments, we found few who could speak authoritatively or out of personal knowledge on foreign technological developments in manufacturing technology in general.

By contrast, in all of the foreign countries we studied, the industrial, academic, and Government communities had well-structured practices for keeping up with developments in all foreign countries including particularly the United States and had mechanisms for diffusing this knowledge. (We did not attempt to evaluate the effectiveness of the diffusion mechanisms.)

Denison did not address the different attitudes and mechanisms in various countries for acquiring and diffusing information on foreign technological developments, and he tends to minimize the importance to relative economic growth among countries of attempts by one country to accelerate its own contributions to advances of knowledge. However, the differences we have perceived in countries' capacities or systems to acquire and apply the best in-world technology (as well as to expedite the diffusion of the technology to the industrial base) could well be one of the important factors contributing to the differing rates of productivity improvement in the industrial sectors of foreign governments.

A perplexing and different problem in any study of relative productivity or economic growth is the length of time it takes to spread or diffuse the first successful application of a new technology throughout the industrial base. (We discuss this problem of diffusion in greater detail in ch. 4.) Not surprisingly, therefore, Denison also had this problem in his analysis of why growth rates differ in various countries.

Denison characterizes the difference between the best practice (in the case we are discussing here, this would be manufacturing practice) possible with the knowledge available at any given time and the average practice actually in use as the lag. 3/ Thus he states that one may distinguish in principle between the contribution to growth of advances of knowledge and the contribution that may be made by a change in the lag of average practice behind the best known. He states:

> "This is an essential distinction * * * and a common one, but it is difficult to give it precision." 4/

Denison has found no way to isolate the various reasons that average practice is below the best or that the margin of difference changes.

He states that there is a possibility that changes in the lag may differ importantly from country to country and that the average level of technique in Europe is generally considered to be below and behind that in the United States, particularly in the techniques of management and the organization of business as distinct from more narrowly defined technology. He observes therefore that there appears to be opportunity for the European countries to add substantial increments to their growth rates by imitating and adopting American practices. He summarizes the organizational and study efforts of foreign productivity centers to apply the best of U.S. practice and states:

> "Under these conditions, a finding that the European countries have secured a substantial increment to growth by narrowing the gap between European and American practices would not be a surprise."

Denison's own calculations do not show that efforts at narrowing the gap explain the considerable differences between the rates of productivity growth in the United States and foreign countries, but he states that this lack of evidence does not prove conclusively that improved European practices were not an important source of difference between the growth rates of the United States and the European countries studied.

Keeping in mind that Denison's studies were directed to the total national economies, our studies would not serve to alter Denison's analyses.

However, with regard to specific sectors of various economies, Denison's results drawn from a broad analysis would not necessarily apply. As pointed out above, although overall productivity is lower abroad than in the United States (see chart 1 and table 2), in all countries, experts with whom we discussed the matter, agree that state of the art or best practice in discrete parts, batch process manufacturing is about equal (although the level of average practice in each of various countries is different).

When one evaluates the level of nationally supported effort being applied by the differing nations to enhance and diffuse computer-integrated manufacturing, particularly considering the successful results of their past effort, in relation to a virtual lack of a directed U.S. national effort, one cannot help but be concerned about the relative rate of progress of the United States over the next 10 to 20 years.

In other words, as we will point out, two important technological advances, the computer and the numerically controlled machine tool, were brought to their present levels of development with major financial support from the Federal Government. Other countries have adopted and enhanced this technology and have large and well-established national programs for further developments. Since these past developments are the result of successful Federal efforts and since there is now no important continuing directed/coordinated Federal effort or other cohesive national effort, there is ample support for concern of the future impact of foreign efforts on U.S. trade balances. There is also concern that American products procured by the Government are not being produced using the most efficient manufacturing methods.

To obtain better information on the use of advanced manufactory methods within our industrial sector, we randomly surveyed some 200 U.S. manufactures to determine their use of numerically controlled machine tools and computers. The result of this survey clearly supports our concern that, for a large body of American industry, the use of these advanced methods is almost nonexistent. (See app. I.)

CHAPTER 3

COMPUTER-INTEGRATED MANUFACTURING--

ITS POTENTIAL

Peter Drucker said that three main areas in a typical manufacturing business account for three-quarters of the capital invested. 7/ These are (1) machinery and equipment, (2) inventories of materials, supplies, and finished goods, and (3) receivables. Yet he says that despite its importance and payoff, not many business managers pay much attention to the productivity of capital. One reason, he says, and "perhaps the single most important one, is that managers, as a rule, get little information on the productivity of capital in their business."

Our work indicates that the emerging technology of computer-integrated manufacturing (CIM) will not only provide managers with better information on the use of capital but also improve the use (and therefore the productivity) of capital. Dozens of machine tools can now be simultaneously operated and controlled by a single, hierarchal computer system known as "direct numerical control" (DNC). Machine use is increased and work-in-process inventory can be reduced. The computer can not only send instructions to the machine tools but it can automatically receive back information and provide managers with the operational results of its instructions and the status of work in process. The computer aids designers in making better designs in less time than manual methods (in some cases modern designers' work cannot practicably be accomplished by manual methods) and frees the designer of laborious manual tasks, thus giving him more time to use his creative skills. Computers can be used to perform production planning and control tasks; to direct work pieces from one machine to another; to test the performance and inspect the quality of finished work; and to direct and control materials handling, storage, and distribution systems. Computers are also used to program and control plant maintenance and to plan factory layouts and machine locations in factories.

Dr. Joseph Harrington, an authority on manufacturing and author of a pioneer work on applying of computers to manufacturing, has characterized this expanding application of computers to the manufacturing environment as follows:

"It now seems apparent that things are about to change--not incrementally, but radically. Fractionated management skills are being reintegrated and the new managers with their broader perspectives are directly controlling versatile machines capable of manufacturing diversified and customized products. The total manufacturing effort is being reintegrated into a responsive directable entity. It is a giant step and a step in a new direction.

"This radical change in direction is a result of the coinciding of many small advances in the state-of-the-art. Taken individually, each advance is an incremental improvement in one field. Taken collectively, when the fields are contiguous, the result is more than just the sum of the parts. All the tumblers in the lock are falling into place; the door is swinging open. It is one of these rare moments in time when all of a compatible and connected set of conditions has been achieved."8/

We have observed some of the above functions being performed by computers in some plants. Some of the more sophisticated and highly capitalized firms are using computers for many of these functions. We found no one firm using all of them. And some firms, particularly small and medium sized firms, who could benefit from these are using none of them.

A BRIEF SUMMARY OF TYPES OF MANUFACTURING PROCESSES

For our study it is convenient to divide manufacturing into three broad categories: (1) continuous process, (2) high volume or mass production of discrete parts, and (3) low volume or batch process of discrete parts.

Continuous process manufacturers turn out a flow of undistinguishable goods in "continuous activity in which the nature of the material is changed." 8/ These include manufactures such as oil refining, brewing, paper, and steel. These industries are highly automated through use of computerization and/or electromechanical devices.

The discrete parts manufacturing industries "change the shape of materials to produce discrete components that are assembled into functional end products."8/ These include manufactures such as lawn mowers, hand tools, appliances, automobiles, or their components. Where standardized discrete parts or products (e.g., brake drums, engine blocks, axles) are produced in high volume (e.g., 500 to 20,000) in a single production order, mass production techniques can be economically used. High volume is required because the mechanization is expensive and relatively inflexible. The automotive "transfer line" (see fig. 1) is a typical example. It is set up to process a particular type of product in high volume over an extended period of time. To produce a new or different product using transfer lines requires a closedown of the line and its redesign or reconfiguration before production on the new product line can be commenced. Although there may be differences in detail from country to country, American mass production industries in general are considered to be among the most advanced in the world.

In contrast to mass production is batch production. (See fig. 2.) This method of production is required when several discrete products are manufactured but the volume of any one product is relatively low, and there is little product standardization. About 75 percent of all metalworking parts are produced in this manner. Consequently a great deal of flexibility is required, and it is necessary for batch production plants to use a wide range of general purpose machines adaptable for making a wide variety of products. (See fig. 3.) This production method, although requiring a smaller initial capital investment than mass production methods, results in a much higher cost for each product. As shown later, modern technology can change this.

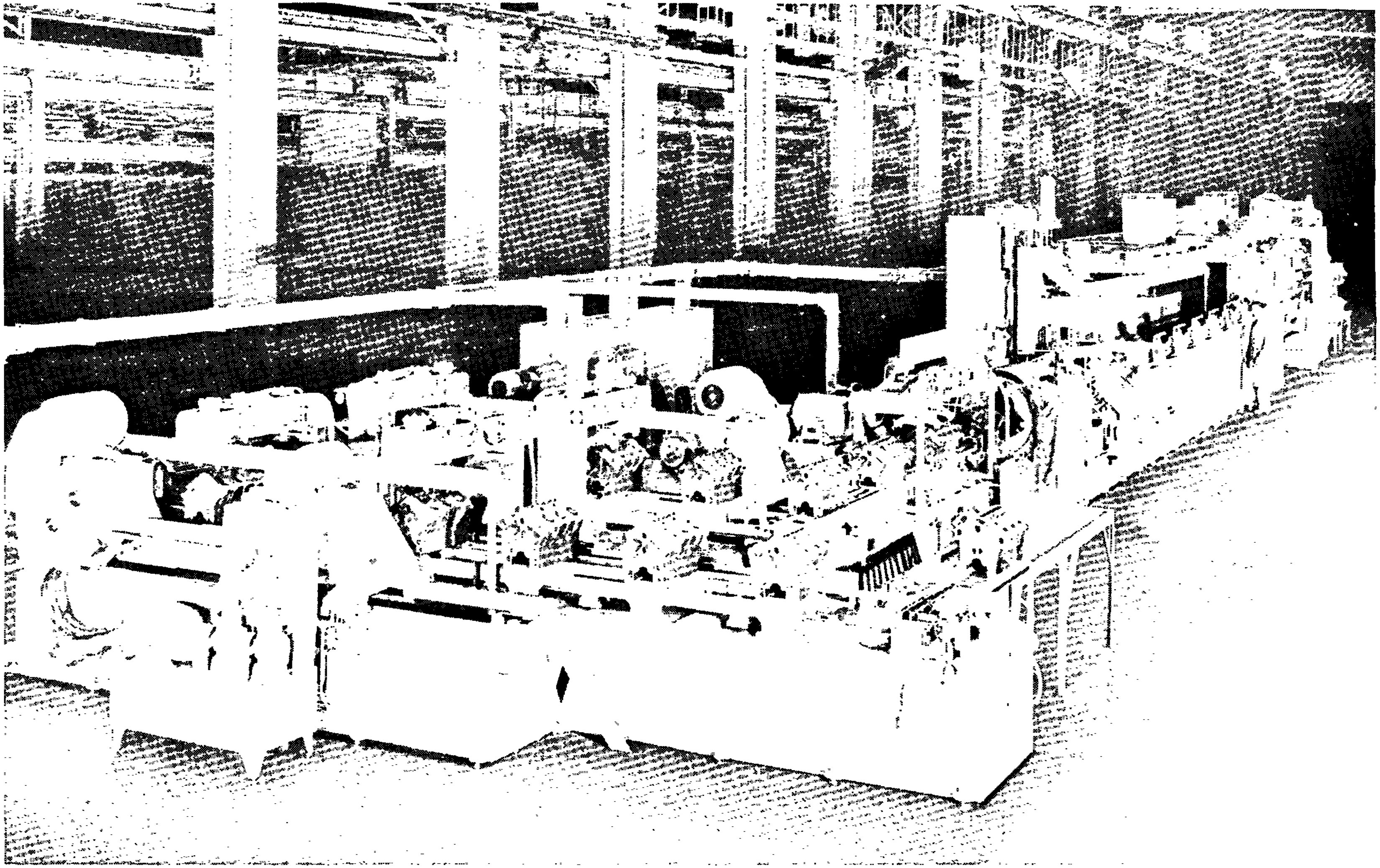
There is also general agreement that this area of manufacturing is undergoing profound changes and offers the greatest opportunity for productivity improvements in the future. Each of the industrialized nations is pursuing its own programs to exploit and enhance this technology.

The manufacturing sequence

Manufacturing may be defined as the process of conceiving a product, designing it, and then through applying manpower, energy, materials, and technology, translating the design into a saleable item.

In this process the product is first designed on a series of drawings by skilled design engineers and draftsmen. The final detailed drawings become the basis for planning the methods to be used to produce the item, such as the type of equipment needed, machining sequences, required materials, etc. These elements are brought together on the shop floor where the skilled craftsman (e.g., machinists) applies his trade to maximize production quality and quantities while minimizing the consumption of energy and raw materials. Before the development of the computer these functions were performed manually, and the quality and efficiency of

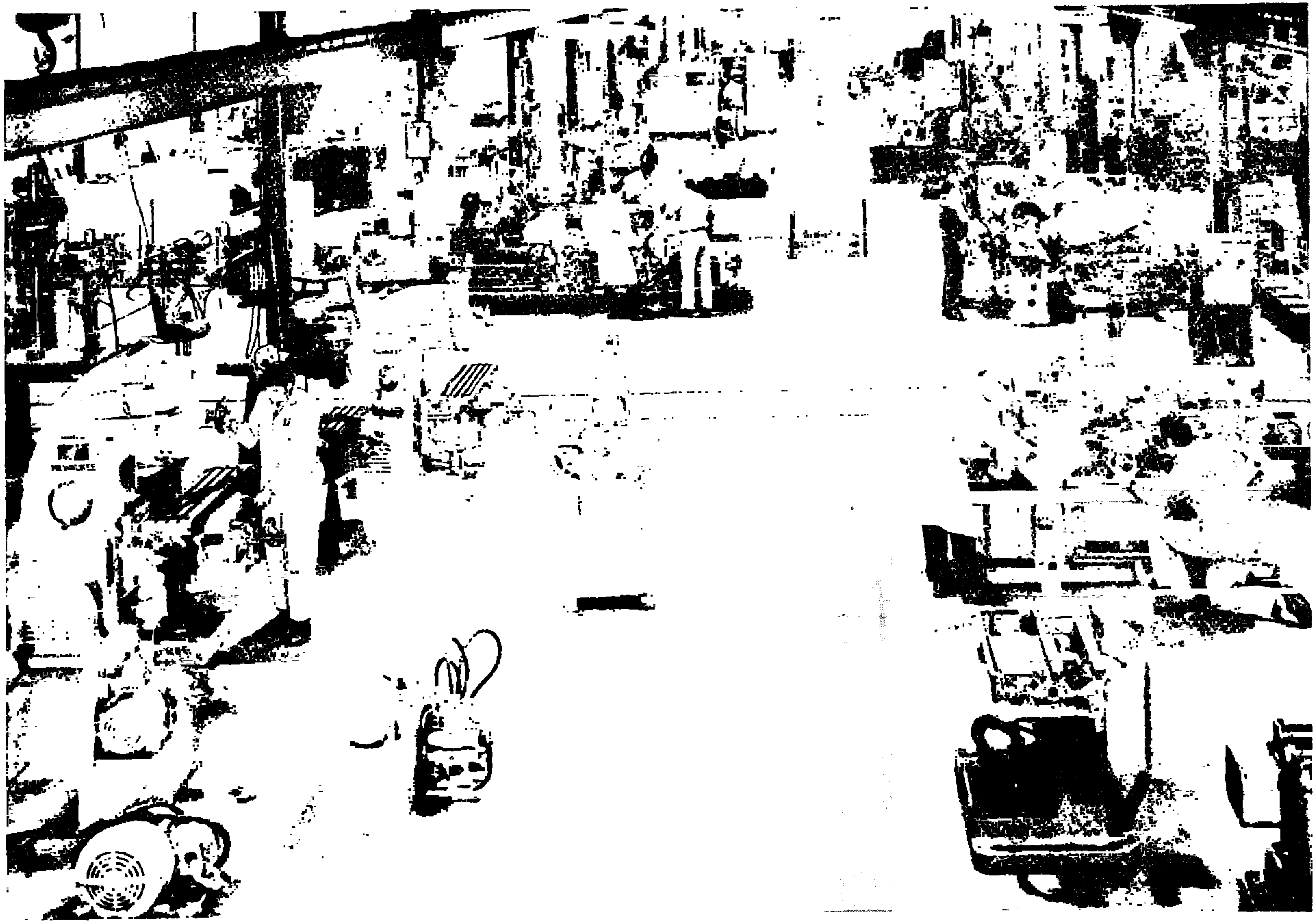
Figure 1



(COURTESY OF CINCINNATI MILACRON)

EXAMPLE OF MASS PRODUCTION TRANSFER LINE

Figure 2

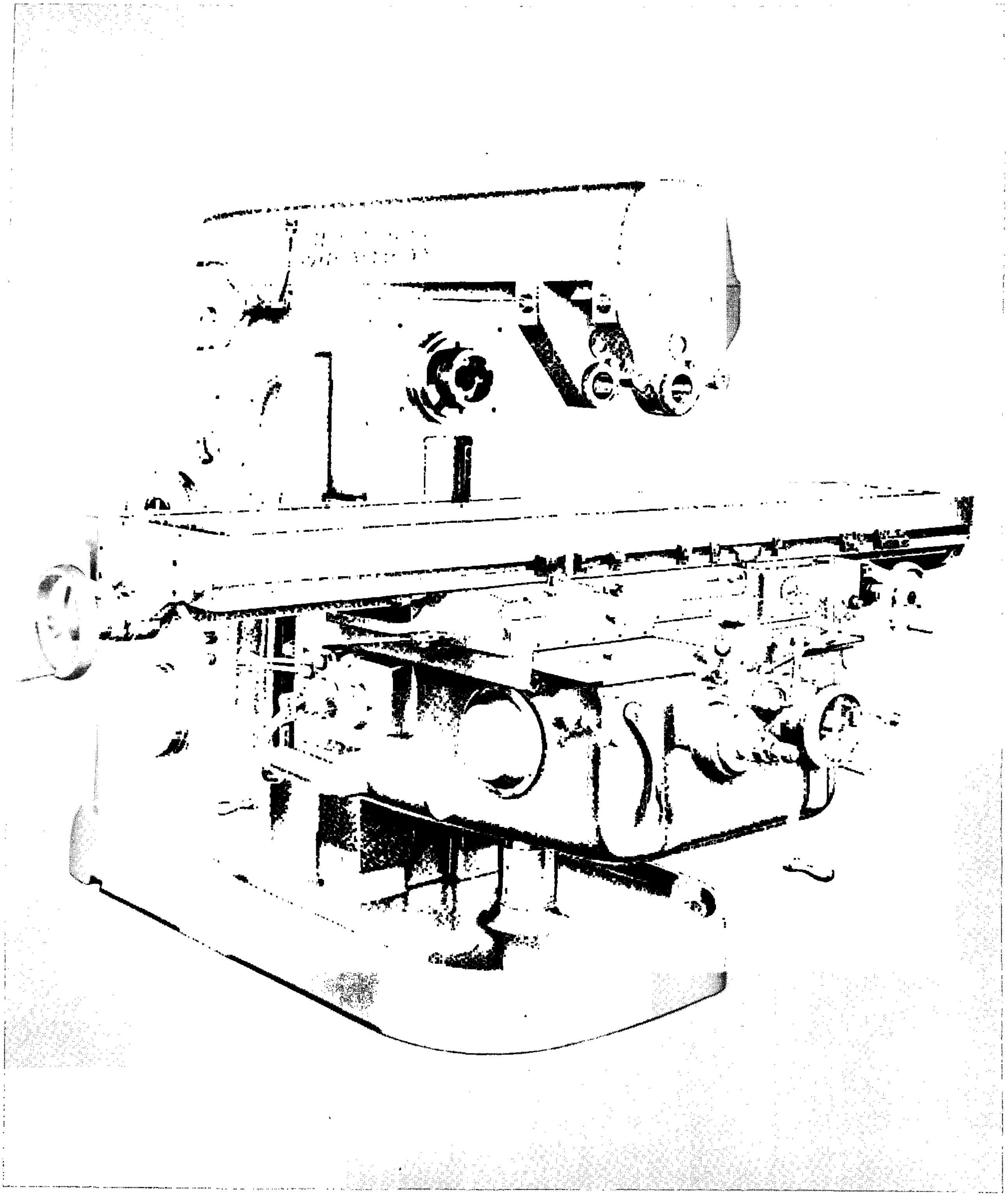


(COURTESY OF MAINTAINCE SERVICE CORP.)

EXAMPLE OF BATCH PRODUCTION ENVIRONMENT

Figure 3

GENERAL PURPOSE MACHINE TOOL



(COURTESY OF CINCINNATI MILACRON)

production were dependent on the personal skills of the designer, production planner, tool operator, inventory control manager, etc.

The computer has now been applied to virtually all phases of manufacturing. Our survey indicates that in firms where computer techniques have been applied, manual skills have been been augmented; functions which could not practicably be performed manually are now being performed; costs have been improved, productivity has increased, and customer service and satisfaction improved. All of the improved functions are playing important parts.

For example, for each product it produces, a company must construct a listing or record of the materials, parts, and components that go into producing the product. The list is known as the bill of materials (BOM). BOM is used to plan for and obtain the materials required for a production run, to record engineering changes, to identify parts common to various and different products, and various other functions. It is a key activity in the manufacturing process. 8/

Many manufacturers said that computerized maintenance and control of the bill of materials file have saved them millions of dollars. Other manufacturers continue to rely on manual methods.

A detailed discussion of techniques and advantages of BOM and of each of the elements of computer-integrated manufacturing is beyond the scope of this report. The individual subjects are covered in great detail in the literature.

However, the efforts of manufacturing are directed in the last analysis to creating parts, components, and final products. The two recent developments that are making major contributions to these efforts which are crucial to continued productivity improvement in the batch production industries are the minicomputer and its adaption to operating machine tools, materials handling equipment, and industrial robots.

COMPUTERS AND NUMERICAL CONTROL

The importance of computers and numerical control to improved productivity in batch production can best be appreciated against a background of the manual operations traditionally employed in machining a part out of metal.

Basic machining function

Seven basic functions have been identified to operate the general purpose machines used in metalworking batch operations. These are performed by the skilled craftsman or machinists on each discrete product produced. They are illustrated in chart 2.

Most parts require several different types of operations that call for the use of different types of machines. Therefore, after the part is worked on one machine, it would have to be routed to another machine for the additional operations which would again require an operator to perform these seven functions. This rerouting, set up, load, unload, manual control, and waiting for the next operation result in much lost time. Authoritative estimates are that a machine tool in a batch process is actually cutting metal only about 15 percent of the time. The remainder is spent primarily waiting for parts, although tool changing and maintenance is also involved. Consequently, there are important productivity improving opportunities through applying technologies which minimize the lost time. In fact, it has been estimated that some applications of computer and advanced machine tool technology could result in machine utilization increases in batch processing of 600 percent or more. Resulting reduction of indirect capital and labor costs and improvement of productivity have been estimated to be potentially as high as ten-fold.

The computer and the numerically controlled machine

A forerunner to applying computers to the actual machining of parts was the development of the numerically controlled (NC) machine tool in the late 1950s. The NC machine was developed by the Massachusetts Institute of Technology under contract with the Air Force. The need arose from the advent of high performance aircraft, the parts of which required three dimensional machining with a much higher degree of accuracy than could be achieved on manually operated machines.

Essentially, a basic NC machine is one that is controlled automatically by coded instructions. Such a system has two elements--a machine to perform the work and an electronic control unit which directs the machine's motions. (See fig. 4.) The coded instructions, representing the cutting path and other operations of the machine are input to the control unit in the form of programed numerical values punched into paper tape or recorded on magnetic tape. This numerical data is automatically read and decoded; operating as an integrated unit, the control device causes corresponding machine movement to perform its functional operations (e.g., drilling, boring, etc.). (See fig. 5.) This system replaces certain functions of the skilled craftsman/machinist, most notably functions 4 and 5 (described above); i.e., establishing machine feeds and speeds, etc. and control of the machine motion. However,

CHART 2

ILLUSTRATION OF SEVEN BASIC FUNCTIONS OF BATCH PRODUCTION

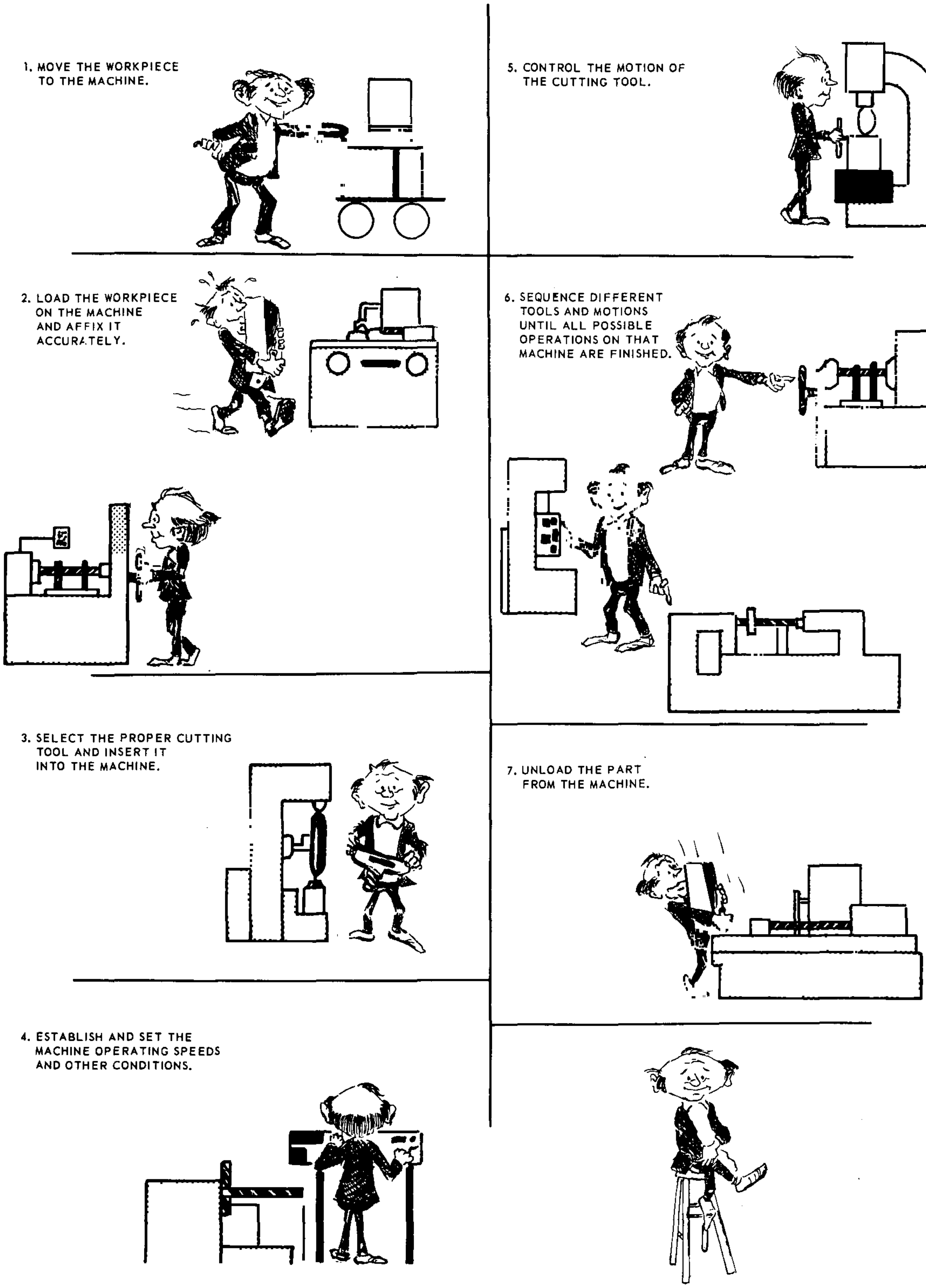
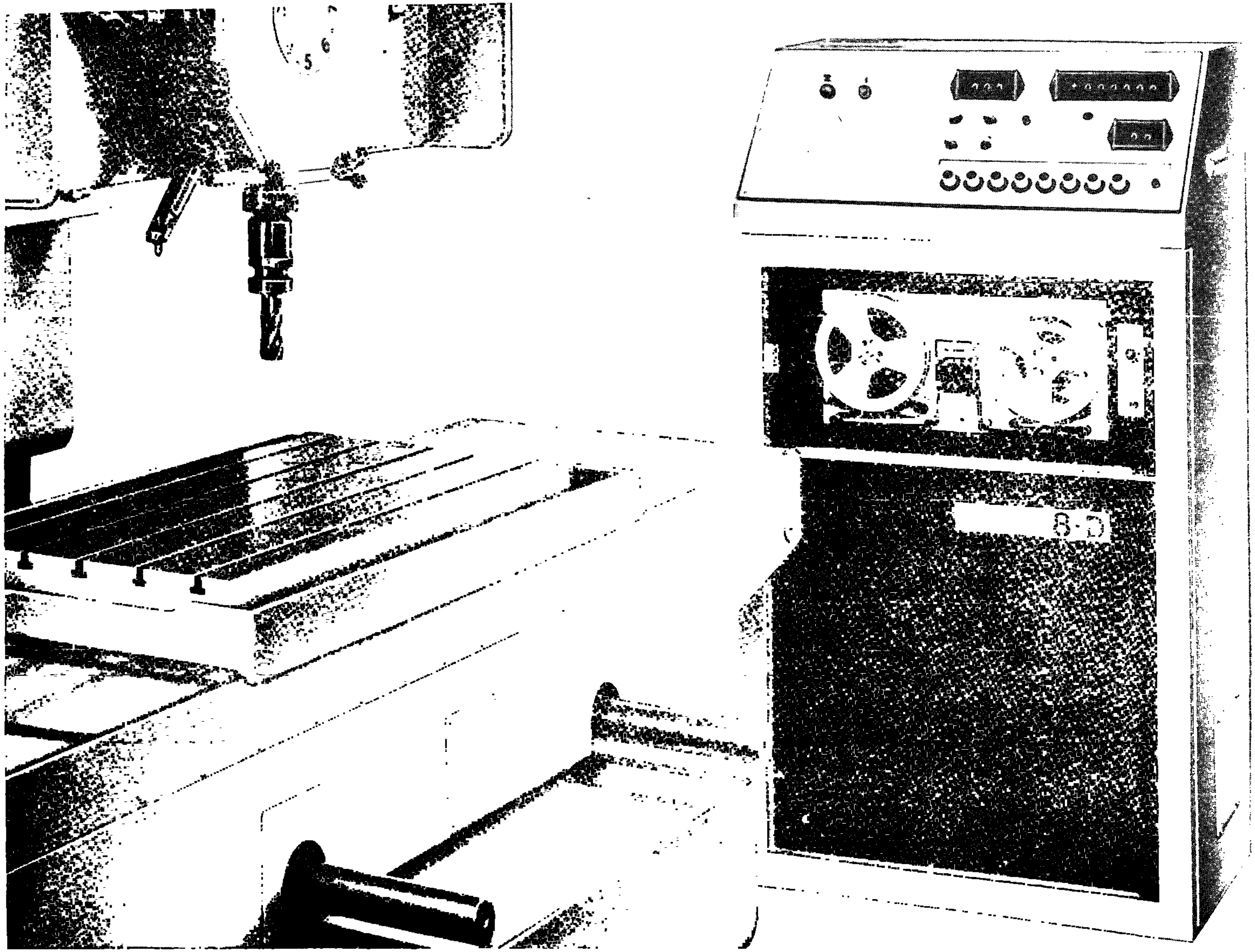


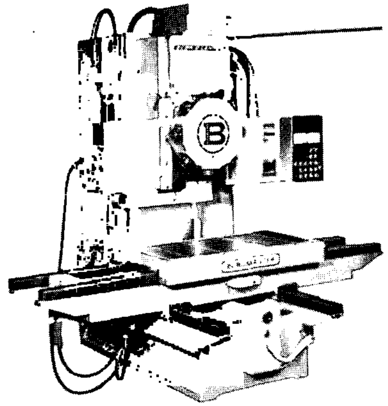
Figure 4



NC MACHINE AND CONTROL UNIT

Figure 5

GENERAL PURPOSE MACHINE TOOL
AND ITS
BASIC FUNCTIONS

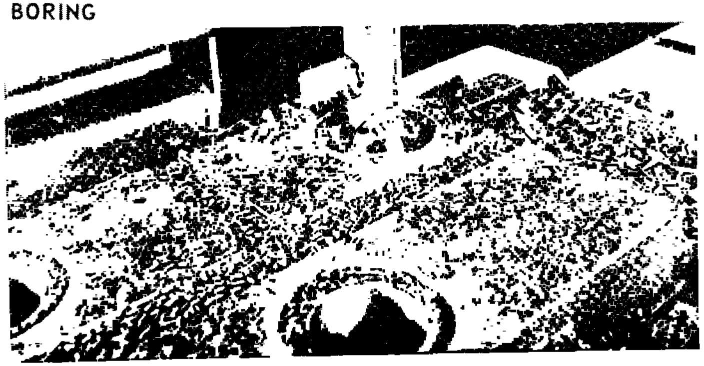


(COURTESY OF BURGMASTER CORP.)

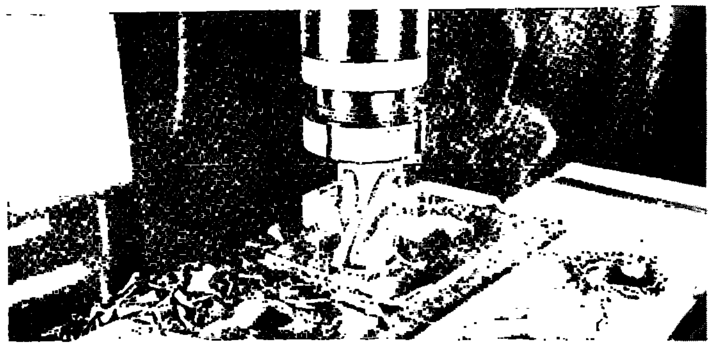
MILLING

DRILLING

BORING



TAPPING



(COURTESY OF CINCINNATI MILACRON)

the system created another highly skilled job--a part programer. This new job requires the expertise of both a skilled machinist and a mathematician's understanding of computer languages. It is his job to extract from the engineering drawings all the data necessary to program the numerical calculations to control the machine movements.*

Numerical control by computer

Although tape is the most common input device in use today, in the latter 1960s software was developed to enable the computer to directly input the numerical data to the machine control unit and to bypass the tape. There are several ways to accomplish this. A large central computer can be used to directly control any number of machines. This system is referred to as direct numerical control or DNC. However, what may be a more important technological advance to computer-integrated manufacturing is the minicomputer and more recently the microcomputer.

These computers can be used to operate a single machine or several machines and can be linked to larger computers in a hierarchal system. This is referred to as computer numerical control, or CNC. Before the development of the minicomputer and microcomputer, only companies with large computer complexes could consider DNC. However, the minicomputer and microcomputer have been reduced in costs so that CNC units are competitive with the older, tape-driven control units.

The use of computers to replace tape controllers adds an element of time saving in reprograming, on a real time basis, the numerical sequences in part programs to correct errors or to implement design changes and enables the feedback of data to management.

As a flexible automation method NC can be programed to perform different functions on a variety of different parts, using the general purpose machine tool in a more efficient manner than possible with manual operation. A major benefit to be gained from using NC equipment is the quality of the part. For example, sophisticated jet aircraft parts require

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*Since the same mathematical data base is needed to create the design as well as to program the machine tool to make the part, the technology has advanced to the point where, in some companies, no engineering drawing need be made. The design is captured in the data base and the computer programs the cutting path.

high precision cuts to meet tolerance requirements. Such parts can be made only with NC. Also with NC each part will be identical to the preceeding one since the judgment element is removed from the cutting procedure. This provides tremendous benefits to the follow on assembly operations, because with closer tolerances, assembly becomes simpler and consequently less costly. Some users feel the major cost advantages come from easier assembly.

COMPUTER-AIDED MANUFACTURING

It has been estimated that a part is on a machine less than 5 percent of the time it is in the shop and for only a portion of that time is the tool cutting metal. (See chart 3.) The remaining time is spent on waiting, moving, setup, downtime, assembly, inspection, etc. The improvements being developed in these operations, not just additional improvement of the metal cutting operation, hold the key to future quantum increases in productivity of batch manufacturing operations.

Early NC machines controlled the operation of only a single type of cutter, such as a drill. As they evolved, these machines were equipped with automatic tool changers that hold various types of cutting tools. These are known as machining centers (see fig. 6) which, as one single machine, perform the functions of several NC machine tools, i.e., drilling, milling, boring, etc. For work in these centers the parts can be fixed onto moveable pallets which eliminates setup time at the machine.

Additionally, there are systems which integrate multiple machining centers and automatically control the movement of work pieces from one NC center to the next on computer-controlled material handling systems. Not only can several different machining functions be performed without removing the parts being machined from this system, but the machine tool operator is relieved of various manual duties in that a single operator can apply his skills to several machines rather than to one. (See fig. 7.) Unlike mass production transfer lines, these computer-controlled flexible systems can randomly handle different types of parts and select and load the part onto the machine that can most economically perform the required operations.

Systems are also in use or are under development for automatically selecting work pieces from storage and moving them to machining centers; moving semifinished parts to intermediate storage and return for final processing, and moving finished work pieces to storage pending shipping and distribution--all under computer control.

CHART 3

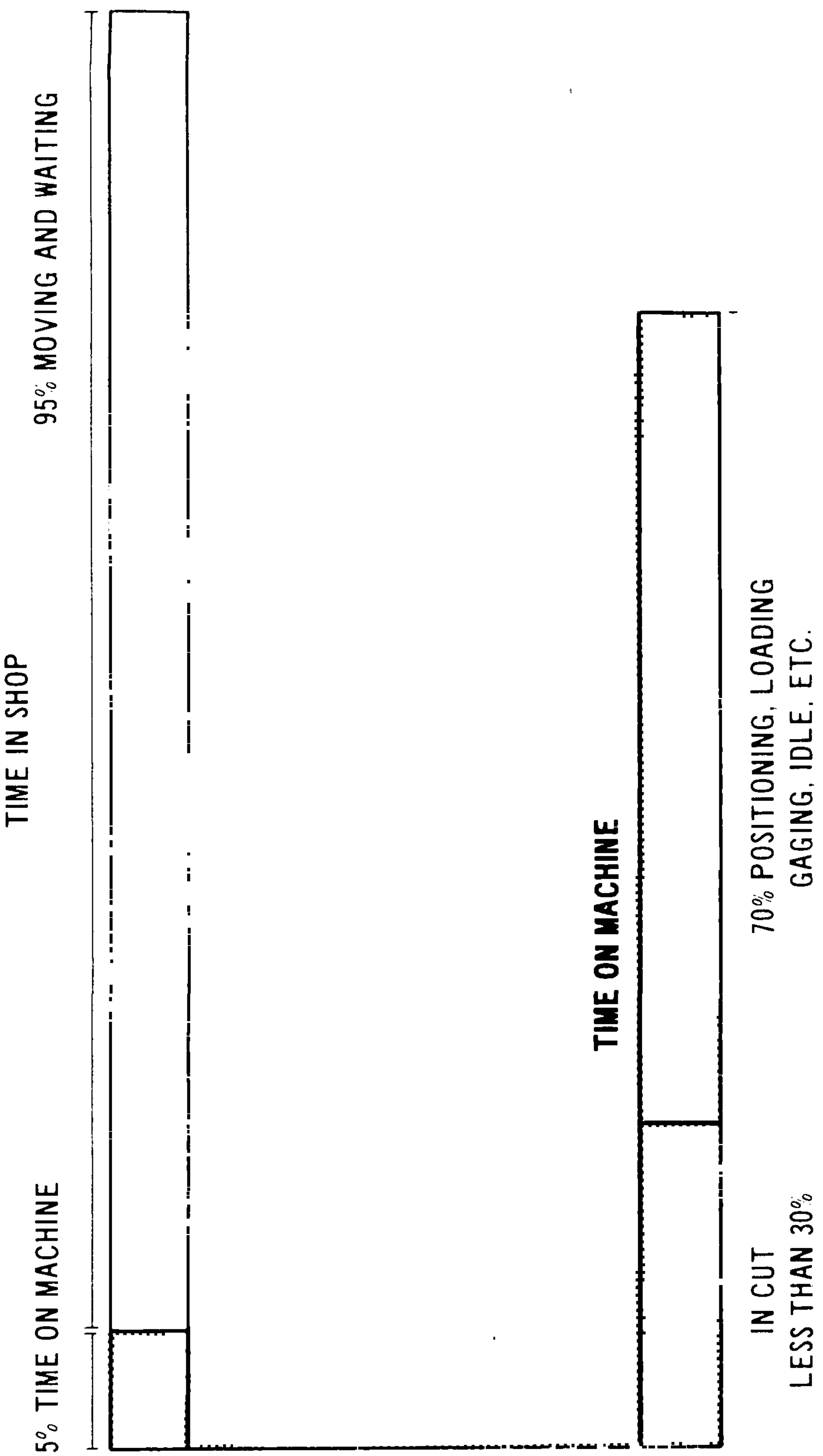
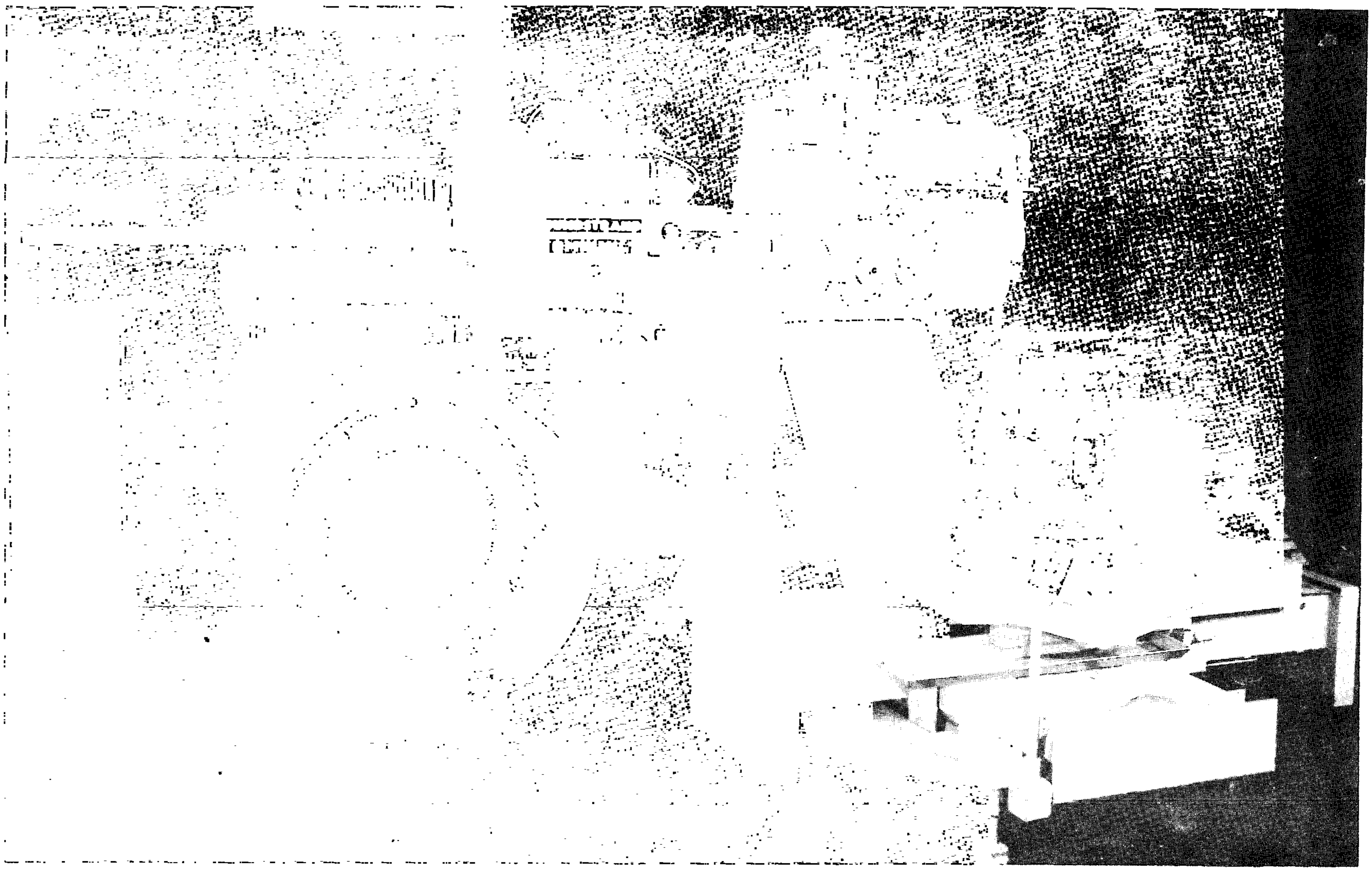

TIME IN SHOP
5% TIME ON MACHINE
95% MOVING AND WAITING
TIME ON MACHINE
IN CUT
LESS THAN 30%
70% POSITIONING, LOADING
GAGING, IDLE, ETC.

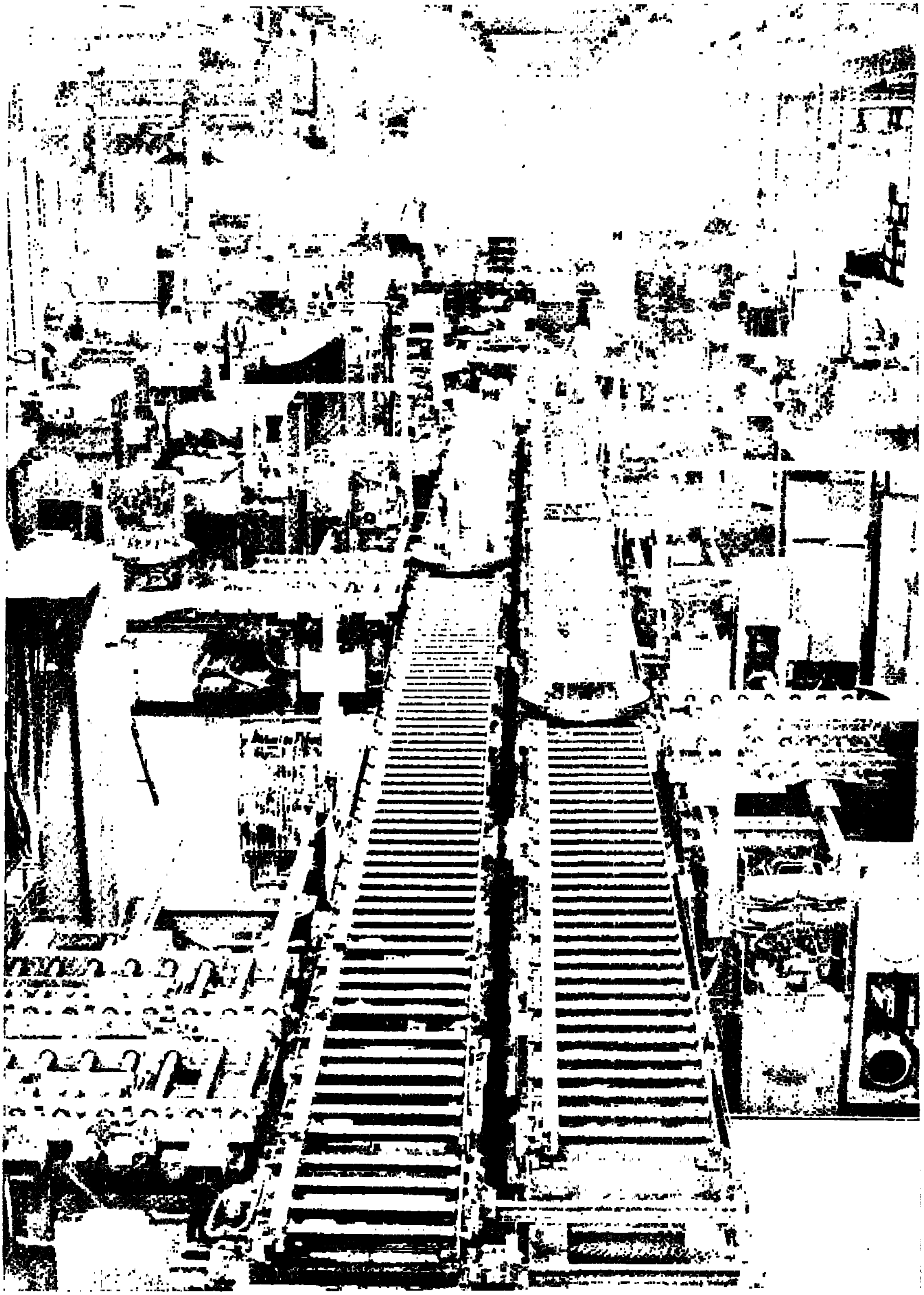
Figure 6



(COURTESY OF SUNDSTRAND CORP.)

MACHINING CENTER

Figure 7



(COURTESY OF INGERSOLL-RAND COMPANY)

COMPUTER INTEGRATED MANUFACTURING FACILITY

Assembly is a major area in which time consuming manual operations are performed. However, development work is being done on industrial robots (artificial intelligence) which can recognize the shape of parts and be programed to perform multiple assembly operations in random sequence.

Work is also being performed to develop systems which monitor maintenance requirements and are able to pinpoint problems and order replacement parts with great time savings and a minimization of downtime. In another area, sensor devices called adaptive controls are being developed which measure such performance factors of an NC tool as heat, vibration, torque, and deflection and automatically adjust the speed and other cutting operations to optimize cutting efficiency and reduce tool wear. Systems which automatically inspect discrete parts, either when finished or while in process, are also being used or developed.

COMPUTER-AIDED DESIGN

Another phase of using computers for manufacturing is in the design process through a procedure called computer-aided design. For many years computers have aided the product designer by performing the mathematical calculations necessary to solve a large variety of design problems. Recent developments in computer technology, however, have provided the designer with "electronic drawing boards" in the form of television tubes (cathode ray tubes) on which he may "sketch" his design ideas. (See fig. 8.) These systems provide the designer with instant feedback as to the engineering feasibility of each sketch. When the designer is satisfied that he has a final design, he can instantly store that design and all the necessary accompanying data in computer files. These files are simultaneously accessible to everyone else in the plant who needs the information. This data is then available to produce the instructions necessary to create a numerical control parts program, order raw materials, sequence the operations and, in some cases, predict the cost to manufacture.

WHAT COMPUTER-INTEGRATED MANUFACTURING ACCOMPLISHES

We have already alluded to the benefits from such functions as material requirements planning and inventory controls. Our discussion here will attempt to summarize only the benefits of the basic design and manufacturing operations.

The flexibility of these systems provides a method of increasing productivity while at the same time permitting

Figure 8

(COURTESY OF GENERAL MOTORS CORP.)

COMPUTER AIDED DESIGN VISUAL DISPLAY

responsiveness to changing market demands. Product changes and improvements can be incorporated easily without costly retooling and downtime. A greater variety of customized products is possible, and recent market trends indicate consumers are demanding a wider variety of products. Eliminating costly setup time gives to the batch industry the benefits of lower cost for each item, without the inflexibility of transfer line techniques used in high volumes.*

A convenient understanding of the results of CIM is obtained by comparing how the seven basic manual functions shown in chart 2, page 27, are accomplished using the computer-controlled methods we have described. Table 5 illustrates these seven functions under various degrees of computer control. Using the most sophisticated machining systems, the computer-controlled machine tools and materials handling equipment accomplish steps one through seven which were previously performed manually. Instead of steps one and seven, the machinist loads the workpiece on a pallet or fixture, but the integrated machining systems moves it to the machine and affixes it, machines it, unloads it, and returns it to the machinist for removal from the pallet or fixture.

For the machining centers, manual steps three through six are eliminated, as opposed to steps four and five which are eliminated by basic stand-alone NC.

As indicated earlier, an area of potentially great improvement is that of percent of machine utilization. This in turn would lead to a reduction of parts in process and the resulting inventory of unfinished parts on the shop floor which are in line for the next operation or assembly. This inventory could be reduced by up to 90 percent. The resulting reduction of indirect capital and labor costs and improvement of productivity could be enormous.

Productivity increases through use of automated systems are usually considered in terms of freeing labor and capital for redeployment in other phases of our economy. However, equally, if not more important today, are other resources such as raw materials and energy. One source recently stated that the manufacturing sector consumes 40 percent of all U.S. energy. Through the benefits available with

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*This is not to say that CIM yields unit costs as low as those achieved using transfer lines. Given the proper volume transfer lines continue to yield the lowest unit cost.

TABLE 5

COMPARISON OF MANUAL MANUFACTURING STEPS
ELIMINATED BY VARIOUS DEGREES
OF COMPUTER CONTROL

Production methods

	Step	Conventional	Stand alone NC	Machining center	CIM
1.	Move workpiece to machine	M	M	M	C
2.	Load and affix workpiece on machine	M	M	M	C
3.	Select and insert tool	M	M	C	C
4.	Establish and set speeds	M	C	C	C
5.	Control cutting	M	C	C	C
6.	Sequence tools and motions	M	M	C	C
7.	Unload part from machine	M	M	M	C

M = Manual operation
C = Computer-controlled operation

CIM--i.e., optimization of cutting, better use of time and facilities, better planning of needs and fewer rejects--substantial energy and materiel savings would accrue.

The new technology also holds the possibility of managing and operating a factory without technicians in the machining areas. The Japanese have developed a concept for just such a plant. (See ch. 6.) An oversimplification, but nonetheless pertinent statement, is that you do not need light or heat in an unmanned factory.

Computer integrated manufacturing can also contribute to the objectives of the Occupational Safety and Health Act of 1970. Computer-controlled machines can reduce or eliminate physical contact of the technician with his machine or machines. In systems which are now evolving (and in some now operating) the machines can operate for long periods in isolation from their human controllers. Thus human exposure to physical injury, noise pollution, and contaminated or unclean environments can be reduced.

SUMMARY

Computer-integrated manufacturing systems are changing the management of manufacturing, are improving productivity, and hold great promise for bringing about continued improvements in discrete parts batch process manufacturing. They provide the basis for improving the productivity of both capital and labor, economies in using materials and energy, and reducing exposure to the hazardous and less appealing work in factories.

CHAPTER 4

COMPUTER-INTEGRATED MANUFACTURING--ITS PROBLEMS

As indicated in chapter 3, various components of computer-integrated manufacturing (CIM) are already yielding improved productivity of capital and labor and CIM has great promise for the future. This is a new technology whose full potential is only now beginning to be understood. It has had problems in reaching its present level of development, and there are problems to be solved and technological gaps to be filled in before fully integrated systems will be achieved or their maximum efficiency will be realized.

Computers applied to manufacturing require new and unfamiliar management and technical skills; the hardware and software products of different manufacturers are not compatible; many areas of standardization need to be studied; further developments and innovations are needed in such areas as process planning and component and finished parts assembly and testing; life cycle costing and cost benefit analysis of the more sophisticated systems are imprecise; and our studies show that many manufacturers are not aware of the technology available to them. Despite their advantages, many components of the new systems are more costly than the older systems or machines they replace, which increases both problems of capital formation and risk. Also the applied research necessary to develop pilot systems designed to reach the potential limits of the new technology require long leadtimes and large amounts of capital and are beyond the capacities of the individual firms which could most benefit from them. For much the same reasons, basic research on new manufacturing methods is minimal.

Additionally, there are weaknesses in (1) national policy for technology,* (2) communication between Government agencies and Government and industry, and (3) market defects (this is a generalization embracing many of the more specific problems mentioned in the paragraphs above) for diffusing the technology and marketing its products.

The list is not complete, but it is sufficiently comprehensive for the reader to sense the problems.

The potential of CIM, the magnitude of the problems to be solved, and differing national approaches to their solution are major factors that dictate a need to examine into the adequacy of the U.S. national effort.

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*See the quote of Senator Bentson, p. 13.

We shall not attempt to discuss all the problems. We shall discuss some of those which are important to the cost of Government procurement, which involve the most difficulty, and for which foreign competitors have developed national institutional mechanisms.

INVENTION, INNOVATION, AND DIFFUSION

In discussing manufacturing technology, it is important to recognize that technology is not a single entity. Technology is the result of a delicate process which can be usefully separated into three phases.

--Invention.
--Innovation.
--Diffusion.

1. Invention is the creative part of the process that is difficult to dictate on demand. The environment provided to the inventor is probably the single most important factor to which public and private institutions can contribute. The environment that should be provided is one that would allow a creative individual or organization to bring ideas to realization. This is the rationale of basic research done at universities and in the public and private sectors.

2. Innovation is the first introduction of an invention into successful practice. It is sometimes described synonymously as being the first new application of a technology.

3. Diffusion is the successive and widespread imitation of successful innovation.

It is the second two phases of technology, namely, innovation and diffusion, on which institutions and management can best exert directed influence. This is not to say that Government is ineffective in encouraging invention. Quite to the contrary. By providing a constructive climate, funding and definition of need, inventors can be encouraged to direct their "inventiveness" in particular directions. The "Research Applied to National Needs" (RANN) program of the National Science Foundation is an example of a program to encourage new development in manufacturing technology.* Both

*Concerning influencing invention, Hough 9/ states that "the direction of new technology generation [invention] can be changed by defining Society's technical needs or goals and providing a market for items which satisfy those needs."

the rate and the direction of innovation and diffusion can, to some extent, be controlled.

The United States has historically excelled in translating both invention and innovation into useful applications, and from our study we believe that this country generally has in place and in operation more of the most advanced manufacturing technology than other countries. This should not necessarily provide a basis for complacency.

Our discussions and research indicate that the United States continues to be a leader in invention and innovation. However, our work suggests that the U.S. applications are concentrated in a relatively few large firms within high-technology industries or within high-capital intensive industries. For the most part these applications are privately sponsored, proprietary systems and the underlying technology is not well diffused throughout the U.S. industrial base. (See app. III for a brief discussion of the stage of development of the automation industry.)

This situation is due to the fact that bringing any new technology through the steps from invention to widespread use is an expensive, time-consuming and risky process, and only the larger and stronger firms can support such efforts. This is generally true for both U.S. and foreign firms.

A general rule of thumb puts the development life cycle of any new technology at 10 to 20 years.

Our studies indicate, however, that this time frame can be compressed through overt attempts at research, development, and diffusion. This compression seems to be the primary thrust of foreign countries' efforts. However, to push the limits of technology, the costs no doubt would be out of reach for even the larger companies. For example, the cost for a typical installation of the most advanced component-manufacturing system in use in the United States today would be from $2 million to $10 million. At that level it competes with other capital expenditures, such as those for other plant and equipment, new products research, and safety and environmental equipments required under the Occupational Safety and Health Act and Environmental Protection Act. One of our largest machine tool companies, after expending an order of magnitude of $5 million on a demonstration project which would have been a quantum jump forward, had to discontinue the project for lack of funding.

We recognize that research and development is necessary to provide long term gains in manufacturing productivity. New methods must be found and much of the existing technology must be refined so that it will be cost effective in the environment of the small and medium batch plants. However, there is technology available, such as the basic NC machine, that could provide significant short run productivity gains in the smaller factory. As previously pointed out, even this technology is not in wide spread use. To emphasize these short term gains, without minimizing the problems of invention and innovation, we therefore turn our discussions to the problems of diffusion.

PROBLEMS OF DIFFUSION

The problems and nature of technology diffusion are not well understood. Professor Hough 9/ and others have studied the matter generally, and we will not cover the prior research in detail here. There is an important point to be made, however, and that is the difference between the approach to manufacturing technology diffusion in the United States and in the other industrialized nations.

In the United States, except where the national interest or other special considerations are involved, the diffusion process is left primarily to the market place with all of its advantages and imperfections. This is not to disparage the Government efforts of such organizations as the National Center for Productivity and Quality of Working Life; Small Business Administration; National Science Foundation; Department of Commerce, including the National Bureau of Standards; National Technical Information Service; and others. But Government efforts are fragmented and are frequently directed to specific products or processes. No overall industry effort or policy is available.

Hough 9/ asserts that the Department of Commerce is logically the agency to support technology diffusion. But he states Commerce's activities have been that of informing or specialized to specific advisory, regulatory and administrative services. He states that "technology may indeed diffuse into the U.S. general economy with little contact with Commerce activities."

Foreign governments have well developed national systems to diffuse their own and foreign technologies. Although there is no empirical data for demonstrating that foreign efforts at diffusion are more effective than those in the United States, there is an implied cause-effect relationship between the foreign organizational structures and their rapid rate of technological progress. Chapter 5 discusses these matters in detail.

DIFFUSION OF CIM

To determine more accurately the status of discrete part, metalworking manfacturing in the United States and to identify barriers to the diffusion of manufacturing technology, we surveyed a random sample of companies in the metalworking industry to ascertain the extent of use and attitudes toward automated manufacturing methods. The metalworking industry comprises over 35 percent of the total manufacturing establishments in the United States. We selected our sample from the 13 leading manufacturing States, which, in terms of the number of manufacturing establishments, encompass over 70 percent of the Nation's metalworking industry.

Initially, we contacted 245 establishments as our sample. We were able to obtain responses from 178, or 73 percent, of these locations.

Probably the most dominant finding in our survey is the confirmation of our own observations that the use of automated methods in this segment of the Nation's industrial base is extremely limited. The only aspect of this new technology to be found to any measurable degree is the numerically controlled (NC) machine tool, one of the preliminary developments of modern batch-manufacturing technology. Of the companies from which we obtained information, only 31, or 17 percent, had at least one NC machine tool in operation. This proportion is probably overstated. Many companies declined to participate because they believed that the survey did not apply to them since they did not have any involvement with automated manufacturing methods.

Perhaps even more indicative of the essentially "manual" nature of much of the existing manufacturing activities in the metalworking sector is our finding that about 51 percent of the establishments surveyed did not use a computer at all, and only 23 percent had a computer onsite.

Although the proportion of companies using NC equipment is not large, the experience of those that have used such equipment appears to have been favorable. We asked for user reaction as to the return on investment, mechanical reliability, and electronic reliability of NC equipment they had been using. Regarding the equipment's return on investment, about 87 percent of those having such equipment, and responding to the question, rated the equipment's performance as living up to or exceeding expectations. About 93 percent considered the mechanical reliability to have reached or exceeded expectations, while a somewhat smaller proportion, about 83 percent, believed that the equipment's electronic reliability met or exceeded expected levels. Twelve of the 31 companies having NC equipment indicated their intention to acquire additional NC equipment within the coming year.

When asked to cite the major barrier to growth in the use of advanced manufacturing methods, 62 percent of the respondents cited the high cost of the necessary equipment. The second most frequently cited barrier (18 percent) was a lack of widespread understanding of the capabilities of such technology.

In view of the frequency with which high cost of equipment was cited as the major barrier to growth in the use of advanced manufacturing methods, it was not surprising the majority of respondents indicated that the most useful Government role in advancing the use of such methods would be a direct economic role designed to reduce such cost. Given a wide choice of possible ways in which the Federal Government could stimulate growth in manufacturing technology, about 59 percent of those responding cited additional tax incentives to spur capital investment as the most desirable. The second most frequently cited choice was the establishment of a clearinghouse for the dissemination of information concerning the technologies involved. As with the first choice, this governmental action would seem to directly respond to the second most frequently cited barrier of a lack of understanding of the capabilities of these technologies.

The principal clearinghouse for dissemination of technical knowledge in the United States is the National Technical Information Service (NTIS) of the Department of Commerce. NTIS serves as a central source for the public sale of Government-sponsored research, development, and engineering reports and other analyses prepared by or for Federal agencies. We matched the 178 respondents to our survey against the subscription files of NTIS. Only 6 of the responding firms were subscribers to NTIS information, although all 178 firms were of a type which should be able to utilize or benefit from such information. Of the six subscribing firms, three were large, high-technology firms or subsidiaries of such firms.

Apart from firms' short-term plans to acquire automated manufacturing equipment, we solicited the views of manufacturers as to the outlook for more advanced automated methods in their own product area and the major barrier to growth of these methods. We asked the firms surveyed to indicate the likely growth rate in using these methods between now and 1980 and between 1980 and 1985. Given a choice of small, moderate, or substantial growth, only about 8 percent of those responding saw a major increase between now and 1980, with about 19 percent indicating a substantial increase between 1980 and 1985. This result can be combined with our finding that NC equipment is limited to about 17 percent of the firms and the general indication of lack of up-to-date technical knowledge. Together this may indicate that, barring a dramatic change in the factors having an impact on plant and equipment investment decision, as yet unperceived by many of the affected manufacturers, the conditions, methods, and processes of metalworking activities in the mid-1980s may not differ drastically from those found during this mid-1970s survey.

See appendix I, for a detailed discussion of the industry survey.

The importance of standards to stimulate the diffusion of CIM technology

A major problem to improving and advancing CIM was identified in discussions with manufacturers. This centers on the lack of compatability of equipment and computer software among the various users and manufacturers. Thus a manufacturer that wants to develop a CIM system, utilizing as components the best equipment for its purposes from various suppliers, would be frustrated by a lack of interoperability of the various hardwares and softwares.

We visited some of the larger, high-technology firms in the United States, such as McDonnell-Douglas, Pratt and Whitney and, IBM, and held discussions with other firms. These high-technology firms are creating their own CIM systems. These firms have developed the technological capability to create or design mechanisms--hardware and software--to mesh the various system components together into integrated systems. But their systems are proprietary, are generally not available to other firms, and would not necessarily meet the special needs of other firms.

Small- and medium-sized firms have neither the technical capability or the capital to put together their own CIM systems from the diverse products available in the market. And there is no definable automation industry to help them solve their problems. (See appendix III.)

We discussed the standards problem with National Bureau of Standards officials who have independently recognized this problem, and they assisted us in defining it.

The National Bureau of Standards plays an important role in stimulating the diffusion of CIM technology, particularly for medium and small firms. The integration of computer-aided design with computer-aided manufacturing, that is, total systems in which design of the part creates data bases which describe the shape of the part and the materials and tools that are required to manufacture the part, offer ever increasing problems in development and integration of many dissimilar components and computer programs. There is now no company offering complete systems of this sort on the market.

A new concept of standardization has emerged in several studies and technical meetings in recent years which could alleviate this situation. This concept is to use standards or guidelines to create a system structure, a framework, within which individual companies could pursue the development, marketing, and application of individual components, and all of these components will fit together into total integrated systems. This is not a normal concept of standardization, since standards usually means an agreement, a consensus on a de facto market product or practice, and a system framework or structure that people can fill in with new technical development. National Bureau of Standards officials said that, if pursued with the wrong motivations, standards could restrict trade. Standards are a major non-tariff barrier to trade and are currently under negotiation by the member countries of the General Agreement on Tariffs and Trade in Geneva.

However, if standards can be set by a truly representative group of supplier and user industries with participation from Government to guarantee the public interest, standards can be an incentive to further development.

The computer language known as APT (automatically programed tool) is a good example of standardization necessary to exploit a new technology. A standard computer language was absolutely necessary to successful utilization of NC machine tools. Each NC tool has its own special software. If separate and different computer languages had to be used to operate every machine tool made, the cost and manpower involved would have meant that NC tools would be limited to performing only tasks which conventional machines could not perform. The U.S. Air Force, which sponsored the development of NC tools also sponsored the development of APT. APT (and subsequent variations thereof) enables the computer-machine tool programer, wherever he may be or whatever NC tool he is using, to write the cutting instructions for a tool in a standard language which the computer then converts to the specific format required for a given machine tool. APT and its variations has become the international standard of machine tools.

This standardization has enabled a number of firms to produce new computer-aided design systems which can be used to produce files of cutting instructions which computers can convert to the specific requirements of any machine tool. At this point, then, from the point of view of the information flow in the computer control system, all of the machine tools are functionally equivalent.

This is a concept that, if extended into a total CIM system, could allow the possibility of creating a system from modular components purchased from competitive manufacturers, without any special engineering or software development, but without depreciating the proprietary characteristics of the components themselves. This would, in turn, make the productivity increases of CIM systems available to the medium and small firms who otherwise could not afford the cost of system integration, since they could build their system one component at a time with assurance of ultimate total system capability.

Computer Aided Manufacturing-International, a non-profit research organization, and Brigham Young University sponsored a meeting, at Brigham Young on February 1975, of many standards organizations working on different aspects of computer-aided manufacturing. This group concluded that interface standards or guidelines were desirable as a stimulus to the further development and diffusion of this technology. The group recognized that the desired interfaces were computer data bases. The main barrier to developing such interface guidelines seems to be a lack of consensus as to the detailed structure of a computer-aided design and manufacturing system. Followup action at the National Bureau of Standards is planned to consider the question of systems structure.

The use of standards to create a system framework to direct the efforts of many fragmented firms is a concept that could optimize the creative forces of the free market if the standards are set in the public interest. Therefore, a need for Government action in stimulating the diffusion of CIM technology is extensive participation in private sector standards committees to insure that the public interest is met and that standards emerge which will stimulate and not hinder the diffusion of this technology.

The development of APT and the resultant proliferation of NC tools throughout the industrialized world are indications of the benefits to improved productivity that can result from constructive standardization.

There is much more in this area that can be done.

Problems of cost

We have already alluded to the high cost of many of the existing components of CIM. And our industry survey shows high cost of equipment to be a major barrier to growth. The costs of pushing the state of the art of the technology to its most productive limits are even more formidable. Although some high technology, highly capitalized companies are developing or have developed high levels of sophistication in proprietary CIM, most U.S. firms lack either the capital or technical know-how for such developments.

A number of responsible and authorative organizations have researched approaches to further developments of CIM. Their proposed pilot projects have preliminary cost estimates ranging up to $100 million, and we will summarize several of these.

Automation Research Council

The Automation Research Council (ARC) is a standing committee of the American Automatic Control Council. The Control Council is an organization formed of representatives of the major engineering societies having an interest in the field of automatic control.

ARC, with the financial help of the National Science Foundation, developed a preliminary draft report "A National Research Plan for Automation." In a summary of its recommendations, ARC said that its plan is designed to:

> "* * * help American Industry to meet the challenge of its foreign competition, to help increase its productivity to the benefit of its consumers, its workers, and its stockholders, and to improve safety and working conditions in its plants, processes and service organizations."

In its study, ARC identified a group of 29 specific topics in automation technology which were vital to automation development and require major research and development effort to be properly used. Topics included were "Universal Manufacturing Data Base," "Overall Plant Control Systems," and "Highly Flexible, Automated, Assembly and Manufacturing Techniques." Twenty-four of the 29 topics were directed to batch-type discrete parts manufacturing. The 29 topics were grouped into 4 proposed demonstration projects.

One of these was a project for batch process manufacturing. Preliminary project cost estimates (early 1974) were about $95 million over a 7-year period. They projected that a project of this type would probably result in substantial productivity improvements. An estimated 20 thousand to 25 thousand companies would benefit from the project, including small shops and very large companies with medium lot sizes.

Investment in research of this magnitude, while applicable to manufacturing generally, could not be undertaken by any one company.

Massachusetts Institute of Technology

In 1973 the Massachusetts Institute of Technology (MIT), in conjunction with the Charles Stark Draper Laboratory, made a preliminary study leading to a proposal for "A National Program To Realize Computer Managed Parts Manufacturing Systems." The study group considered computer-managed parts manufacturing (CMPM) as a major subsystem of CIM.

In defining the proposal, the researchers said:

> "CMPM systems would have high machine utilization, short product throughput time, and high labor productivity. These systems would combine some of the major advantages of mass production transfer lines * * * with advantages of general purpose job shops * * * without having to accommodate the drawbacks of either system."

MIT goes on to point out that the few U.S. companies at work in CMPM are engaged in proprietary efforts on limited budgets, but there is no systematic national pattern within which the work is being carried out. MIT contrasts this work with the work being carried out by institutes in Norway, Germany, Japan, and the Soviet Union. The work is sponsored jointly by industry and government.

MIT estimated that the 2-year cost of the first phase of the program would be over $600,000 (1973 prices) and that the total project would take over 5 years to complete, with a cost of $8 million to $10 million (1974 prices).

National Science Foundation product system productivity research study

A study group under the sponsorship of the National Science Foundation has conducted a survey to study the structure of technology; assess the state of the art and trends, including problem areas; and suggest some research experiments.

This study group developed several potential research programs, each of which would require over 5 years to complete, with costs running into millions of dollars. These programs included:

--Research program in assembly.

--Research program in cellular manufacturing systems (covering all aspects of machining centers and movements of material between them. (See ch. 3.)

--Illustrative research experiment on a specific product or product combinations.

The cost of these programs, which would be for general application to industry, would be beyond the reach of indiividual firms. The study group contemplated cost sharing by industry, the Government, and supporting institutions.

CHAPTER 5

U.S. POSITION RELATIVE TO FOREIGN NATIONS

As shown in chapter 2, our overall output per employed person is higher than any other nation. Although this is also true of manufacturing, we have already indicated in table 1 that the U.S. average increase in productivity has been the lowest in the Western world and Japan.

If these higher rates of growth in manufacturing productivity in the foreign countries are sustained and, as shown in chapter 2, there is no way of determining that they will not, then the absolute advantage of the United States would disappear.

But, why should we be concerned about such a possibility? If Americans are employed and enjoying a standard of living satisfactory to Americans, what does it matter, except for a matter of national pride, that other countries may surpass the United States in manufacturing productivity?

We believe the answer lies in the consequences of not maintaining this advantage with today's growing economic interdependence of nations. The ability to maintain the satisfactory standard of living we have achieved depends greatly on our ability to compete with foreign manufacturers in the world markets, as well as in the U.S. domestic market. Relative productivity and the costs of the output of manufacturing determine this competitive position. In spite of the fact that in terms of best practice, the industrial nations are now relatively equal, there is no apparent reason why American manufacturing technology should fall behind if we properly recognize and adjust to the changing world conditions confronting us.

Another and related consequence involves the potential in foreign countries for directed efforts to improve productivity in selected manufactures. For example, the Japanese system provides for selective product development and productivity improvements in specific sectors.

A Department of Commerce study 10/ states that:

"When all * * * factors have been weighed, however, there is still a missing element in explaining Japan's performance, and it is the element with which this study is primarily concerned and which is of primary concern to the American business community. It is the special and unique way in which the Japanese government has guided the economy's development and the interaction of government and enterprise which is the peculiar hall-mark of the Japanese economy. Japan's economic destiny has not been left to the free play of market forces. The government has undertaken from the beginning of Japan's modernization and industrialization to identify objectives and priorities for the Japanese economy. The government has also sought to facilitate the achievement of these goals. It has, in any case, tried to assure that the private sector does not lack the wherewithal for this purpose.

"Yet, put all this together and one does not come out with a totally planned economy of the Russian type--far from it. The essential characteristic of the Japanese government-business relationship is that the business community and the various government departments have been in close communication with each other from the days of the Meiji Restoration. The result is a style of industrial development which has allowed Japanese business considerable initiative and independence even when subject to administrative guidance facilitated by a variety of government aids and incentives. The acceptance, to a greater or less degree, by Japanese businessmen of the government's goals and priorities is based on two all important factors:

--a reluctance on the part of both business and government to unilaterally adopt policies or undertake major moves in the high priority sectors of the economy without consulting each other;

--a propensity, which all Japanese share, for a consensual approach to harmonizing differences that may exist within as well as between each group.

"These cultural traits are the essence in explaining how 'Japan, Incorporated' works. For, as one authority points out, only a limited legal basis exists for the government's involvement with the private sector. The 'administrative guidance' which takes place is no less compelling than law. There are a number of such intangibles, both subtle and complex, in the interaction of government and business in Japan. Together with the extensive apparatus which has been constructed to facilitate this interaction they have produced a government-business relationship unique to Japan."

The direction of Japanese research and development efforts in recent years to the machine tool and machinery industries and to development and use of industrial robots are good examples of selective development, which are not matched by comparable efforts in the public or private sectors in the United States.

Although the Japanese Government-industry-labor relationship is unique to Japan, similarly exceptional arrangements exist in other countries. In Germany, for instance, there is an unformalized but nevertheless structured institutional relationship which enables the German Government to pour millions of dollars into computer aided design and computer aided manufacturing research with considerable emphasis on computers, machine tools, and other manufacturing machinery.

INDICATORS OF RELATIVE CHANGE IN MANUFACTURING BASE

We are now entering an era in which a strong national economy and competitiveness in world markets will be key ingredients to the future U.S. socioeconomic system. Not that those ingredients have not been important in the past; indeed, they have contributed greatly to our way of life. But there is general agreement that for the next 10 to 20 years the United States will face the need to import more raw materials at higher unit costs. Oil is one example, but there are others. To pay for these increasing, higher cost imports, the United States will have to export more of its products at a time when the other industrial countries are facing exactly the same problems. In other words, the industrialized countries will be competing both for the available raw materials and the international markets in which to sell their manufactured products. Our foreign competitors' economies are much more attuned to foreign market competition than the United States since they have traditionally relied on exports to a greater extent than the United States and since they have created effective national mechanisms for productivity improvement to either recover from World War II and/or to bridge the gap between their own and U.S. levels of productivity and standards of living.

This means that both mature and emerging industrial nations must rely on their manufacturing base for their economic leverage in the international marketplace and to gain the quality of life they are seeking. However, as shown in chapter 1, there are indicators that our manufacturing base has some problems. These indicators are discussed in more detail below.

PRODUCTIVITY

The most obvious indicator of the problems in our manufacturing base is our national productivity. Throughout the industrial world this is an accepted means of measuring how efficiently resources are converted into useful output products. It is usually defined in the manufacturing environment as the relationship between output (products manufactured) and input (resources consumed in the manufacturing process). For comparative purposes output per man-hour of input is commonly used. There are other important inputs, such as capital, materials, energy, and technology, which could be used as a basis for measurement. However, for international comparison, historical figures are more available for man-hours than any of the other inputs; consequently, when we speak of productivity in this study, it will be output per man-hour of input.

As we have indicated in table 1, manufacturing productivity has increased at a dramatically higher rate in other industrial nations.

During the period 1960-73, U.S. productivity increased at an average annual rate of 3.3 percent. This increase is considerably less than the 5.7 and 5.8 percent average annual increases registered by the European Economic Community and West Germany during that same period, and less than one-third of the 10.7 percent average annual increase that Japan achieved.

In terms of total manufacturing output, the U.S. average annual growth rate is closer to that achieved by the other nations as shown in table 6. It can be seen, however, that the United States achieved its increase in output with a 1.5 percent average annual growth in man-hours, whereas the European Economic Community and West Germany experienced average annual decreases in man-hours and Japan's substantial increase in output was achieved with a man-hour increase only slightly greater than that of the United States.

TABLE 6

Average Annual Percent Change in Output, Man-Hours, and Output per Man-Hour in Manufacturing, 1960 to 1973 (note a)

	Average 1960-73
Output:	
U.S.	4.9
European Economic Community	5.4
West Germany	5.6
Japan	12.6
Man-hours:	
U.S.	1.5
European Economic Community	-.3
West Germany	-.2
Japan	1.8
Output per man-hours:	
U.S.	3.3
European Economic Community	5.7
West Germany	5.8
Japan	10.7

Source: U.S. Department of Labor.

a/ Any differences between these numbers and those in table 1 are due to rounding and data source.

With few exceptions our industrial competitors have maintained stability in the growth of the labor force by controlling or restricting the flow of imported labor. However, this has led to actual labor shortages and therefore an increasing emphasis on improving the productivity of the existing labor force.

Some of these nations, however, do not have the magnitude of unemployment or labor displacement problems the United States faces. The United States has an immigration policy which is not tied into labor needs. Increased immigration, legal and illegal, coupled with our increasing population growth has resulted in a larger total labor force. Although the result has been expanded gross output, our rate of growth may actually have been inhibited.* Therefore, the U.S. productivity problem may be more difficult than those of our principal competitors. We must increase our capital expenditures for expansion and technology to improve our international competition while providing jobs for a labor market expanding more rapidly than that of our competitors.

International trade

The prime market for U.S.-manufactured products has always been our own domestic market and as a result, relatively little attention has been given to export markets. Even in 1974 we exported only about 7 percent of our GNP, and this export activity was concentrated in a small percentage of our firms. Our domestic market has been of sufficient size to foster economies of scale in manufacturing. In contrast, other industrial nations such as Japan and Germany have depended more on the world markets than the United States. (Nevertheless, mass consumption domestic markets are the cornerstone of the Japanese and German economies.)

It would appear that with our rich national resources and the size of our domestic market we have not, in the past 30 or so years, been seriously concerned about balancing our imports with exports. The imports we required were readily available and inexpensive and were easily balanced with the overflow of manufactured goods that made up our exports. From about 1893 to 1971, we enjoyed a positive trade balance; i.e., exports exceeded imports. However, competition among advanced nations in the sale of their internationally traded products, especially high-technology products, has increased in recent years. It appears that this will become even more intense in the years ahead.

In 1971 our trade balance turned unfavorable. An analysis of our trade experience shows that for more than 10 years, agricultural products and a segment of our high-technology exports (i.e., aircraft, computers, communication

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*Analysis of labor force composition changes and their impact on productivity is much more complicated than we have presented. However, differences in immigration policies is one of the principal factors to be considered when analyzing the labor impact. Japan for instance imports very little foreign labor as do Sweden and Norway. Germany does import labor but under very controlled conditions.

equipment, and nonelectrical machinery) have been the principal highly competitive export components on the international scene. Low-technology exports such as textiles, paper products, furniture, glass, etc., have long been confronted with keen competition from other industrial nations and have been running a trade deficit. During this period our total share of the world-manufactured goods market has been decreasing.

There are some areas of high technology that are showing signs of difficulty. For example, U.S. exports from 1968 to 1973 for machinery and transport equipment declined, as a percentage of world trade, by over 21 percent, even though actual exports did increase during this period. Table 7 gives details.

TABLE 7

United States' Share of World Exports
Machinery and Transport Equipment
1968 to 1973

	1968	1969	1970	1971	1972	1973	Change 1968-73
World trade: (billions)	$47.9	$56.4	$66.0	$75.3	$89.5	$118.6	+147.6%
U.S. exports	$14.5	$16.5	$18.0	$19.6	$21.7	$ 28.1	+ 93.2
Percent of total world market	30.3	29.2	27.3	26	24.3	23.7	-21.8

Source: U.S. Department of Commerce.

This situation may be partially the result of vast U.S. investment of capital and transfer of its technology to foreign countries. Although it is difficult to assess technology transfer as a factor, the common method of measuring it is receipts for royalties and licensing fees, and when used with caution this can indicate the direction we are going.

During the 1960s royalties and licensing fees received by the United States for technology rose in terms of current dollars from $650 million to $1,879 million, while payments for technology remained relatively low, $66 million to $192 million.

Japan has been able to retain a large degree of control over technology imports by monitoring those imports and by bringing Japanese companies together to jointly exploit the available benefits. This resulted in limiting foreign investments to minority ownership. (This policy has changed under the recent liberalization agreements.) Through planning and industrial policy, Japan has encouraged technology in desired growth industries. Most of this technology has been concentrated in the fields of electrical and nonelectrical machinery, metalworking equipment, and chemicals.

The amount of fees Japan paid the United States annually rose from $54 million to $209 million during the 1960s. This has been estimated to be 50 to 60 percent of their total importation of technology. Japan has been able to use this acquired base of industrial know-how as a springboard for its own research and development.

Facilities obsolescence

Over 17 percent of U.S. business facilities and equipment are reported to be 20 years old or older. Moreover, in 1974 U.S. manufacturers reported that from a technological point of view, over 14 percent of their plant and equipment was outmoded, compared to 12 percent 2 years previous. This is illustrated in table 8.

In another study, Nake Kamrany 11/ states:

> "Capital goods used by U.S. manufacturing suffers from old age and obsolescence. One estimate indicates that 80 percent of the machine tools in the U.S. are at least 30 years old; another states that 64 percent are 10 years old or older. F. J. Trecker calculates that 2,200,000 standard machines have been installed over 40 or more years.* It is estimated that the replacement cost of the existing old and obsolete equipment will amount to around $100 billion. The above conditions have culminated in production processes that are underutilized and inefficient, which require long production-cycle times and long working of production time."

*Francis J. Trecker, "Industry Advisory Council Subcommittee on Industrial Mobilization," (New York), January 11, 1971. Also, see U.S. Department of Commerce, U.S. Industrial Outlook, 1972.

TABLE 8

Condition of Manufacturing Plant and Equipment

	Percent outmoded Dec. 1972	Percent outmoded Dec. 1974	Percent increase or decrease(-)
All manufacturing	12	14	17
Durable goods:	12	16	33
Misc. transportation equipment	44	57	30
Iron and steel	15	20	33
Nonferrous metals	8	18	125
Machinery	15	18	20
Autos, trucks and parts	6	17	183
Aerospace	9	17	89
Instruments	5	15	200
Stone, clay, and glass	17	13	-24
Fabricated metals	14	10	-29
Electrical machinery	12	9	-25
Non-durable goods:	12	13	8
Rubber	13	21	62
Food and beverages	14	17	21
Paper and pulp	18	14	-22
Textiles	20	13	-35
Chemicals	14	10	-29
Petroleum	8	9	13

Source: McGraw Hill Publications Company

Our findings are consistent with these reports of aging machine tools in the United States. The establishments we surveyed reported that an average of 21 percent of their machine tools were over 20 year old and 52 percent were over 10 years old. Indications are that the outlook for improvement of this picture is not bright as sources of money for equipment replacement become more scarce. (See app. I.)

Capital expenditures

One indicator of the dynamics of growth of a manufacturing base is the capital expenditures being put into industry to foster expansion and modernization. One method of analyzing the changes in capital expenditures is the amount spent a year for each worker. We found that from 1967 to 1973, in constant 1967 dollars, the amount spent per worker declined by almost 15 percent or from $258 to $220 in the United States. During the same time, West Germany increased from $298 to $693 or about 133 percent and Japan went from $191 to $324 or an increase of about 70 percent.

A recent study by the Treasury Department showing capital investment as a percent of real national output* also confirms that the United States is behind most other industrialized countries. This is illustrated in table 9.

TABLE 9

Average Annual Investment as Percent of

Real National Output 1960-73 (except as noted)

(1973 estimated)

Country	Percent
Japan	29.0
West Germany	20.0
11 OECD Countries (1960-1972)	19.4
France	18.2
Canada (1961-1973)	17.4
United kingdom (1961-1973)	15.2
Italy	14.4
United States	13.6

The Treasury study concluded that the falling share of U.S. resources allocated to investment has limited job opportunities.

Increased capital expenditures to update our facilities and apply advanced technology to improve productivity would assist in providing the needed edge in international competition. This would create the potential for industrial expansion and the subsequent creation of new jobs, not only in manufacturing but also in all phases of a growing economy, including the service sector.

There are many reasons for the inability or unwillingness of U.S. industry to increase its investments. Although prices have increased in recent years, so have the costs of manufacturing. Manpower, material and energy costs,

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*This is defined as nonresidential investments, including nondefense Government outlays on machinery and equipment in private investments. This concept was used to conform with Organization for Economic Cooperation and Development (OECD) figures.

including oil import costs, were up in 1974 over 1973. Depreciation rates and other tax policies also have an influence over the willingness of industry to invest the funds necessary to maintain a healthy rate of capital expenditures during such a period of strain.

Although factors other than capital investment contribute to productivity improvement and growth, capital is basic to modernization and expansion of a growing economy.

Science and technology

As Denison and others have pointed out, advances in knowledge are prime factors in productivity improvements. Research is a key element in advancing knowledge. Denison 4/ analyzed the question of whether the European countries have been doing more than the United States to obtain growth by promoting advances of knowledge.

He found that the United States spends more on total research than Japan or all of the European countries combined. The expenditures are also larger in relation to population, employment, and GNP.

He said he was unable, however, to quantify with sufficient precision the relative contributions of research to productivity.

Research in different countries is directed to different objectives, and we were unable to find conclusive comparisons between the amounts of research and its results on productivity in manufacturing in different countries.

We observed that foreign governments direct more intensive and well-organized efforts to research for industry generally than does the United States and have been doing so for a longer period of time.

There is also some instructive material from other researchers which is useful in forming judgments.

The following tables from Hough's study 9/ which we updated show U.S. expenditures for applied research are heavily oriented toward specific objectives.

Table 10 shows the objective direction of applied research to agriculture, health, defense, space, and energy.

Tables 11 and 12 show that although substantial amounts of applied research go to engineering, the bulk of such funds go to defense, space, agriculture, and energy.

TABLE 10

Federal Obligations in Applied Research

(in millions of dollars)

FY	Department of Agriculture	Department of Health, Education, and Welfare	Department of Defense	National Aeronautics and Space Administration	Atomic Energy Commission (note a)	Others	Total
1956	68	57	404	29	42	46	646
1957	76	104	361	31	44	46	662
1958	81	133	378	41	59	52	744
1959	87	165	386	95	83	71	886
1960	87	214	693	166	95	75	1331
1961	97	291	1000	263	53	92	1796
1962	101	384	1107	398	55	121	2166
1963	104	416	1374	558	62	137	2652
1964	114	497	1431	653	71	132	2898
1965	128	559	1488	762	76	151	3164
1966	134	640	1587	799	90	182	3431
1967	137	710	1307	775	90	251	3269
1968	140	750	1313	701	120	280	3304
1969	145	803	1135	618	132	318	3151
1970	156	741	1310	773	146	430	3555
1971	174	905	1351	817	152	543	3941
1972	200	1003	1493	712	149	589	4146
1973	211	1001	1497	610	150	611	4080
1974	219	1290	1516	776	232	675	4708
1975 (est.)	245	1368	1522	867	321	818	5141
1976 (est.)	268	1245	1727	1004	421	886	5551

a/ Beginning in 1974 these figures are for the Energy Reserach and Development Administration.

Source: National Science Foundation, Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1974, 1975, and 1976.

TABLE 11

Selected Federal Agency Obligations for Applied Research, FY-1974 ($1000)

	Total	Life Sciences	Psychology	Physical	Environmental	Math	Engineering	Social	Other
All agencies total	4,707,700	1,545,915	93,288	385,499	428,413	78,080	1,813,920	218,340	144,245
USDA:									
Ag. Rsch. svcs.	107,878	65,903	-	22,747	802	164	17,196	1,066	-
Coop. rsch svc.	55,441	38,096	-	2,772	347	-	1,900	12,326	-
Forest Svc.	41,582	23,283	-	2,561	3,893	1,045	6,352	4,448	-
Misc. health svcs.	158,331	96,220	35,407	8,540	-	1,165	3,065	11,282	2,368
NIH	1,008,199	903,956	5,195	10,528	-	15,796	11,383	8,593	52,748
DOD	1,516,273	108,144	33,672	152,067	69,604	53,241	1,047,095	6,666	45,784
NBS	26,508	-	-	15,268	-	1,113	10,127	-	-
Patent ofc.	247	-	-	-	-	-	247	-	-
NASA	775,637	9,896	5,924	11,105	258,035	1,501	487,269	540	1,367
ERDA	232,254	75,731	-	118,550	14,320	-	23,653	-	-

Source: National Science Foundation, Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1974, 1975, and 1976.

Table 12

SELECTED FEDERAL AGENCY OBLIGATIONS FOR APPLIED RESEARCH IN ENGINEERING IN FY/74 ($1000)

	Aeronaut	Astronaut	Chemical	Civil	Electric	Mechanic	Metallurgy and Materials	Other
Federal total ($1,813,920)	578,504	180,177	65,472	106,100	206,012	90,638	166,850	420,167
USDA:								
Ag. rsch. svc.	-	-	2,452	2,085	43	590	-	12,026
Coop. rsch. svc.	-	-	-	-	-	-	-	1,900
Forest Svc.	-	-	274	1,611	186	1,011	-	3,270
Misc. Health svcs.	-	-	1,441	-	122	490	-	1,012
NIH	-	-	-	-	-	-	-	11,383
DOD	333,758	77,219	36,527	34,990	167,019	66,980	68,475	262,127
NBS	-	-	-	1,749	1,634	377	901	5,466
NASA	240,765	102,495	220	742	19,452	4,078	63,725	55,792
ERDA	-	-	7,537	-	920	1,363	13,333	500

Source: National Science Foundation, Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1974, 1975, and 1976.

Terutoma Ozawa 12/ analyzed comparative research and development between Japan and its competitors. He refers to a report by the Organization for Economic Cooperation and Development (OECD). 13/ Table 13, taken from his study, shows comparative research and development efforts for 1963 to 1964.

This table shows that the United States led all countries in percentage of GNP devoted to research and development. The table also shows the percentage of research and development in the business sector and the percentage supplied by company funds. Note the large percentages supplied by company funds and the large numbers of personnel engaged in research and development. This, considered in the light of the earlier tables showing the emphasis of Government-supported applied research and development in the United States, indicates (although certainly not conclusively) that the bulk of the effort, manpower and money, in Germany and Japan are directed to developments in and for private industry generally, whereas the bulk of the U.S. effort is directed toward specific national objectives other than manufacturing generally.

Ozawa 12/ makes the point that 64.3 percent of Japan's research and development funds came from the private sector--a ratio second only to that of Belgium, which was in marked contrast to the United States where research and development efforts were heavily devoted to defense, space, and nuclear fields. He concluded that compared to the United States, Japan had a comparative advantage in orienting research and development efforts more strongly to industrial and consumer markets, thereby improving its commercial competitiveness both at home and abroad.

While acknowledging that U.S. military and aerospace research and development did spin off some available technical knowledge for commercial applications, Ozawa observed that this emphasis might have strained the civilian sector by increasing the demand for scarce research and development resources. He cited an Eli Ginzberg observation:

> "It would only be a slight exaggeration to say that the civilian sector is being 'starved' for research funds, and even more importantly, for research personnel, who are overwhelmingly attracted to the more exciting work on the frontiers of defense and space." 14/

TABLE 13

Indicators of R&D Efforts in Industrialized OECD Member Countries in 1963-1964

Country		GERD a/ (millions) of $ U.S.)	GERD per capita ($ U.S.)	GERD/GNP at market prices (%)	QSAE b/ engaged in R&D (full-time equivalents) Number	Per 10,000 of population	R&D performed in the business sector (%)	Company funds (%)
Japan	1964	1,060	10.9	1.4	197,225	20.3	64.6	64.3
United States	1963-1964	21,075	110.5	3.4	696,500	35.8	66.4	32.0
France	1964	1,650	34.1	1.9	95,574	19.7	49.5	33.1
Germany	1964	1,436	24.6	1.4	105,010	18.0	65.9	56.5
Italy	1963	291	5.7	0.6	30,280	6.0	62.6	61.5
United Kingdom	1964-1965	2,160	39.8	2.3	159,538	29.4	67.3	40.3
Austria	1963	23	3.2	0.3	3,220	4.5	63.5	53.8
Belgium	1963	137	14.7	1.0	15,600	16.8	69.0	64.4
Canada	1963	425	22.5	1.1	23,850	12.6	41.3	33.5
Netherlands	1964	330	27.2	1.9	31,310	25.8	65.5	51.4
Norway	1963	42	11.5	0.7	3,820	10.4	51.7	37.0
Sweden	1964	257	33.5	1.5	16,530	21.6	65.6	47.7

Source: OECD, Gaps in Technology: Analytical Report (Paris: 1970).

a/Gross National Expenditures on Research and Development

b/Qualified Scientists and Engineers

Our discussions with university and business engineers confirm that funds and students and graduates have been attracted away from the types of engineering education and occupations useful in general manufacturing.

Since it is well established that Japanese industry was built by acquiring foreign industrial technology, primarily American, it is reasonable to ask why the Japanese have spent so much and are constantly increasing expenditures on industrial research and development. Ozawa 12/ makes several observations on this issue. He points out that, in most instances, Western firms simply accorded the rights to use their techniques and equipment while supplying only minimum know-how. Moreover, Japanese often purchase newly developed techniques even in their rudimentary stages. In these circumstances, it was necessary for the Japanese to work out the details in adapting these techniques to profitable uses. He cites a Japanese Science and Technology Agency "1969 White Paper on Science and Technology" to the effect that approximately 62 percent of imported technology during the period 1950 to 1968 was still in rudimentary stages of development and required further adoptive research and development. Ozawa believes that Japan has caught up with the West in many areas of industrial technology. He states that early in the 1960s the Japanese realized that they could no longer depend on Western sources for further technological development and began to invest heavily in their own unique research and development facilities and activities. They are now reaching the stage of being a technological leader rather than a borrower.

Robert Gilpin addressed the general question of technology, economic growth, and international competitiveness in a study prepared for the Subcommittee on Economic Growth, Joint Economic Committee. 15/ The thrust of Gilpin's study is that technological innovation in the civilian industrial sector of our economy is at a critical point and that America's once unchallenged scientific and technological superiority has deteriorated.

He cites various scholarly studies and authorities to demonstrate (1) that the foremost input to economic growth is the advancement and utilization of knowledge and (2) that technological innovation and industrial know-how have become recognized as the major determinant of international competitiveness. He states:

> "In particular, a high wage economy such as that of the United States in a world where new knowledge and technological innovations rapidly diffuse to lower-wage economics, must be able

to innovate and adopt new technologies with equal rapidity. American firms must in fact run faster and faster merely to stand still."

Gilpin demonstrates through a series of tables and charts, as did Ozawa, that although the United States invests heavily in research and development relative to its principal foreign competitors, the United States trails Japan, West Germany, and certain other countries with respect to civilian industrial research and development. He uses, among others, the following graph (chart 4) prepared by OECD to show comparative government expenditures by objective for 1963 and 1971. The chart shows the emphasis on the civilian sector by our foreign competitors.

Gilpin reaches a number of conclusions and proposes a national strategy for science and technology. Gilpin emphasizes certain emerging weaknesses which can adversely affect America's technological position and international competitiveness, and he stresses the importance of technological innovation if we are to grow economically, compete internationally, and meet our social needs.

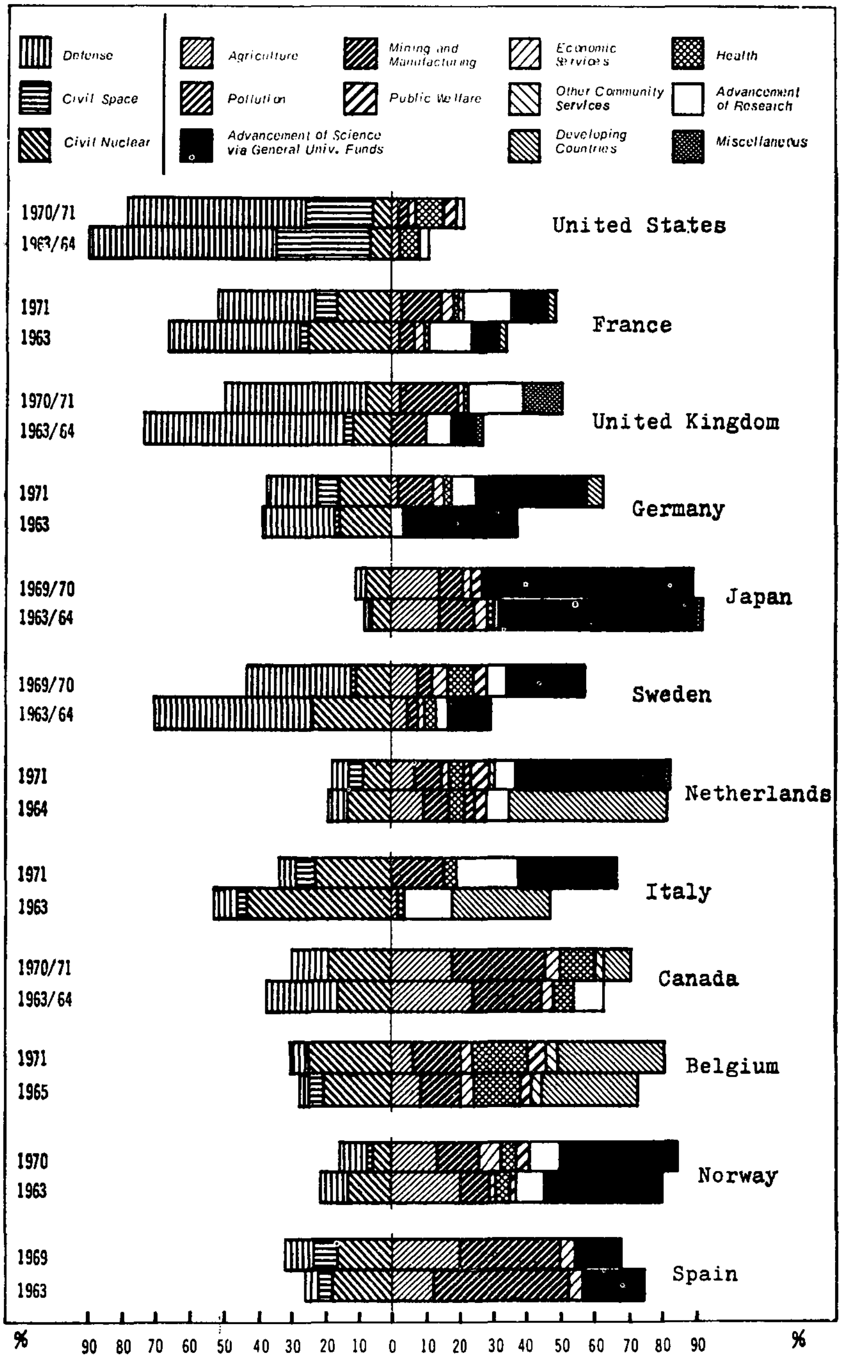
GAO OBSERVATIONS

As indicated earlier in this report, GAO staff visited manufacturing firms and discussed computer-integrated manufacturing with members of Government, the academic community, and associations and institutes both in the United States and abroad. Our observations here relate to our evaluations of the relative competitive position of the United States.

We made no attempt to make direct comparisons or identify subtle differences in technology between the United States and its foreign competitors. We also were unable to determine the extent of the diffusion of computer-integrated manufacturing throughout the various industrial bases. Our observations were, therefore, directed to the best practice and to the mechanisms for diffusion in the various countries. We discuss the diffusion mechanisms in chapter 6.

We are aware of no statistics from which to make comparisons of computer-aided factory management systems and design systems of various countries. In terms of the soft factory management applications, such as computer-aided production planning and controls over work in process, it is our judgment that the U.S. continues to lead. We saw or learned of big and small U.S. firms with well-developed systems and big and small U.S. firms with relatively primitive systems. And the same was true in foreign countries. However, the larger or more sophisticated U.S. firms appeared to have more

Total Government R. & D. Expenditure by Objective 1963 and 1971.



Source: OECD, "Patterns of Resources Devoted to Research and Experimental Development in the OECD Area, 1963–1971" (Mimeo), May 17, 1974, p. 32.

advanced (and usually proprietary) systems than their foreign counterparts. A distinction, however, was the apparent dedication of foreign firms and institutions to the development and diffusion of low-cost systems to medium- and small-sized firms. As indicated by our industry analysis (see app. I) diffusion seems to be one of the weaker areas in U.S. technology application.

In the area of computer-aided design, it is our impression that the United States is substantially ahead of the other countries. On the other hand, the technological know-how appeared about equal. Here again, however, we saw substantial foreign government-supported developments designed to aid the medium and small firms.

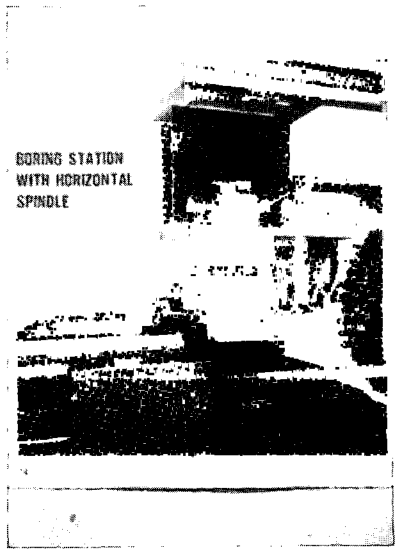
It is easier to physically observe the hard areas or the machinery and machine tools and systems in use. These systems--the tools that make tools and other products--are at the core of manufacturing technology. In addition, there are statistics available from which to make some judgments.

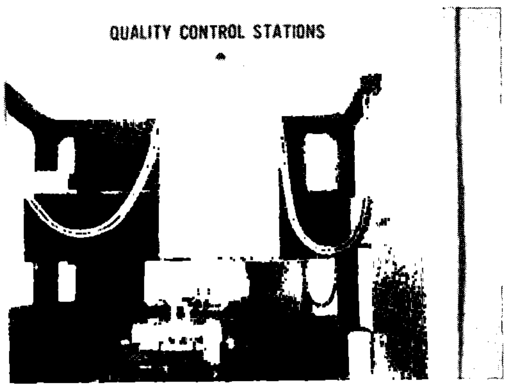
In general, the United States has in place more of the advanced machining systems than other countries. However, from our discussions with experts who have visited Japan, there are more of the integrated machining centers, operating at a high degree of effectiveness and sophistication, in Japan than in the United States. We are unable to directly confirm this since we have not visited Japan. The U.S. aerospace industry has more of the most sophisticated direct numerical control systems--that is various machining centers operated under a hierarchal computer control--than any other industry we have seen or been advised of.

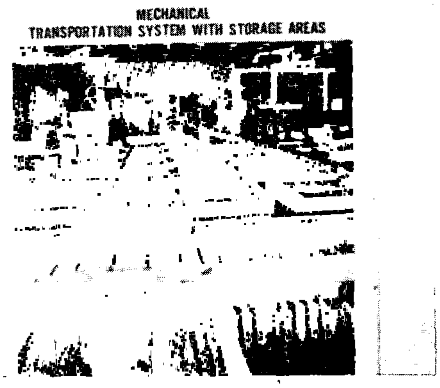
A number of American firms are operating systems of machining centers interconnected by materials-handling equipment, all under computer control. However, the most advanced factory of this type we have seen was a medium-sized firm (6 to 8 thousand employees) in West Germany. This firm has been so effective as to eliminate its only effective international competition--an American firm--for the types of products it produces.

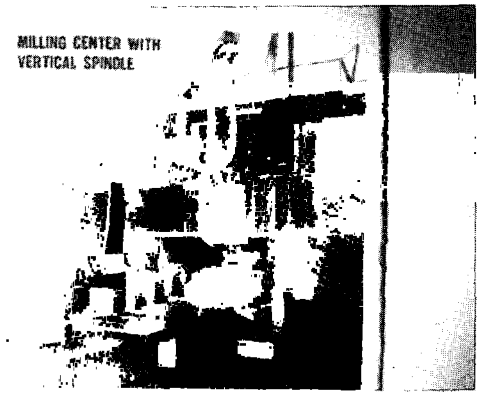
Another advanced installation is in a factory constructed in in East Germany for the manufacture of machine parts. Figure 9 is a picture of the principle operating elements of this factory.

Figure 9









EAST GERMAN MANUFACTURING FACILITY

The information in table 14 concerning machine tools is indicative of the comparative situation.

TABLE 14

Machine Tool Production

	Numerically controlled		Percent numerically controlled		Total machine tool production		
	1973	1974	1973	1974	1973	1974	Change
U.S.A.	2,865	4,054	0.93	1.21	306,570	334,108	8.9%
Japan	2,765	3,046	1.16	1.58	239,343	192,806	-19.4
W. Germany	992	1,367	0.46	0.66	214,331	206,745	-3.5
U.S.S.R.	3,788	4,405	1.45	1.61	260,500	272,900	4.8

Note: Data is from these sources:
U.S.A.--National Machine Tool Builders Association (NMTBA).
Japan--NMTBA and Japan Machine Tool Trade Association.
Germany--German American Chamber of Commerce and the German. Association of Machine Tool Industries.
U.S.S.R.--Official U.S.S.R. statistics.

Between 1973 and 1974 numerically controlled machine tool production increased for all countries while total machine tool production in Germany and Japan decreased. The ratio of of U.S. NC production against total machine tool production increased 30.1 percent whereas the ratio in Japan, Germany, and U.S.S.R. increased 36.2 percent, 43.5 percent, and 11.0 percent, respectively. This would indicate that from any vantage point these major industrial nations are starting to emphasize numerically controlled machine tool production.

Unfortunately, reliable data is not available to indicate either the type of the NC production (i.e., stand alone NC, CNC, DNC, or CIM) or the amount for domestic versus foreign consumption. In the case of Japan we have unconfirmed information from reliable sources that about 12 percent of these machine tools are CNC, versus 1 to 2 percent in the United States.

We have not attempted to obtain a qualitative comparison of the machine tool production of the various countries. Such information as we have indicates that quality in the Western industrialized world, Japan, and East Germany is high, whereas the quality and sophistication of U.S.S.R. production is suspect.

The technology now in place is one consideration, but the outlook for the future is another. The foreign government's approach is to focus on the development of their computer industries and machine tool industries. The American technological lead in computers is strong, and the American computer industry is strong and should remain highly competitive. Whether foreign government efforts to take computer preeminence from American firms will be successful is speculative. However, both the Japanese and German Governments are pouring substantial sums into domestic computer development. The Boston Consulting Group 10/ in a study prepared for the Department of Commerce reported Japanese Government funding of $33 million to develop a particular phase of Japanese computer technology. A German program, called the Second Data Processing Program, is a 5-year effort funded at about $760 million to improve all aspects of data processing.

In the machine tool area, the challenge seems more formidable. The American machine tool industry is highly fragmented, and the largest firm is not considered large by American standards. Therefore, the potential for any large-scale research and development is limited. It has not been practicable for us to develop the specifics of the foreign government support of its machinery industries. But our observations and discussions and research indicate that governmental efforts are substantial. The performance of the Japanese tool industry since 1970 in developing NC capacity is dramatic evidence of the success of the coordinated efforts of government, industry, and labor in Japan.

In his doctoral dissertation analyzing the American Machine Tool Industry completed in February of 1976, Clifford Fawcett 22/ states

> "In summary, the statistical evidence shows that the United States has lost its leadership as the No. 1 producer of machine tools to foreign nations. Further, the increasing level of high technology imports, essentially representing U.S. technology returning home to roost with foreign labels, provides further proof that these nations are not only surpassing the U.S. in world markets but are endeavoring to capture the U.S. domestic machine tool market as well."

Fawcett concluded that:

> "The survival and growth of the machine tool industry and other manufacturing industries in the U.S. * * * are vitally dependent on national leadership, governmental seed money, and joint action of government, industry,

and universities to develop and implement far-reaching national programs to promote advanced technologies and increase industrial productivity."

CHAPTER 6

COMPARISON OF NATIONAL INSTITUTIONS FOR IMPROVED PRODUCTIVITY

Virtually all the industrial nations of Europe and Japan have established formal productivity centers to develop, promote, and enhance productivity in their respective countries. These centers generally focus on management technology and productivity improvement in the service sectors of their economies. Concerning management technology, we believe that the centers are institutions which accomplish goals similar to those of U.S. graduate schools of business, organizations such as the American Management Association, and management consulting firms. Business education at the university level has generally not reached the high levels in foreign countries that it has in the United States. While there is a certain informing role played by these centers, they do not play a major role in the process of manufacturing technology invention, innovation, or diffusion.

Manufacturing technology productivity efforts for private industry are carried out by loosely knit yet cohesive consortiums of governmental, academic, private industry, trade associations, societies, and labor unions. These consortiums in many ways resemble the institutional arrangements for agricultural development, energy development, and space exploration in the United States, but direct comparisons are not appropriate.

The United States has no comparable institutional arrangements and no formal national productivity or technology development goals. The National Center for Productivity and Quality of Working Life, which was given statutory authority in November 1975, replaced the National Commission on Productivity and Work Quality, which was in existence since 1971. Both of these organizaions were created in an attempt on the part of the United States to provide a national productivity focus.* The Center has not as yet involved itself in manufacturing technology.

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*The National Commission issued a comprehensive statement on U.S. national productivity policy in October 1975.

PRODUCTIVITY CENTERS

European centers

European productivity centers were a direct outgrowth of U.S. aid to Europe following World War II. The most important step in the European productivity program was carrying out the congressional mandate set forth in 1952 in section 115(k) of the Economic Cooperation Act of 1948. 16/ Under this mandate 11 countries established objectives and agreed on broad national productivity programs funded by the U.S. Government, the participating national governments, private industry, and local government sources. The countries established national productivity centers to meet these objectives.

The administrators of the U.S. role 16/ identified some activities of the newly established centers.

--A general information program.

--A technical information program.

--Advisory and informational programs for particular manufacturing branches, agriculture, marketing and distribution, and building industry.

--Managerial exchanges.

--Finance research and studies into particular productivity problems.

--Extensive expansion of training facilities for European management and labor.

--Establishing regional productivity centers which supplement the activities of the national centers.

--Developing pilot plants for which productivity loans and technical assistance would be provided to increase productivity. (By 1958 some 500 pilot plant programs had been developed.)

--Rationalization programs for small- and medium-sized firms.

After the end of U.S. aid, productivity centers were continued. They are in the private sector and receive a combination of public and private support. We have discussed the financing arrangements with representatives of the various foreign productivity centers. With exception of Japanese and Israeli centers--which draw the bulk of their support from the private sector--these representatives were unanimous in stating that public financial support is essential to successfully continue their activities.

In 1966, 16 formal European centers formed an autonomous body called the European Association of National Productivity Centers. Membership includes Belgium, Czechoslovakia, Denmark, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Spain, Turkey, and Yugoslavia.

Asian productivity centers

Asian productivity centers are an outgrowth of the Japan Productivity Center (JPC) which was created through the efforts of the U.S. post-World War II aid to Japan. In December 1953 the U.S. Government offered to support a productivity center in Japan under conditions similar to those provided to European countries. 17/ After over a year of preparation, the Japan Productivity Center was established in March 1955. U.S. aid for the period 1955 through 1962 amounted to over $6 million.

The productivity movement started with technical exchanges of personnel between the United States and Japan. JPC states that the main contributions of these exchanges to Japan's industry were introducing modern management techniques in such areas as top management, marketing, and industrial engineering.

Technical exchanges encouraged a nationwide productivity movement which resulted in creating various organizations for promoting productivity by region, specialty, and industry.

The major areas of emphasis of JPC are:

--Management education.
--Modernization of labor relations.
--Management consulting.
--Information processing activities.
--Overseas management exchanges.
--Productivity studies.
--Publicity and publications.
--Audiovisual activities.
--Extension of the movement's organizational network.

JPC operates through a system of regional centers and receives its primary support from the private sector, although there are annual contributions from its government. JPC also created the Academy of Management Development which has become the Japanese center for management training.

In 1961, with strong support from Japan, the Asian Productivity Organization was formed of 14 member countries: Ceylon, Republic of China, Hong Kong, India, Indonesia, Iran, Japan, Republic of Korea, Nepal, Pakistan, Philippines, Singapore, Thailand, and Vietnam.

These formal centers concentrate on applying productivity-improving soft technologies (e.g., social and behavioral), education, and consulting services. These centers generally concentrate their activities in the service sectors of their economies and in the general business administration and management techniques fields. Nevertheless, they usually maintain some competence in and liaison with the organizations devoted to hard technology developments. Most of the formal centers, both in Europe and Asia, were established or reorganized after World War II. Their purposes, although each slightly different, are basically to coordinate and encourage applying productivity-improving technology within their economies.

In May 1975, the National Commission on Productivity and Work Quality published for general reference a summary of the structure and activities of foreign productivity centers. 18/ The European Association of National Productivity Centers, headquartered in Brussels, has also published in English a "Handbook of Member Centers," and JPC has many publications.

Informal centers

Little, however, is written about the "informal centers." A useful study 19/ of technology enhancement programs in Canada, the United Kingdom, France, Germany, and Japan was published in 1972; the previously cited works of Ozawa 12/ and Kaplan 10/ give insights into the Japanese organizational structure for technology development. However, it is not until one actually visits other countries that it becomes evident that their informal centers contribute considerably to their substantial productivity gains through technology. While each country has variations to fit its own environment, most informal centers concentrate on productivity-improving hard technologies which are primarily associated with the manufacturing process.

In West Germany information on hard technology is promoted and disseminated through the collective interaction of numerous public and private organizations. These organizations are interwoven to form a structure for planning and implementing research in the Federal Republic of Germany (FRG). These are not centers physically located under a single organization hierarchy. The organizations are dispersed throughout FRG. Key personnel of decisionmaking bodies have overlapping responsibilities, creating an informal interrelationship among the organizations. Moreover, each governing body usually includes representatives of Federal and State governments, industrial associations, universities, labor, and private enterprises.

This complex representation system supports decisive action in developing hard technologies by

--formulating and achieving national goals for improving productivity,

--effectively channeling available public and private funds,

--disseminating information between organizations,

--carefully screening potential projects, and

--better use of research and manufacturing facilities.

For example, FRG established national programs for developing scientific data including one in the data processing area. This program, called the Second Data Processing Program, was initiated under the Federal Ministry of Research and Technology and is a 5-year effort funded at about $760 million. One objective of the second ADP program is to accelerate the application of computers to improve productivity both in the design and manufacturing process.

Although public and private financial support for this and other manufacturing technology activities is funneled through various government and private organizations, most of the support appears to be carefully, but informally, distributed primarily to the Technical Universities of Berlin, Aachen, Stuttgart, and Hanover. Each of these universities has developed expertise in hard technology focused on an inindividual function of manufacturing, such as turning, milling, grinding, forming, computer control, and computer design.

The performing staffs of each university meet about every 2 months to discuss their progress, recommend new projects and directions, and eliminate unnecessary overlap and duplications. Additionally, the senior staff members are also members of advisory bodies to the Federal Ministry of Research and Technology, as well as to other public and private organizations doing similar work. Each university functions as a productivity center for its area of expertise.

Also, in the private sector is an independent association of 170 of the approximately 500 machine tool manufacturing firms in FRG, whose member companies produce about 75 percent of the machine tools. The purpose of this organization, in addition to generally representing the interests of its members, is to conduct applied research for its member firms who could not otherwise conduct the research because of their relatively small size and limited capital. The results of the research are published for its members, and after 1 year are available to nonmembers.

Similarly, East Germany has emphasized its machine tool industry because it recognizes that much of the success in improving the manufacturing process depends on the capability of the machine tool industry to supply the necessary machines. East Germany has divided its machine tool industry into five categories: round-part production equipment, box-shaped production equipment, metal-forming equipment, tools and fixtures, and precision equipment. East Germans are actively applying new technology to batch production and currently have several of the most modern operations in place.

Other European countries also realize the importance of furthering hard technology through an informal structure. For example, in France there is an association made up from 50 of the largest French firms whose policy is to promote productivity-improving technology applications in small- and medium-sized companies. The association provides assistance to these companies in acquiring modern equipment; offers symposiums, publications, technical and scientific advice, and consultation; and sponsors applied research in universities. This group receives about 50 percent of its funding from the French Government; about 20 percent from membership dues; and about 30 percent from sales of services, educational material, publications, and other projects it sponsors.

Not unlike FRG, Japan has also emphasized using productivity-improving technology. To attain a favorable balance of hard currency after World War II, the Japanese Government encouraged the selected import of advanced technologies and foreign investment which would "contribute to the self support and sound development of the Japanese economy * * *." 12/ Government support, coupled with the unique web of industrial connections spun within each keiretsu* group, provided the opportunity for phenomenal progress.

The Japanese Economic Planning Agency used highly sophisticated analytic techniques (e.g., input-output matrixes) to predict the future needs and productions of the Japanese economy. The Ministry of International Trade and Industry (MITI) developed a policy plan to guide industry through various incentives. 10/ Under MITI national guidance was provided to develop or acquire technologies and industries most relevant to furthering Japan's economic progress. Areas such as chemicals, petroleum, and machinery were made priorities, and resources were marshaled to select the best available technology from other industrial nations (most notably the United States). 12/ For the most part the technology was readily available. Incentives including financial, tax, and export licensing were provided to those organizations meeting the plan's criteria, and through formal and informal productivity centers (very similar to those of West Germany) the appropriate technology was diffused. Encouraged by MITI business adopted the technology, increased productivity, introduced new products, and developed export markets.

For example, under MITI's sponsorship Japan has developed a national plan to speed up the normal cycle time for planning and implementing a new technology through developing a totally automated batch manufacturing plant by the mid 1980s. The program is called Methodology for Unmanned Manufacture. The program's governing committee identifies its membership sources as follows: 2 government agencies, 32 universities, 1 trade association, 1 industrial journalist, 1 trade union, 1 "Think Tank," and 6 industries. Government funding will be about $116.6 million. In addition, the industrial participants will bear a significant part of the remaining cost themselves. We do not know the specific level of their funding participation.

The unmanned plant is expected to be approximately 250,000 square feet and staffed by a control crew of about 10 persons. (Conventionally, a factory of this size would require approximately 750 workers.) The product would be some 2,000 different machinery parts in batches of 1 to 25. These will be automatically assembled into some 50 different machine components (e.g., bear boxes, spindle heads, motors). The automatic processes would include forging, heat treatment, welding, presswork, machining, inspection, assembly, and painting.

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*The keiretsu are groups of closely affiliated firms and subsidiaries which usually have as their nucleus a bank or general trading company.

Foreign country informal centers allow more personal contact among the participants, and as a result, the average industrialist, university professor, and government official in most foreign countries are more thoroughly aware of the international state of technology than his U.S. counterpart. These officials are continuously touring industrial facilities and laboratories in foreign countries. For example, at the time we visited the University of Berlin, a major center for developing manufacturing technology in Germany, over half the engineering faculty was returning from a tour of advanced industrial facilities in the United States. Many of the same people had visited Japan, France, Britain, and Warsaw Pact Nations.

In the United States we found relatively few public officials, university people, and individuals from private U.S. firms or associations who had firsthand knowledge of technical developments and applications in foreign countries. We refer here to technology in general and not to the knowledge of an individual firm about its specific foreign competition.

The activity of the foreign centers, both formal and informal, essentially revolves around applied research and diffusion of technology (hard and soft) throughout their manufacturing and service sectors. These activities achieve a balance of initiatives between hard and soft productivity-improving technologies and seem well adapted to promote the quantum jumps in national productivity required to improve their countries' standard of living and world trade position.

U.S. DIFFUSION ACTIVITIES

Several uncoordinated government and private initiatives address one phase or another of manufacturing technology development and diffusion. However, no meaningful organizational or institutional structure in the private or public sectors in the United States centralizes the assessment and diffusion of current domestic and foreign technological developments or directly assists using those developments to improve U.S. productivity and competitiveness. In fact the United States is perhaps the only nation in the free world which has not undertaken a coordinated program at the national level to stimulate commercial technology development in the private sector.

The Government has supported developing manufacturing technology in the private sector for those industries directly related to defense, energy, and space through programs in the Department of Defense; the Energy Research and Development Administration; the National Aeronautics and Space

Administration (NASA); the Department of Commerce; and others. For example, in the area of safety the National Bureau of Standards is working on standardizing interfaces of subsystems and developing "intelligent" industrial robots to perform various functions under hazardous conditions. Only the National Science Foundation has a research program applied to manufacturing, although it has low funding by foreign standards. However, there is generally no formal technology diffusion mechanism for the Nation.

This lack of a program intensifies the problem of inadequate availability of capital to the small firm for invention and innovation as well as for diffusion of existing technology. Since this problem relates most directly to small manufacturing firms, one obvious focal point in the Government would be the Small Business Administration (SBA).

A 1971 report by the SBA discusses the potential for small business using modern manufacturing technology and the problems of the availability of this technology to small firms, such as the majority of batch producers in the United States. The report recognized that use of advanced technology by small U.S. firms will be necessary for them to remain competitive, and it made a clear case that batch automation could be effectively used by this segment of industry.

Several proposals were outlined to overcome the major problems which SBA perceived were being faced by small firms in obtaining and applying advanced technology; i.e., availability of capital, access to reliable information about the technology, and the need to educate management concerning its economies and use. The report emphasized that educational needs outpaced financial needs. Also hearings held before the Subcommittee on Science and Technology of the Senate Select Committee on Small Business on June 24, 1971, brought out that small firms have difficulty competing with large firms in research and development, which, in view of the rapidly developing technology, could have a tendency to expand the technology gap between large and small firms to unacceptable proportions.

However, in the 5 years since the report was issued, U.S. productivity has declined, its trade balance turned negative during three of these years, foreign programs have accelerated, and conventional sources for acquiring capital have been reduced. The need for using technology has increased, but its access to small firms has been reduced.

Many of SBA's proposals are as valid today as they were 5 years ago; however, little has been done to implement them.

The need still exists for identifying areas where small firms could productively use new technology along with technical and financial assistance to these firms. SBA's original proposals included a more active role for SBA in technical and management assistance, education, economic research, and promotion of technology use by small firms. In today's economy emphasizing innovative financial arrangements is also necessary.

Other Government agencies will be involved in related aspects of diffusion to some degree. For example, the Treasury Department will be faced with the question of applicability of existing tax policy, including equipment depreciation rates, if quantum jumps of increased use also bring about greatly increased machine wear rates. The Justice Department will be concerned with interpretations of antitrust legislation if small firms find it necessary to cooperate with each other to economically develop advanced technological systems and to compete internationally.

Due to the inability to promptly identify the effects on the economy of technology imports and exports, GAO has also studied international transfer of technology and the repercussions on employment, the gross national product, and the balance of payments. GAO expects to publish this study in the future.

It is not, however, within the scope of this report to elaborate on the activities of the various Government agencies and private organizations who are individually working toward improved productivity of American manufacturing. Nevertheless, conversations with officials of each of these organizations indicated that they are concerned that no single group has the charter or financial backing to act as a focal point. Hough points out that many problems requiring development and diffusions of technical solutions have been so complex that they could be accomplished only by the large multidisciplinary organizations found in Federal agencies. 8/ However, even though more than half the national research and development budget is spent by Federal agencies, comparatively little common technology is generated. Limited technology spinoffs, however, have been achieved. But these have been the result of establishing national goals such as those for agriculture and aerospace. This lack of national goals for discrete manufacturing technology, as seen in other countries, contributed to the poor coordination of existing U.S. programs.

CHAPTER 7

MISCELLANEOUS MATTERS

Although beyond the immediate scope of this study, several recurring factors in our review warrant brief discussion.

MARKETING

With few exceptions, U.S. Government, university, and private industry authorities are primarily American-market oriented.

Many American products are not selling in foreign markets possibly because the small producer is not marketing them. We found that the small batch producer is not well-suited by background, inclination, or experience to think in terms of the export market, like his foreign competitors. Comparatively few U.S. firms do any exporting.

From July 1971 through April 1975 the GAO completed over 20 studies of trade-related matters. (See app. II.) From the data examined GAO concluded that less than 10 percent of U.S. manufacturing firms are consistently involved with export business.* Department of Commerce officials stated that, even though there were an estimated 300,000 manufacturing establishments in the United States, they had experienced considerable difficulty in recruiting companies to participate in overseas trade institutions. The officials attributed this difficulty, at least in part, to U.S. companies' pervasive lack of export awareness and of knowledge of the Commerce Department's programs. 20/

Although there are numerous U.S. trade centers overseas, attaches indicated that primarily large firms and multinational corporations pursue foreign markets aggressively. Smaller U.S. manufacturers, although numerous, are not prominent in marketing American products overseas. At one embassy, the attache discussed many market opportunities he had for evaluation and processing. According to the attache,

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*See testimony of J. Kenneth Fasick, Director, International Division, U.S. General Accounting Office, Report of Hearings on the Proposed Reductions in the Budget for Expert Promotion Programs and Changes in Fees for Services Provided by the Department of Commerce before the Subcommittee on Foreign Commerce and Tourism, Senate Committee on Commerce, 94th Congress, first Session at 25 (1975).

American firms did not pursue their overseas market opportunities and sales possibilities were lost because of the attache's staff limitations for processing the material.

Even for the high technology, export-oriented firms, selling in foreign markets will become more difficult through increased competition.

An example of this increased competition was presented in a GAO report, entitled "Export of U.S. Manufactured Aircraft--Financing and Competitiveness" dated March 12, 1975. While 72.4 percent of commercial jet aircraft in foreign fleets, excluding Russia's, were manufactured in the United States, increased competition is expected from other industrialized centers including the European community, Russia, and Japan. Japan currently has an aircraft development program underway with 85 percent government financing. The United States is expected to have difficulty maintaining this market.

U.S. manufacturers are concerned that European governments have developed a blueprint for an integrated commercial aviation-manufacturing capability. The plan provides for government support of research and development as well as marketing and price support.

Recognizing that other trading nations have enhanced their position in world markets by aggressive promotional activities, the Department of Commerce made a study comparing major facets of its programs with those of Canada, France, Germany, Italy, Japan, and the United Kingdom.

The study, released in July 1970, showed that the United States, compared with those countries, placed less emphasis on (1) stimulating domestic companies to export, (2) providing promotional activities in developing countries, and (3) working closely with companies in planning to increase their export activity. Some major conclusions in the study were:

--Competitor nations devoted a higher portion of their total export promotion activities to the domestic stimulation of increased export activity than did the United States. This was particularly noteworthy in view of the fact that the United States business community did not have as much export awareness as any of the other countries.

--Other nations emphasized their presence in less developed countries, apparently laying a base for commercial presences as economic development occurred in those countries.

--The United States did not plan export programs or policies in concert with American industries or exhibit business-Government export expansion collaboration to the degree encountered in virtually all the competitor nations.

--The United States lagged far behind all other countries in using, and cooperating with, the private sector in export expansion activities.

Although the comparative study did not demonstrate that the United States necessarily could, or should, pattern its approach after the other major trading nations, it did point out that the above areas should be considered in formulating a more effective solution to the problem of promoting exports.

ANTITRUST

Antitrust legislation has been valuable to the United States in developing and maintaining our competitive system. These regulations, which were developed in an economy primarily concerned with its internal marketplace, have restricted monopoly growth, unfair competition, and other practices not in the public interest. While this is still a desirable goal, the growing need of American firms to compete internationally requires that the Nation study the environment in which these regulations operate.

We found that fear--justified or not--of antitrust actions may be having an inhibiting effect in various actions which could improve productivity and the competitiveness of U.S. firms. These include, among others, joint actions in research and development by groups of firms which do not have sufficient resources to perform their own research and development or joint marketing efforts.

The high cost of research and development is beyond the reach of all but a relatively few large firms. The suppliers of manufacturing process technology--the machine tool companies--are also relatively small and cannot individually afford the large-scale investment in research and development necessary to reach for the limits of technology.

The cost of a demonstration project for development of the leading edge of technology would be prohibitive for a single company. One of our larger machine tool companies reportedly spent over a 7-year period in the magnitude of $5 million on a CIM demonstration project but had to terminate the project because of a lack of funds.

Other industrialized countries are overcoming these problems by combining companies, creating specialization, and promoting joint research.

There is a great deal of concern and confusion among U.S. firms as to what they are permitted to do under the antitrust regulations. As a result, companies said they are reluctant to consider joint projects to develop and refine advanced technology. The fear of antitrust, whether justified or imagined, has placed U.S. firms at a disadvantage in the international race to reduce the time of manufacturing technology development through highly funded concentrated efforts.

Department of Justice officials said that, although they are familiar with these concerns, they feel that they are based more on misunderstanding the regulations than on actual prohibitions. While individual circumstances are involved, there is no absolute prohibition against joint research by competitors. Without rejecting the competitive approach to solving technological problems, combinations which lead to an improved allocation of the Nation's resources are normally permissible. In an industry made up of many relatively small firms, such as most of those in the discrete batch production environment, a serious problem may very well require both a financial and a technological investment far beyond the capacity of an individual firm. In such cases industry wide cooperation or a number of competitive joint ventures may be a desirable and acceptable answer.

A business review procedure exists in which firms may obtain the prior opinion of the Department of Justice about enforcement intentions for a proposed joint effort. We were told that the Department of Justice had never sued a firm who had received a business review letter and operated within the scope of that project.

In the area of foreign trade, concern for operation of the antitrust system is also a major deterrent to America's competitiveness. This was discussed in a GAO report, entitled "Clarifying Webb-Pomerene Act Needed to Help Increase U.S. Exports," dated August 22, 1973. Although it has not been as evident as it is today, the need for promoting exports has been a concern for over 60 years. In 1918 the Webb-Pomerene Export Trade Act was passed to overcome the advantages held by other nations. As a rule, foreign businessmen are much freer to cooperate and join forces to compete in international trade than are U.S. businessmen. Foreign governments often encourage cartels and promote mergers to strengthen competitive positions. The 1973 GAO report stated that definite restrictions were lacking on export cartels in 15 major trading nations, including Japan.

The Webb-Pomerene Act was to assist firms in meeting foreign competition by permitting exemptions from antitrust laws for associations formed to engage in export trade. Also the act was to encourage small business exports.

However, the potential has not been realized and fear of antitrust restrictions still places U.S. industry at a disadvantage. Of the limited number of U.S. firms exporting, in 1971 only about 3.5 percent of all exports were accounted for by registered associations.

The failure of the act comes from an environment of uncertainty over possible antitrust implications arising from what some manufacturers have termed "confusing legislation." Although associations register with the Federal Trade Commission, which can regulate their activities, the Department of Justice is free to take independent action without prior notice. The Department of Commerce at one time promoted formation of associations but eventually took the position of not actively promoting the provisions of the act because of this ambiguity. Many firms feel that since qualified exemptions from antitrust actions are only assumed, it is too risky to commit their resources to such an activity.

Not only are existing opportunities to export being lost, but opportunities to develop new export undertakings are also being lost. The future impact is emphasized by the fact that, while the leading U.S. exports are the high technology items that are beginning to face increased competition from foreign activities, the Department of Justice reported that in 1972 none of these products were represented by exports of an association formed under this act. However, those multinational companies engaged in exporting probably possess the same leverage as an association. Eighty percent of the exports by associations were consumer goods and industrial raw materials.

TAX POLICY

As mentioned in chapter 2, a tax structure can encourage or discourage capital formation and investment in technology. Individual programs, such as the investment tax credit, can assist in capital formation as can depreciation policies on asset life and on writeoff method. However, it is the total tax system, in relation to the tax systems in other industrial countries, which determines the relative effectiveness of any encouragement of capital investment.

To be effective, a system must be flexible and quickly responsive to changing needs. For example, a simplified method of depreciation may allow greater flexibility in handling new, highly technical machinery which is subject to rapid obsolescence than a highly structured depreciation system. Rapidly changing hardware may require similar treatment as software; i.e., a very rapid writeoff or, if warranted, be treated as an expense. However, it would have to be done through a tax system designed to actively promote capital investment. Department of the Treasury officials said they were basically neutral and it was not within their statutory authority to provide the tax incentives through depreciation we found in other industrialized nations.

MONETARY POLICY

The international monetary system until recently valued the American dollar artificially high in relation to most foreign currencies, making the price of foreign products attractive in the most lucrative world market--the U.S. market--and the price of U.S. products less attractive in foreign markets. Thus foreign nations and firms could plan their investments in improved productivity with some assurance that they would have a price if not a quality edge in the world marketplace.

Recent dollar devaluations made U.S. goods more price competitive in world markets; however, this may be just a shortrun effect in that productivity trends and manufacturing technology diffusion rates are still unfavorable to the United States.

STATE AND OTHER PRODUCTIVITY AND PROMOTIONAL CENTERS

Following are some examples of disparate but determined efforts to address the growing awareness of the need for a productivity movement in the United States.

A number of States--such as Georgia and North Carolina--have established "productivity" centers, usually centering on the State technical university. For example, the School of Engineering, North Carolina State University, has an Industrial Extension Service which provides "technical and managerial resource service for North Carolina business and industry." The university provides extension education, technical and managerial information services, and consulting services designed to diagnose a company's managerial or technical problems and to refer the firm to the proper source for resolving the problem.

An example in Pennsylvania is the Pennsylvania Science and Engineering Foundation established in 1967 which is primarily State funded. It has programs for aid to small business, technology transfer, and a network of interrelated programs involving 146 colleges, universities, and technical schools.

U.S. News and World Report (April 21, 1975) reported that 18 States now have offices in Europe to spur exports of their States' products and to attract foreign investments to their States.

Computer-Aided Manufacturing--International, Inc. (CAM-I), is a not-for-profit research organization created by a variety of industries. CAM-I operates with a Business Review Letter (described in the antitrust section above) from the Department of Justice. A preface to a brochure for its 1975 membership program states that "CAM-I was conceived and organized to provide a focal point for industry, academic, and government communication for the common development of computer applications to manufacuturing. It exists to increase productivity." CAM-I has devoted its primary activities to software and standardization problems.

As our studies were being completed, three new organizations were in the development stages--one to concentrate on the human element in the working environment; the other two on manufacturing technology.

The first of these, the "Work In America Institute", will serve to enhance the quality of working life. The second organization, the National Center for Manufacturing Technology is intended to expand manufacturing research and development.

The organizers of the National Center have proposed an industry sponsored nonprofit corporation to act as a focal point for improving U.S. manufacturing productivity, with emphasis on discrete metal part manufacturing. The purpose would be to act as a catalyst for advancing both manufacturing technology and manufacturing education. In addition to sponsorship of cooperative efforts to achieve practical solutions to actual manufacturing problems, they will perform research of a general interest to a larger number of companies. One planned approach to assure the proper selection of research projects will be the monitoring of the activities of foreign research and development programs and informing their U.S. counterparts of technology advancement. The goal of the educational program will be to assist U.S. industry in applying new technology in their production facilities. The organizers are currently soliciting membership to support the center.

The third, called the American Productivity Center, would be a privately funded and operated center, sponsored and controlled by management and labor. Its effort would be directed to all segments of our economy for the purposes of increasing productivity and the quality of working life and preserving the private enterprise systems.

EDUCATION FOR MANUFACTURING

As mentioned in chapter 2, Denison found, as have others, that the education level of employed persons is one of the prime determinants of the productivity level of a nation. An important observation made by several manufacturing engineering executives was that they learned the engineering of manufacturing on the job. Most of them were trained as mechanical engineers, electrical engineers, civil engineers, etc. Graduate school educators have stated that the glamour of aerospace and atomic and nuclear energy have attracted both talent and resources away from the academic disciplines important to basic manufacturing.

With regard to secondary school education, one prominent educator asserted that virtually all American public school students devote a great deal of time to learning about the anatomy of a frog, whereas less than 15 percent of the students learn about the insides of a factory and the economics and technology that makes it work.

The Society of Manufacturing Engineers in 1971 conducted a National Forum for Manufacturing Engineering Technology Education. The foreward to the report issued in January of 1972, stated:

> "The development of Manufacturing Engineering oriented curricula is particularly important at this time because of lagging productivity and because of the increasingly sophisticated manufacturing environment."

Our study was not directed to comparing national educational systems in terms of their impact on manufacturing technology, engineering, and management. We found, however, that nationally supported institutions of higher learning in the Western European countries developed graduate manufacturing engineers who were attuned to the actual manufacturing environments in which they would work. Selected universities--such as those at Aachen, Berlin, and Stuttgart in Germany--have become focal points for national productivity activities in the manufacturing technology area.

We believe that those engaged in manufacturing and education in the United States feel that greater emphasis on manufacturing at the secondary, undergraduate, and graduate levels in the United States would contribute to future improvements in national productivity.

This subject requires more study than our present work encompasses.

CHAPTER 8

SUMMARY AND OBSERVATIONS

OBSERVATIONS

The U.S. Government, with over $50 billion annually in purchases of goods from the American economy, has a direct interest in reducing these procurement costs through improving manufacturing technology and thus increasing productivity. Domestic supplies of raw materials are diminishing, and there will be a need to increase our raw materials imports with the probability of continually increasing unit prices. It will be necessary to increase our exports to pay for the increased imports of raw materials. This can be done through more concentrated overseas marketing efforts as well as through reduced prices for our goods.

Unless our productivity increases in a manner which reduces product costs and increases outputs in relation to inputs, the cost of exporting more and more to pay for the increased imports will result in a lower standard of living. In other terms, it seems our output per unit of input must increase just for American living standards to remain constant while we pay for our increased imports.

At a time when our Nation must become increasingly export conscious, our international competitors are capturing increasing shares of foreign markets, and are increasingly penetrating U.S. markets. It is significant that they are competing in those markets with U.S. high-technology manufacturers.

The primary sources of U.S. exports for the future appear to be primarily agricultural products and the products of our discrete parts, batch process manufacturing industries. This is also true at present in that U.S. principal exports are agricultural products, aircraft and components, electronics--principally computers--and nonelectrical machinery.

Technology is currently available which can significantly enhance the competitiveness of our batch processing industries. However, the nature of the batch-producing industries and the structure of our society create a number of barriers to timely improvements and diffusion of this technology. These include (1) a rather widespread lack of understanding of available technology--principally among small- and medium-sized firms--(2) general inhibitions toward joint research created at least in part by widespread misconceptions of the U.S. antitrust restrictions, (3) a problem of access to capital, (4) a tax system which may not be as responsive to rapidly changing technology as the tax systems of some of our foreign counterparts, and (5) labor resistance to adoption of productivity improving techniques.

Significant short term benefits are possible through improved diffusion of the available technology. For long term sustained productivity increases, research and development is necessary to find new methods, and to refine existing technology so that it can be economically used outside the few highly capitalized, high technology firms.

In foreign countries, the problems of improving and diffusing existing technology throughout the industrial base and the technological and managerial problems of medium- and small-sized firms are not significantly different than those in the United States. However, unlike the United States, our principal foreign competitors have well-developed government-directed programs and structures for overcoming barriers to diffusion of existing manufacturing technology throughout their industrial bases and for advancing the state of the art through coordinated research and development programs. At least inferentially as a result of such programs, these countries have shown better results than the United States in such areas as rate of increases in productivity, international trade, modernization of facilities, and capital investment in modern technology.

Increased output at a lower cost is the goal of advanced manufacturing technology. However reduced costs do not only mean a reduction of labor, they also relate to a reduction in material and energy inputs. Use of these technologies will free labor for redeployment or will substitute for labor where it is not available, and, of course, this is one of the benefits of CIM. In our many discussions with industry, we were told that it was apparent that manufacturing was already facing isolated labor shortages in today's environment of an overall labor surplus. Industry said that it believed the trend away from employment in manufacturing will continue regardless of the use of technology. (The Bureau of Labor Statistics has estimated that about 24 percent of the labor force will be employed in manufacturing in 1985 as compared with 35.4 percent in 1947, although the absolute numbers employed in manufacturing will increase by 7 million persons.) 21/ In fact, batch automation is a partial solution to a labor situation as opposed to being solely a creator of a situation.

We do not mean to minimize the labor problem. Indeed we believe these statistics emphasize it. The trend toward lower participation of the labor force in manufacturing is already occurring. What may present a problem is the lack of national recognition of this trend and a national approach to its analysis. The potential results can range from unemployment to new job opportunities in service and leisure industries to intentional labor slowdowns because of misconceptions about the results of automation. We were told by a representative of one prominent manufacturing systems company that it had designed and installed an automated system with twice the necessary capacity because of management's conviction that the labor force would not permit it to operate at capacity. Although we did not verify the accuracy of the report, it may be that some institutional mechanism could be developed to reassure the labor force about its future so that optimum systems could be installed. In any event, there is a national interest in the impact of automation on the labor force.

One labor leader, Anthony W. Connole 23/ has stated that:

> "Contrary to what some think, most workers and their unions welcome increased automation and advancing technology in their jobs"

He went on to state that general employee approval doesn't free an employer from the responsiblity to consider the impact of timing and other factors on his work force when he innovates. He points out that displacing labor is the prime motivation behind the introduction of automation and technology. To say that automation produces more jobs in the end ignores the fact that each worker reacts not to eventual aggregate effects, but subjectively to its personal effects. Connole cites a number of steps which can be taken by employers and Government to minimize the effects on labor in order to receive labor's support of automation and technological advances.

Although total U.S. investment in research and development has been greater than in other countries, research and development in the general or civilian manufacturing areas of foreign economies is receiving greater emphasis than in the United States.

However, it must also be stated that the United States generally has more of the most advanced manufacturing technology in place than any other country, both in absolute and relative terms. We believe that American managerial competence and technology will continue to be a hallmark of excellence.

Therefore, the principal concerns are directed to the future. Our study suggests that the manufacturing technological advantage, in terms of best practice, which the

United States enjoyed since World War II is at an end. Therefore, even with traditional methods of manufacturing, we could expect not only increased foreign competition but also increasingly new and innovative advances in the foreign area in terms of best practice.

But in addition to improvements in traditional methods, the computer and the numerically controlled machine are changing both the management and the engineering technology of manufacturing. We believe, as Dr. Harrington 8/ stated, that manufacturing methods are about to change not incrementally but radically. We can see that the changes are already taking place in the foreign countries where the productivity-improving institutions and mechanisms were created to recover from the adverse effects of war. There mechanisms are well-established and are exploiting the new technology, enabling these countries to catch up to the United States.

As found by Piekarz and Thomas 2/, we know of no way to determine for the future whether the gap in overall technological comparabilities (as distinguished from best practice) will contract, widen, or remain the same. What we can reasonably conclude is that the foreign institutional mechanisms designed to advance manufacturing productivity and technology have been prima facie successful. There is no reason to believe that they will be less successful in exploiting the new computer-aided technology. This is also apparently true of American agriculture--unlike manufacturing--which despite its advanced state has a rate of productivity improvement comparable to that of the advanced nations and a well-developed institutional base for exploiting agricultural advances.

Increased productivity through use of programable automation has the potential to help strengthen some of our industries whose export-import ratios are declining; i.e., those industries receiving intense competition from foreign counterparts.

Generally, use of the most efficient manufacturing methods can favorably affect the cost of Government procurements and the costs of products to Americans.

CURRENT ACTIVITIES

Because of inflation and increased imports of high-quality foreign items, such as automobiles, steel, radios, television sets, and household appliances, there is a growing national interest in and concern about productivity.

In the private sector, organizations are emerging to address various phases of the problems in research, development and diffusion. The Computer Aided Manufacturing-International (organized in 1972) is devoted to improved productivity through computer software development; it is an international organization not devoted exclusively to improving U.S. productivity.

The Work in America Institute, a nonprofit organization, was formed in 1974-75 with private funding. It strives to enhance the quality of working life so as to strengthen our society economically, socially, and politically. It is based on the thesis that advances at the workplace translate into improved living standards, enhancement of mental and physical health and welfare, and increased individual fulfillment, human satisfaction, and dignity.

A "National Center for Manufacturing Technology" (NCMT) has been proposed in the private sector with a goal of developing "a broad, coordinated, advanced technology program" for improving prductivity in U.S. manufacturing.

Also, the American Productivity Center is organizing to address the total spectrum of problems involved in improved productivity.

Various institutes, such as the Stanford Research Institute, Massachusetts Institute of Technology, and the Illinois Institute of Technology Research Institute, are centers of research excellence. But their level of funding and program orientation do not match the efforts we observed in foreign countries.

Organizations such as the Society of Manufacturing Engineers are working to diffuse technology and to improve education for manufacturing. Ohio State University (there may be others) has developed courses in manufacturing for use in secondary schools. Our studies did not look at the adequacy of education with the exception of the observations by various educators and senior manufacturing engineers that education for manufacturing could be markedly improved.

Although at the Federal level national policy goals are poorly defined, there are various activities, each with particular goals but none coordinated to meet national policy goals. For example: The Department of Commerce has a widespread mission, field offices, and the technological capability in the NBS, NTIS and other departments to assume a position of leadership in technological innovation and diffusion.

The basic goal of the National Bureau of Standards is to strengthen and advance the Nation's science and technology and to facilitate their effective application for public benefit. The NBS staff has a thorough understanding of the problems and potential in computer-aided manufacturing. Because of its pivotal role in standardization and technology, NBS is uniquely equipped for a major role in improving productivity in manufacturing.

The NTIS is the central point in the United States for the public sale of Government-funded research and development reports and other analyses prepared by Federal agencies, their contractors, or grantees. The majority of these reports do not deal with productivity and do not accomplish what a responsibility center might do. However, while no Federal agency has the responsibility for collecting and translating or writing about foreign technology developments and technology developments in the private sector in the United States, NTIS has a readymade organizational structure to absorb, organize, and distribute the literature to American industry. As indicated by our industry survey, however, large segments of industry most in need of NTIS publications do not subscribe to this service.

The purposes of the National Science Foundation include: increasing the Nation's base of scientific knowledge and strengthening its ability to conduct scientific research; encouraging research in areas that can lead to improvements to economic growth, energy supply and use, productivity, and environmental quality; promoting international cooperation through science; and developing and helping implement science education programs.

The foundation has a "Research Applied to National Needs" program, which is exploring various phases of technology, some of which relate to manufacturing technology. Because of its experience with such programs, NSF is ideally suited to provide an operating and management interface with the academic community, research institutes, and private enterprise. The basic problem of NSF, given limited funds, is assigning priorities to its projects. Given the importance of manufacturing technology to the country's future and the relatively higher levels of civilian manufacturing-oriented research and development in foreign countries, it would seem that research applied to improving productivity in manufacturing should be high on the NSF list of priorities.

In April 1975 the Deputy Secretary of Defense announced a new program for cost reduction initiatives. In his announcement he said:

"I am convinced there are numerous opportunities to obtain significant cost savings in the production of Defense materiel by increasing the application of state-of-the-art manufacturing techniques and by the development of new or improved manufacturing technology. For example, not only should we be making more effective use of numerically controlled machine tools and other new, highly productive manufacturing processes, but we should also be exploiting emerging technologies such as computer aided manufacturing, laser welding, diffusion bonding, use of computers, etc."

Because its requirements are so diverse, a well-directed program of improved manufacturing for defense production can have beneficial results for the total economy. However, there must be a societal mechanism for coordinating the defense developments in such a way as to enable diffusion of the results throughout the industrial base.

Also, both ERDA and NASA have specialized circumstances requiring the use of automated manufacturing technology, and they have highly qualified staffs performing in this area.

In mentioning the above agencies, we do not mean to imply that other agencies do not have important roles. For example, the Department of State has embassies and consulates all over the world with commercial and scientific attaches who could make continuing technology assessments for use by American industry. Also, the Departments of Labor; Health, Education, and Welfare; and the Small Business Administration have key roles in any effort to raise the levels of productivity in manufacturing in the United States.

The National Center for Productivity and Quality of Working Life, and its predecessor the National Commission on Productivity and Work Quality have had a short and tenous duration.

Their efforts have been directed to such areas as food distribution, formation of labor management committees, health care, and productivity of the railroad industry. With a small staff and limited funding, they have done outstanding work under difficult circumstances. However, they have not directed their efforts to manufacturing, and within their current funding and organizational framework would find it difficult to undertake this effort on their own.

RECOMMENDATIONS

On the basis of the information presented in this report, there is a need to establish manufacturing productivity as a national priority, and to create a national focal point to achieve productivity improvements and assist U.S. industry both in reaching for the most advanced manufacturing technology and diffusing it throughout the private sector. One organization could not do all of the things necessary to be done; however, a cooperative effort can be initiated to perform a leadership, coordinating, and catalytic function.

In this respect, GAO recommends that, as a top priority effort, the National Center for Productivity and Quality of Working Life, develop a national policy and appropriate means for achieving balanced productivity growth in the industrial/manufacturing base. Further, GAO recommends that the National Center, in carrying out this recommendation, seek the cooperation and assistance of the Department of Commerce and other appropriate agencies. In addition, GAO recommends that the Department of Commerce strengthen its efforts to support and develop productivity enhancing technology related to manufacturing, and to encourage others to actively support these objectives. Some of these potential efforts are outlined below.

The combination of the existing expertise of the National Center and the Department of Commerce and their close coordination with other public and private organizations (e.g., NSF, DOD, DOL, SBA, CAM-I, etc.) would facilitate early initiatives with a minimum start up time. Moreover, Commerce could thereby provide the much needed focal point to coordinate all the disparate Government and private work in developing, standardizing, and diffusing manufacturing technology, and assist the emerging state and regional productivity organizations in their efforts to advance manufacturing technology.

We believe the National Productivity Center and the Department of Commerce can provide needed leadership in a number of areas such as:

- --Providing a centralized source of timely knowledge about existing technology by:
  - --Assessing on a continuing basis technological developments in the United States and abroad, and performing import analysis to assess trends which can impact U.S. manufacturing. In this effort there is a need to provide a center for

translating into English foreign language technical publications and papers.*

--Maintaining liaison with foreign productivity centers and other institutions fostering technological improvements and increased productivity.

This liaison should include interchange visits, conferences, and tours of foreign industrial facilities.

--Sponsoring computer-aided design and computer-aided manufacturing demonstration projects.

--Generally structuring a national technology diffusion mechanism.

--Furthering the development and acquisition of new technology by:

--Encouraging increased industrial capital investments by performing research into such areas as the desirability of developing flexible tax policies to promote industrial expansion; i.e., timely and realistic depreciation rates for newly developed manufacturing hardware.

--Examining the desirability of providing tax and investment incentives to selected industries or for particular types of productivity improving efforts, where increased productivity is especially important to the national interest or the U.S. international competitive position.

--Encouraging maximum use of joint ventures for research and development through existing procedures of antitrust regulations.

--Sponsoring research and development projects beyond the capital capabilities of individual firms.

--Exploring alternatives for financially assisting identified categories of firms, which need and merit capital assistance, in acquiring the most modern equipment and advanced technology.

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*Appropriate notification of U.S. firms about efficient manufacturing methods of their foreign competitors may enable firms to respond with increased efficiency and avoid adjustments assistance provided in the Trade Reform Act of 1974.

--Assisting firms in adapting to management and marketing changes created by advanced technology and foreign competition.

--Developing simplified cost-effectiveness analysis techniques for use by managers in decisionmaking on capital investments in new technology.

--Continuing work on standards.

--Evaluating potential affects of automation on the work force and developing programs to minimize these affects. In this effort the Department of Labor and the representatives of labor must be continuing partners.

--Assisting in encouraging additional exports of manufactured products through such actions as providing a microanalysis of trade patterns by industry, encouraging increased support from overseas trade missions, and promoting trade associations under provisions of the Webb-Pomerene Act.

In June 1975 the Federal Council for Science and Technology, Commitee on Automation Opportunities in the Service Areas, published a report which, with appropriate modification for the differing problems of manufacturing and the service sectors, contains observations and suggestions for the service sector quite similar to those we have reached for the manufacturing sector. Appendix III contains some excerpts from that report which we feel are relevant to the matters we are reporting on and to national productivity generally.

GAO has supported the efforts to strengthen our national science and technology policy and organization and to establish the national productivity center. Central to the GAO position, is a recognition that widely disparate activities affecting productivity and technology are now taking place at the Federal, State, local, and private sector levels. These disparate efforts, if coordinated and complemented, could yield greater or more effective results even if additional funds are not invested.

Basic, however, to all of the proposed Federal actions is fostering developments in the private sector and assuming funding support only for those actions which for various reasons cannot be assumed by the private sector. We feel the private sector itself can do more, to assure that the national interests are met through accelerating the application of advanced manufacturing technology. In doing this, it needs to coalesce and define its own problems more clearly, and do more to participate in creating centers of excellence devoted to reaching for the limits of manufacturing technology and management.

CHAPTER 9

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APPENDIX I

SURVEY OF
METALWORKING ESTABLISHMENTS
IN THIRTEEN STATES

UNITED STATES GENERAL ACCOUNTING OFFICE

CHAPTER 1

SURVEY OF METALWORKING ESTABLISHMENTS

INTRODUCTION

As part of our study of manufacturing technology in the United States, we made a survey of metalworking establishments. Some of these establishments were subsidiaries of larger corporations or one of several plants; they were treated as separate entities exclusive of their other affiliations. The survey's objective was to find out (1) the extent to which computer-related manufacturing technology was being used in the metalworking field and (2) the attitudes of manufacturers toward both the new technologies and the role of the Government in furthering the use of such technologies.

Using statistical techniques, our survey was based on a random selection of 257 establishments from more than 27,000 located in 13 States. This universe accounted for more than 73 percent of the U.S. manufacturing establishments. Twelve of the establishments selected were no longer in business or could not be located. Of the remaining 245 establishments, we obtained data concerning 178, or 72.7 percent.

Most of the 178 establishments were personally visited by our audit staffs. Survey questionnaires were completed during those visits by GAO interviewers or by officials of the establishments either before our visits or subsequent to the visits. In the latter cases, as well as in the cases in which no visit was made, questionnaires were returned to us by mail. Survey data was gathered during the December 1974 to February 1975 period.

CHAPTER 2

DESCRIPTION OF THE RESPONDING ESTABLISHMENTS

The 178 establishments were distributed across the 13 States.

Figure 1

Geographical Distribution of Surveyed Establishments

State	Number of establishments	Percent
Calif.	23	12.9
Conn.	9	5.1
Ill.	14	7.9
Ind.	14	7.9
Mass.	10	5.6
Mich.	15	8.4
Minn.	3	1.7
N.J.	11	6.2
N.Y.	19	10.7
Ohio	24	13.5
Pa.	21	11.8
Tex.	10	5.6
Wis.	5	2.8

The establishments for which we obtained data can probably be considered as small or medium. Across the 175 establishments providing such information, employment levels ranged from 12 to 4,000. Figure 2 shows a breakdown by four size ranges. The overall average number of employees per establishment is 236, but about 26 percent of the establishments reported having 200 or more employees.

Figure 2

Number of Employees in Surveyed Establishments

Employee range	Number of establishments	Percent of total	Cumulative percent
1 to 49	56	32.0	32
50 to 99	51	29.1	61.1
100 to 199	23	13.1	74.3
200 and over	45	25.7	100.0
Information not furnished	3		

In terms of sales volume, the establishments surveyed, for the most part (77.9 percent of those providing such information), are under the $10 million level annually. A breakdown of sales volumes as reported for 1973 is shown in Figure 3.

Figure 3

Sales Volumes for Surveyed Establishments

Annual sales volume	Number of establishments	Percent of total
Less than $1 million	38	22.1
$ 1 million to $ 2 million	40	23.2
$ 2 million to $ 10 million	56	32.6
$ 10 million to $ 50 million	32	18.6
$ 50 million to $100 million	2	1.2
$100 million to $500 million	4	2.3
Information not furnished	6	

Seventy-one of the establishments, or 40 percent of those responding to the question, reported that they were divisions or subsidiaries of other organizations.

In addition to their manufacturing operations, 71 percent of the establishments providing the information reported having at least one employee engaged in product design activities.

The average number of machine tools* per establishment was 131. We asked each establishment to estimate the percentage of total machine tools falling in each of four age categories. Their responses are shown in Figure 4.

Figure 4

Age of Machine Tools in Surveyed Establishments

Age category	Average percent in category
Under 3 years	13.0
Between 3 and 10 years	34.4
Between 10 and 20 years	31.9
Over 20 years	20.7

*The respondents were asked to include only those pieces of equipment having a unit cost of more than $2,000.

CHAPTER 3

EXTENT OF THE USE OF COMPUTER-RELATED TECHNOLOGY

In the establishments that we surveyed, computer-related manufacturing technology was very limited. Fewer than half the establishments made any use of a computer. Only 23 percent of the 176 establishments furnishing such information had a computer located at the establishment site. From the answers that we obtained to a series of questions relating to the use of computers in activities directly related to manufacturing operations, the uses being made of computers were generally the more traditional accounting and administrative uses rather than the more recently developed manufacturing-related applications.

The only recently developed manufacturing technology being used to great degree was the tape-driven numerically controlled (NC) machine tool. Even this was found to be present to only a limited extent. Thirty-one of the establishments or 17.4 percent had one or more numerically controlled machine tools. Twelve of the 31 establishments had only one such machine tool, and only 1 establishment had as many as 12. In total, the 178 establishments surveyed reported only 124 NC machine tools. This total represents about 0.3 percent of all machine tools reported by the establishment surveyed.

In addition to inquiring as to equipment in place, we asked about planned equipment acquisitions. The responses we received indicated relatively few acquisitions of computer-related equipment through the end of 1975. Again, the only new technology that we found to any degree was the NC machine tool. Twenty-one of the establishments indicated firm plans to acquire such equipment during 1975.

CHAPTER 4

ATTITUDES TOWARD TECHNOLOGY AND GOVERNMENT ROLE

Of major interest to us were the attitudes of manufacturers toward the recently developed manufacturing technologies and their opinions concerning any role that the Government might have in furthering the application of these technologies.

We tried to find out the extent to which manufacturers were satisfied with the performance of any new technology they had thus far employed. The only such technology with which there had been any degree of experience among the establishments we surveyed is the NC machine tool.

We asked those manufacturers that were using NC machine tools to indicate their satisfaction or dissatisfaction with that equipment in three respects: electronic reliability, mechanical reliability, and return on investment. In each of the three categories, the level of satisfaction was high. In no category did more than five of the establishments indicate disappointment.

The manufacturers were given the following responses from which to choose: "very disappointing," "disappointing," "generally as expected," and "better than expected." The 30* establishments that had at least one NC machine tool responded as shown in figure 5.

Figure 5

Manufacturers' Assessments of Performance of NC Machine Tools

	Number of establishments			
Category	Very disappointing	Disappointing	Generally as expected	Better than expected
Electronic reliability	1	4	20	5
Mechanical reliability		2	24	4
Return on investment	1	3	24	2

*One of the 31 establishments with numerically controlled machine tools did not respond to any of the questions concerning his satisfaction with their performance.

To determine the overall views of manufacturers toward computer-related manufacturing methods, we asked two questions. First, we asked each manufacturer to forecast the degree to which it believed that the use of computers in manufacturing could increase in the future in its specific product sector. Next, we asked for an identification of the greatest barrier to growth in the use of computer-aided manufacturing methods.

In general, the manufacturers' forecasts were that only small to moderate growth would take place in the use of computers in manufacturing over the next 10 years. The manufacturers saw high cost as the major deterrent to computer growth, with a lack of understanding of the capabilities of computer-aided manufacturing methods as the second most significant barrier.

As can be seen in figure 6, the manufacturers forecast a greater increase in the use of computers in manufacturing during the 1980-85 period than during the 1975-80 period, but for neither period did the percentage of respondents predicting major growth reach 20 percent.

Figure 6

Manufacturers' Forecast of Increase in Use of Computers in Manufacturing

Amount of increase	Number of manufacturers predicting the amount of increase during the time period	
	1975-80	1980-85
Very little	106 (63.5%)	68 (42.8%)
Moderate	47 (28.1%)	61 (38.4%)
Substantial	14 (8.4%)	30 (18.9%)
Number not responding	11	19

The pattern of expectations regarding growth of computer-related manufacturing methods varied with the size of the establishments. Examining the forecasts of three groups of establishments, we found statistically significant differences, as can be seen in figure 7.

Figure 7

Comparison of Forecasts by Three Sizes of Establishments

Number of employees	Percent of manufacturers forecasting extent of increase use of computers in their area					
	Small		Moderate		Substantial	
	1975-80	1980-85	1975-80	1980-85	1975-80	1980-85
Under 50	69	59	21	25	10	16
50 to 99	73	54	27	37	0	9
100 and over	53	22	33	49	14	29

In the forecasts for each of the two periods, the largest establishments reflect the greatest optimism, having the largest percentage of "substantial" forecasts (14 percent and 29 percent) and the smallest percentage of "small" forecasts (53 percent and 22 percent). The establishments in the 50 to 99 employees range are the most pessimistic about the 1975-80 period, with 73 percent predicting small growth and the remaining 27 percent predicting only moderate growth. These same establishments are fairly pessimistic about the 1980-85 period, having the lowest percentage of "substantial" forecasts. The smallest establishments generally fall between the other two groups on the pessimism-optimism scale.

Although not differing to a statistically significant degree as with forecasts of increased computer use, the same three groups of establishments differ in the proportions of each that viewed high cost as the greatest barrier to increased use of computer-aided manufacturing methods.

The percentage of all respondents citing high cost was 62.2 percent. In the case of the largest establishments (100 or more employees), only 54 percent cited high cost. From the middle-size group, however, 75 percent did so, while the smallest establishments were again between the other two groups at 61 percent.

The entire range of choices as to the greatest barrier to growth in the use of computer-aided manufacturing methods is shown in figure 8.

Figure 8

Choices As to the Greatest Barrier to Growth in the Use of Computer-Aided Manufacturing Methods

Barrier	Number of establishments
High cost	79 (62.2%)
Lack of widespread understanding of capabilities	23 (18.1%)
Threat of rapid obsolescence of selected system	6 (4.7%)
Unfavorable reaction from labor force	5 (3.9%)
Short supply of trained operating personnel	4 (3.1%)
Likelihood of inadequate support from computer system contractor	3 (2.4%)
Questionable reliability of electronic equipment	3 (2.4%)
Questionable reliability of mechanical equipment	1 (.8%)
Inadequate software development	1 (.8%)
Other--suggestions not listed on the questionnaire	2 (1.6%)

Note: Only 127 usable responses were received. Seventeen establishments did not furnish any response and 34 establishments indicated two or more barriers.

A major question being explored in our study of manufacturing technology is to what extent and through what mechanisms the Government should become involved in furthering the use of advanced technology in the manufacturing sector. For this reason we included in our survey a question concerning a possible role of the Government in advancing the state of technological development in the Nation's metalworking industry. We asked each manufacturer in our sample to indicate the way in which it believed the Government could make its greatest contribution.

As was the case with the question concerning the most significant barrier to growth in the use of computer-aided manufacturing methods, there was a clearly dominant choice among the respondents. Nearly 60 percent of the respondents saw the provision of additional tax incentives to stimulate capital investment as being the way in which the Government could make its greatest contribution to advancing the state of technological development. The second choice, at only about 12 percent, was the establishment of a permanent clearinghouse for information on manufacturing technology. Only about 8 percent of the respondents saw no useful role for the Government.

The responses to this question seem consistent with those to the question concerning the barriers to growth in the use of computer-aided manufacturing methods. The manufacturers perceived high cost as the major barrier and the lack of widespread understanding of capabilities as the second most significant barrier. The roles that they selected for the Government are viewed directly at overcoming those barriers. Tax incentives would reduce the cost to the manufacturer of investing in advanced manufacturing equipment, while the clearinghouse would help to overcome the perceived lack of awareness of the capabilities of such equipment.

Thus, what emerges from the responses of the manufacturers to these two central questions of the survey is a clear picture of what, in the view of those most directly involved, must happen if computer-related methods are to make major inroads in the U.S. manufacturing sector. Two hurdles must be overcome, one economic and one informational. Of the two, the more significant, by far, is the economic hurdle.

Figure 9 lists manufacturers' responses to the question "Which of the following do you believe would be the way in which the Federal Government could make its greatest contribution toward advancing the state of technological development in the nation's metalworking industry?"

Figure 9

Responses as to the Greatest Government Contribution Toward Advancing Technological Development in the Nation's Metalworking Industry

Government action	Number of establishments
Provide additional tax incentive to stimulate capital investment	a/92 (58.6%)
Establish a permanent clearinghouse for information on manufacturing technology	18 (11.5%)
Take no new action	13 (8.3%)
Sponsor periodic seminars, discussions, etc., to facilitate the interchange of information	9 (5.7%)
Provide funding to nonproprietary organizations for the development of manufacturing methods	9 (5.7%)
Modify antitrust law provisions to permit increased cooperation among companies	4 (2.5%)
Develop demonstration facilities at Federal manufacturing activities, such as arsenals, repair and overhaul facilities, etc.	3 (1.9%)
Other--suggestions not listed on the questionnaire (note b)	9 (5.7%)

a/Percentages shown refer to the 157 establishments that responded to the question. Twenty-one establishments did not respond.

b/The handwritten responses were (1) standardization of NC language, (2) remove restrictions on importing skilled foreign labor, (3) productivity imprpovement and incentives, (4) subsidize purchases of machine tools, (5) reduce Government spending, (6) reduce taxes and leave us alone, (7) low interest loans, (8) establish standards for computer programs and document the use of them for manufacturing, (9) support the free enterprise approach and maintain equitable competitors.

CHAPTER 5

ESTABLISHMENTS USING NUMERICALLY CONTROLLED MACHINE TOOLS

To gain some insight into the future use of computed-related manufacturing methods, we examined the establishments in which NC machine tools are now in use.

We found that the establishments reporting at least one NC machine tool generally were larger than the other establishments. This is exemplified by the statistically significant differences that we found between the average number of employees and average number of machine tools found in the establishments using NC machine tools and those same averages found in the establishments not using numerical control. Figure 10 compares the two sets of establishments.

Figure 10

Comparison of Number of Employees and Number of Machine Tools for Establishments With and Without Numerical Control

	Number of employees	Number of machine tools
Overall average	236.4	131.3
Establishments with NC	609.8	360.5
Establishments without NC	155.9	83.9

Establishments using numerical control are above the overall average of the establishments in the sample. Figure 11 allows a comparison of the percentages of NC, non-NC, and total establishments that reported sales volumes in each of the several ranges.

Figure 11

Sales Volume Comparison of Establishments With and Without Numerical Control

	Percentage of establishments in sales range				
	Under 1 million dollars	1 million to 2 million dollars	2 million to 10 million dollars	10 million to 50 million dollars	Over 50 million dollars
All establishments	22	23	33	19	3
Establishments with NC	17	13	30	27	13
Establishment without NC	23	25	33	17	1

Forty percent of the establishments having NC machine tools reported annual sales of over $10 million, whereas only 18 percent of the other establishments were at that sales level. Also, while only 1 percent of the establishments without numerical control reported sales of over $50 million, 13 percent of the NC establishments were in that sales range. Three of the establishments with NC reported annual sales of between $100 million and $500 million, while only one of the 136 non-NC establishments furnishing sales data reported sales of that magnitude.

The establishments using NC machine tools were more likely to be subsidiaries or divisions of others organizations than were the non-NC establishments though not to a statistically significant degree. Fifty-five percent of the NC establishments are subsidiaries or divisions, while 37 percent of the establishments not using NC machine tools are in that category.

A much more significant difference between the two groups is apparent in the percentage of each that uses a computer in some way in their operations. Eighty-four percent of the establishments having NC machine tools reported use of a computer. Of the establishments not using numerical control, only 41 percent make use of a computer.

A matter of considerable interest among manufacturers considering the acquisition of NC machine tools is the one of the appropriateness of numerical control for their specific manufacturing operations. Frequently, this is discussed in terms of the general lot size range for which numerical control can make its greatest contribution. It seemed of particular interest, therefore, to examine the average lot sizes for the establishments in our sample that use numerical control.

Although we expected to find a concentration of NC establishments within a rather narrow lot size range, there was a uniform spread over a wide variety of lot sizes, as shown below.

Figure 12

Most Prevalent Lot Size Ranges
As Reported by Establishments Using
Numerical Control

Range of lot sizes	Percent of NC establishments reporting their most prevalent lot size as being in the range
1 to 50	27
51 to 100	20
100 to 500	27
over 500	26

This result may not be indicative that general presumptions regarding the appropriate lot size for numerical control are in error. The limitations of our data should be clearly understood. The data shown in figure 12 resulted from the following question: "In which of the following lot size ranges are most of your production lots?" This question calls for an overall impression and does not in any way refer specifically to the use of NC machine tools. It is quite possible that NC machine tools in the possession of the establishments in our sample are used for work in specific lot size ranges and that most of the establishment's production lots are of a considerably different size.

Only 21 of the establishments surveyed indicated firm plans to acquire NC machine tools during the remainder of 1975. Of these, 14 are establishments currently using numerical control. We found that about 45 percent of the NC establishments planned to acquire additional NC, while only about 5 percent of the non-NC establishments had such plans.

This result is consistent with the previously discussed high degree of satisfaction with NC among those establishments that are using it.

It is probably, at least in part, a result of their satisfactory experience with numerical control that the NC establishments tend to have much greater expectations of growth in the use of computers in their manufacturing area than do the non-NC establishments. Figure 13 compares the forecasts of the NC and non-NC establishments.

Figure 13

Comparison of Forecasts of Growth In Computer Use Between Establishments Using Numerical Control and Those Not Using It

	Percent predicting each degree of increase in computer use		
1975-80	Small	Moderate	Substantial
Establishments with NC	27	46	27
Establishments without NC	72	24	4
1980-85			
Establishments with NC	7	48	45
Establishments without NC	51	36	13

These statistically significant differences might reflect either a difference in ability to make the economic commitments involved in the move into computer-related technology or a difference in perception regarding the capabilities of such technology. On the basis of the overall survey results as to the barriers to growth in use of computer-related technology and the most useful role of the Government in furthering the use of such technology, we believe the former explanation to be the more likely one. Whatever the explanation may be, it is abundantly clear that the two groups, NC and non-NC, have dramatically different expectations concerning computer-related technology.

CHAPTER 6

SUMMARY AND CONCLUSIONS

As stated in chapter 1, the objective of the survey was to obtain an indication of the extent to which computer-related manufacturing technology is being used in the metal-working field and to ascertain the attitudes of manufacturers toward both the new technologies themselves and the role that the Government should play in furthering the use of such technology.

Our survey disclosed relatively moderate use of the technology we set out to find. The only technology that we found in any quantity was the tape-driven NC machine tool; this equipment was found in only relatively small numbers. Although NC machine tool use was not widespread among the establishments surveyed, its performance apparently met expectations.

In the opinion of the majority of the manufacturers surveyed, the major barrier to greater use of computer-related manufacturing methods is the high cost involved. In addition, there is an indication that the level of understanding of the capabilities of computers in a manufacturing environment is as yet relatively low.

Consistent with the manufacturers' stated opinion that high cost is the major barrier is the factual finding that, in general, it is the larger establishments, among those surveyed, that have acquired NC machine tools. Since, in the metalworking area the NC machine tool may be viewed as a basic building block in arriving at computer integrated manufacturing, and the establishments surveyed generally were not large, it seems reasonable to conclude that, under present circumstances, only a small percentage of the manufacturing establishments represented by those surveyed will be employing the more sophisticated computer-related technologies in the near future.

This conclusion could easily be what is being reflected in the rather pessimistic forecasts of the manufacturers regarding future growth in the use of computers in manufacturing. Given the investment cost of newly developed mechanical and electronic hardware, as well as the cost of related software development, and the relatively small size of the majority of establishments surveyed, it appears likely that, in the absence of some dramatic change in the economics of acquiring and operating such equipment, the technological picture in 10 years from now may, as suggested by our respondents, not be drastically different from that found during our survey.

When asked, in effect, how could the Federal Government most effectively accelerate the changing of this technological picture, the manufacturers suggested direct economic assistance in the form of tax incentives to stimulate investment and a clearinghouse of information.

LISTING OF GENERAL ACCOUNTING OFFICE REPORTS ISSUED SINCE JULY 1, 1971, ON TRADE-PROMOTION RELATED MATTERS

OPPORTUNITIES FOR INCREASING EFFECTIVENESS OF OVERSEAS TRADE EXHIBITIONS Departments of Commerce and State	B-135239	November 4, 1971
WAYS TO INCREASE U.S. EXPORTS UNDER THE TRADE OPPORTUNITIES PROGRAM Departments of Commerce and State	B-135239	January 28, 1972
IMPROVED FOREIGN MARKET ANALYSES CAN INCREASE U. S. EXPORTS Departments of Commerce and State	B-172255	July 6, 1972
COMMERCIAL OFFICES ABROAD NEED SUBSTANTIAL IMPROVEMENTS TO ASSIST U. S. EXPORT OBJECTIVES Departments of Commerce and State	B-172255	October 24, 1972
WAYS TO INCREASE FIELD OFFICE CONTRIBUTIONS TO COMMERCE'S EXPORT EXPANSION EFFORTS Department of Commerce	B-172255	November 14, 1972
FOREIGN VISITOR TRAVEL TO THE UNITED STATES CAN BE INCREASED U. S. Travel Service Department of Commerce	B-151399	November 12, 1973
WAYS TO IMPROVE U. S. FOREIGN TRADE STRATEGIES Department of State, Commerce, Agriculture; Office of Management and Budget	B-172255	November 23, 1973
NEED FOR BETTER IDENTIFICATION AND ANALYSIS OF NONTARIFF BARRIERS TO TRADE Departments of State and Commerce, and Office of the Special Representative for Trade Negotiations	B-162222	January 21, 1974

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LOW U. S. SHARE OF WORLD BANK-FINANCED PROCUREMENT Multiagency	B-161470	October 17, 1974
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IMPACT OF SOYBEAN EXPORTS ON DOMESTIC SUPPLIES AND PRICES Department of Agriculture	B-178753	March 22, 1974
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EXPORT OF U.S. MANUFACTURED AIRCRAFT--FINANCING AND COMPETITIVENESS Department of Commerce and Export-Import Bank of U.S.	B-114823	March 12, 1975

STAFF PAPER ON EMERGING CONCERNS OVER FOREIGN INVESTMENT IN THE UNITED STATES	B-172255	Mar. 24, 1975
ASSISTANCE TO THE NONRUBBER FOOTWEAR INDUSTRY Multiagency	B-179342	Mar. 25, 1975
REVIEW OF U.S. GOVERNMENT'S ROLE IN EAST-WEST TRADE	B-162222	Feb. 4, 1976

LISTING OF CURRENT ASSIGNMENTS

INVOLVING TRADE MATTERS

Title	Estimated Completion Date
Study of the Objectives, Policies, and Accomplishments of the Public Law 480, Title 1, Concessional Sales Program	July 1976
Agency Action on Recommendations in Commodity Shortage Report	April 1976
The Administration of Buy American Policies and Their Impact Upon Domestic Industry, International Balance of Payments, and Internal Inflation	July 1976
Study to Determine Feasibility of Assessing Impact of Direct Foreign Investments on Local Communities	March 1976
Review of U.S. Quantitative Import Restrictions	April 1976 - June 1976
Review of U.S. Trade Policy Toward Developing Nations	April 1976
Review of Agriculture's Implementation of GAO Recommendations on Commercial Intelligence System	May 1976
Follow-on Review of Overseas Trade Centers and Exhibitions	May 1976

Automation Opportunities in the Service Sector

Report of the Federal Council for Science and Technology
Committee on Automation Opportunities in the Service Areas

1. Introduction

The Federal Council for Science and Technology in May 1971 commissioned the Committee on Automation Opportunities in the Service Areas. The Committee was charged with recommending "technological possibilities, with particular emphasis on automation techniques, for reducing the cost of delivering services in areas of government interest, such as education, health, housing and transportation services."

3.4 The Automation Industry

Automation is accomplished through such a wide range of diverse technologies and applications that it is virtually impossible to define an "automation industry."

An industry is roughly defined as a group of companies which supplies a given product (or service). The steel industry is comprised of the suppliers of the product, "steel." These suppliers have a number of characteristics in common and jointly serve the customers for steel. Although there is a wide variety of products all classified as "steel," there is a significant, clearly perceived commonality among the producers so categorized.

There is not yet an identifiable group of firms which can be said to supply "automation products." Indeed, automation products have more characteristics that separate them than unify them. In addition, only a small portion of all firms which supply automation products, supply only—or even principally—automation products. Quite frequently, a supplier offers a given product or machine in both "automated" and "non-automated" form.

This present inability to identify an automation industry is indicative of the diffuseness, both as to product and to customers, associated with a young immature industry.

The relative immaturity of the automation industry is borne out by ratios of the sales of selected automation products to the total market for the product in question. For example, the present-day situation can be exemplified as follows:

Market For	Related Automation Product	% of Market Held by Automation Product
Machine tools	Numerical-controlled machine tools	20
Control instrumentation	Automated test equipment (ATE)	6
Material handling equipment	Automated material handling	2

Some of those suppliers which can be identified as providing typical automation products together with estimates of sales include:

AUTOMATION PRODUCT SUPPLIERS: ESTIMATED U.S. SALES: 1972

	Dollars (in Millions)
Computer and Related Equipment Manufacturers	
General Purpose Systems ..	6635
Minicomputers	645
Peripheral Equipment	745
Remote Terminals	150
Software Product Companies ...	405
Process Control Equipment Manufacturers	
Special Purpose Computers..	100
Process Control Devices ...	245
Numerical Control Tool Manufacturers	200
Industrial Robots Manufacturers..	7
Material-Handling Machine Producers	41
Automatic Test Equipment (ATE) Manufacturers	95
Special Purpose Automation Suppliers	
Factory Data Collection	60
Automated Photo-typesetters	75
Total	9403

The non-existence of an automation industry hampers the development of institutional structures coupling automation suppliers to service industry customers. Hospitals, for example, have difficulty in dealing with the disaggregated and large numbers of instrument suppliers, computer manufacturers and medical record services.

Similarly, the standardization of automation products—a necessary prerequisite for the diffusion of automation—falls, by default, to customers rather than to the suppliers. This is evidenced by the legislated requirements on the Federal Government to develop Federal information processing standards for automated data processing in lieu of awaiting industry standards.

The research and development necessary to improve and advance automation is necessarily fragmented with much resulting indirection. This is most apparent in the more intellectual research efforts epitomized by artificial intelligence, information theory, control system theory, etc., all of which are highly relevant to the newer applications of automation.

Finally, the lack of a definable automation industry leads the writers of this report to direct their findings and recommended actions principally to the service industry customers for automation products, the consumers of services and to government officials. Indeed, the burden of managing automation today falls on its users rather than on its suppliers.

2.3 Automation

The term, automation, has never been clearly defined. It has grown in scope in recent years to include the use of machines and devices to assist as well as replace human control function. Automation technology, in turn, appears to be describable as a set of four supporting technologies; namely, sensor, control, actuator and coupling technology. These technologies are undergoing rapid change at disparate rates. There is no overall governmental support for automation technology at this time.

Automation is a process which has already grossly changed the agriculture industry through mechanization that has dramatically improved productivity and reduced the percentage of the national labor force engaged in farming from over 50% in the 1950's to 4.5% in 1970.

Automation is widespread in manufacturing but has not yet saturated it as was the case in agriculture. Automation has not had the dramatic effect on productivity and labor movement in manufacturing as it did in agriculture. One reason for this difference is the institutional mechanisms employed by unionized labor in manufacturing to control and slow the spread of automation.

There is no identifiable automation industry supplying automation products. The present inability to define an automation industry is indicative of the diffuseness, both as to product and to customers, associated with a young immature industry.

The lack of a structured automation industry hampers the development of institutional structures coupling automation suppliers to service industry customers. In fact, today, the burden of managing automation falls on its users rather than on its suppliers.

The automation market is disaggregated; standardization, the necessary prerequisite to widespread application is virtually nonexistent and research and development in automation technologies is fragmented with much indirection.

LISTING OF FINDINGS AND RECOMMENDATIONS FOR ACTION

- The Service Sector has provided fertile ground for meeting certain national goals which are in conflict with traditional marketplace objectives. Examples include equality of education and absorption of unemployed laborers from other sectors of the economy and national defense. Industry, the public and government have not demanded or expected typical business pricing practices, output levels or quality throughout the Service Sector. Thus, the Service Sector is a good area to which national policies for nationwide benefits can be applied.

- Government and government controls already are widespread in certain service areas—particularly public services and government administration. Thus, Federal intervention is commonplace and would not be considered as a surprise to the Service Sector industries or the consumer public.

- The Federal Government should take the lead in initiating efforts in the national interest where the motives for automation are compelling, namely in:

  1. Services in environments hazardous to people or harmful to their safety.
  2. Satisfying the increasing public demand for accountability in the provision of public services and for protection of individual rights, such as privacy.
  3. Services that are tedious, boring or demeaning for people to do and are therefore performed poorly by people.
  4. Services that demand faster operations than can be performed by people.

- The major percentage increases in employment in service areas in the 1960-1970 decade occurred in State and local government services, education, health care and welfare. Major percentage increases are anticipated in these same areas in the 1970-1980 decade. The increased employment in State and local government and public service areas is directly attributable to:

  1. Increased public demand for government support (in whole or part) of those services deemed to be for the public good.
  2. Increased public demand for accountability by government and the suppliers of public services.
  3. Increased public demand for equality of service availability and quality independent of geography, personal income, age, race, color and sex.

- Government services, especially at the State and local levels, are plagued by low productivity.

- The Federal Government should take action, in conjunction with State and local governments, to improve productivity through the use of automation, especially in automated information handling and recordkeeping.

- The consumer public is accustomed to government paying for all or a part of many services received. In addition to public services, the government, for example, pays some of the costs of transportation, utilities, communications, pollution control and environmental services. The exertion of leverage by the government on such service areas is thus expected or accepted by the public.

- The Federal Government should accelerate, in the national interest, its participation and/or intervention in rapid mass transit, health care, communications, education, environmental services and postal services. It can do this without anticipation of any negative public reaction.

- There is widespread consumer dissatisfaction with services—much more so than with goods or products. There is thus an immediate need for technological innovation, incentives for service improvement and better practices in service supply. Based on its previous activities in the Service Sector, the Federal Government should take a lead role in dissipating consumer dissatisfaction with services through these types of actions. The areas where government interest and intervention are most needed are in equipment maintenance and repair services.

- Since customer participation is typical of service transactions, any innovations and changes in practices or policies in the Service Sector contemplated by the government must take into account the customer. Government planning and policy must anticipate the inclusion of the consumer in service transactions and must be predicated on consumer acceptance if success is to be achieved. The Federal Government should actively encourage existing consumer groups or should encourage the establishment of public or consumer groups to work with it in introducing automation to best meet the public needs and serve the public interest.

- Major technological innovation as well as research and development activities in the Service Sector will probably have to involve the Federal Government. The reasons include 1) the typically small size of service firms, 2) the third-party role played by the government in assuming part of many service costs, 3) the lack of consumer information as to quality and price of services, and 4) the potential of the Service Sector in achieving national goals.

- The principal experiences with automation in the Service Sector have been in the applications of computers and the mechanization of paper handling. More government R&D investment has been made in automation in the Service Sector than in other segments of the economy. This has occurred because:

  - Public services are partially or totally funded by government.
  - The Federal Government provided most of the R&D funding in computer technology in the first fifteen years of development (1950-1965).

- The Federal Government should convince itself of what seems to be of national benefit, namely, it is playing similar roles in the automation technologies of control, activators, sensors and coupling to the role it played in computer technology. In this instance, through procurement practices and encouragement of capital investment by the private sector, the Federal Government would accelerate areas of civilian technology of proven worth in the domestic and international marketplace.

- The government is the primary agent through which society can act to resolve conflicts between societal goals and institutional practices. The role of the Federal Government in this regard is particularly important for Service Sector problems because of the lack of understanding of Service Sector institutions and their practices by the public, and also because of the disaggregation of the consuming public for services.

- Presently, there is no methodology for dealing with Service Sector institutions, their practices in or their impact on the innovation or diffusion of technology. Possibly the best means available to the Federal Government in this situation—in addition to encouraging the development of such a methodology—is to use examples of institutional practices as learning vehicles. This approach necessitates increased involvement by government and more intensive documentation of on-going situations in which institutional practices are impeding innovation in automation within the Service Sector. The Federal Government can and probably should deal first with these barriers as they mitigate against automation innovation in governmental or public services.

- The Federal Government should accelerate efforts to properly measure and assess the outputs of the Service Sector. The inadequacies of the productivity measure have been identified and so has the lack of alternatives to productivity as a measure for assessing the performance of the Service Sector. Sponsorship or support of a Productivity Institute concentrating solely on the traditional measure might mitigate against developing such better alternatives. Experience suggests that Federal agencies should take the lead in conjunction with State and local government and the private sector in supporting separate institutional efforts for measuring performance and output in individual public services; e.g., health care, education, communications, transportation, and government services. These separate institutionalized efforts should emphasize means for reflecting service quality. They should also emphasize the development of curricula in academia that further education in measures of Service Sector performance:

• The Federal Government (perhaps through the FCST) should initiate immediate efforts to improve understanding and/or use in services, of:

1) Standardization

2) Division of labor practices

3) Automation technologies, per se

4) Appropriate legal, regulatory and procurement procedures

5) Automated information handling practices

6) A wider mix of resources, e.g., capital as well as labor.

• The Federal Government should make special efforts to work with organized labor, and similarly encourage the private sector to do so, in planning for automation. This will ensure that the compelling motivation for automation that transcends individual or privileged group interests can be met while not increasing undesirable labor replacement or displacement.