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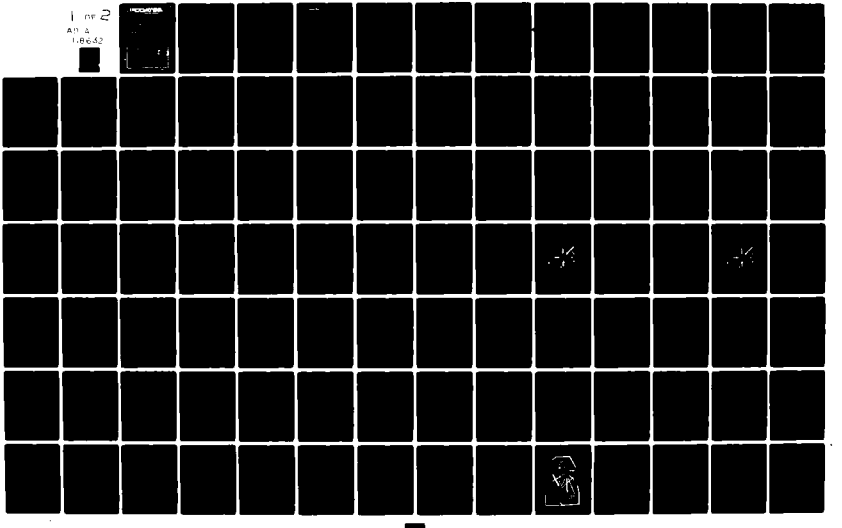

J.F. COATES INC.

METRIC USE IN THE MACHINE TOOL INDUSTRY

A STATUS REPORT AND A TEST OF ASSESSMENT METHODOLOGY

W. Edward Cushen

April 20, 1982

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This study served a dual purpose of testing the most promising methods of assessing metric status in the United States while providing an assessment of the current status and progress of metrication activities of the machine tool industry. The machine tool industry provides capital equipment for other manufacturing industries including the automotive, aerospace, construction, and farm machinery industry. It is a small but critical segment of the national economy.

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20. Continued

There have been a number of studies of industrial metrication, but they dealt with broad categories of industry and provided little detailed information about specific industries or about the process. This study draws directly on the experience of industry companies and on data from many public and private sources. It emphasizes the present and potential interactions of metrication with other issues and problems facing the machine tool industry.

Some of the major findings are:

(1) Metrication is progressing slowly but steadly in the U.S. Machine Tool Industry.

(2) The U.S. Machine Tool Industry meets overseas demand and the small domestic demand for metric tools by building metric-capable machines.

(3) The serious decline of the U.S. share of the world market has been somewhat masked by the fact that the dollar volume of U.S. overseas sales has increased.

(4) Because of the paucity of data, assessment of metric status in specific industries cannot be handled through econometric modeling or aggregation of massive amounts of statistical data.

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METRIC USE
IN
THE MACHINE TOOL INDUSTRY

A STATUS REPORT AND A TEST OF ASSESSMENT METHODOLOGY

W. Edward Cushen

April 20, 1982

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PREFACE

The U.S. Metric Board was established in 1978 to help industries, companies, government, and other private and public sector groups who chose voluntarily to convert to use of the metric system of measurement. The Metric Board was also instructed to report to the President and the Congress, and to inform industry and the public about the status of metrication in large and small businesses, and to support it in carrying out this mandate.

This study, performed for the U.S. Metric Board by J.F. Coates, Inc., is an exploratory assessment of the status of metrication in the machine tool industry. It demonstrates the use of several analytical techniques which would be useful in status assessments of other industries. The study relied heavily on structured and informal discussions with more than one hundred people involved with the machine tool industry. The Principal Investigator thanks them for their invaluable assistance. Members of the Machinery Sector Committee of the American National Metric Council gave generously of their time and their knowledge of the industry and are due special thanks. Mr. John Deam of the National Machine Tool Builders' Association (NMTBA), Ms. Karen Horowitz of the Bureau of Labor Statistics (Dept. of Labor), and numerous industry personnel also provided invaluable assistance. At the Metric Board Eugene Visco, Stanley Parent, David Freund, and John Tascher provided valuable guidance and advice throughout the project. At J.F. Coates, Inc., Joseph F. Coates contributed heavily to the logical design and inferential work of the project; Henry Hitchcock and Vary T. Coates were effective collaborators and critics; Vary Coates edited a mass of near-final manuscript into a shorter, well-ordered report; the production of the report was the responsibility of Rhoda Baum who was assisted by Bernice Mann, Barbara Bullard and Christopher Thiel; Suzanne Nettles did some of everything and all very well.

EXECUTIVE SUMMARY

Sponsored by the U.S. Metric Board, this study is an assessment of the status of metrication (conversion to the use of metric measurement) in the United States machine tool industry. The study tested and evaluated several methodological approaches which will be useful in further metric status assessments or in studying the diffusion of other technological changes. The study will be of value to the industry, to consumers, and in carrying out the functions of the Metric Board.

There have been studies of industrial metrication, but they dealt with broad categories of industry and provided little detailed information about specific industries or about the process of metrication. This study draws directly on the experience of industry practitioners and on data from many public and private sources. It emphasizes the present and potential interactions of metrication with other issues and problems facing the machine tool industry.

The machine tool industry provides capital equipment for other manufacturing industries including the automotive, aerospace, construction, and farm machinery industry. It is a small but critical segment of the national economy. Findings of the study are summarized below.

- METRICATION IS PROGRESSING SLOWLY BUT STEADILY. The machine tool industry is strongly oriented toward meeting customer-defined needs. Its major customers are increasingly using metric dimensions in design and manufacture. They are pulling the machine tool industry gradually into metrication.
- OTHER IMPORTANT FACTORS are the desire of multinational corporations to have U.S.-produced machines compatible with those used in their overseas subsidiaries, and the dawning recognition by the machine tool industry that its share of the overseas market is eroding. Imports, especially Japanese imports, are also making inroads on domestic markets.
- Metrication is not a primary factor in meeting the growing challenge facing the machine tool industry, but ACTIONS CALCULATED TO DEAL WITH THIS CHALLENGE ARE LIKELY TO PROVIDE AN IMPETUS TOWARD FURTHER METRICATION.

• THE AMERICAN MACHINE TOOL INDUSTRY MEETS OVERSEAS DEMAND AND THE SMALL DOMESTIC DEMAND FOR METRIC TOOLS BY BUILDING METRIC-CAPABLE MACHINES. There is evidence that about ten percent of total sales now involves metric-capable products and for some companies the proportion is about thirty percent. The demand is perceived to be growing, but to be growing very slowly.

• PROGRESS IN METRICATION IN THIS INDUSTRY IS NEARLY ALWAYS ASSOCIATED WITH INTRODUCTION OF A NEW PRODUCT LINE. This product line decision usually follows a policy decision by corporate management to convert new product lines to metric in some degree when economically desirable.

• While adoption of new manufacturing technologies like industrial robotics and flexible manufacturing systems do not require metrication, THE SPREAD OF NEW TECHNOLOGIES MAY SPEED UP CONVERSION TO METRIC USE.

• THE MAJOR FACTORS INHIBITING METRICATION are the large stock of customary unit machine tools already on hand, the long lifetime of these tools, which are generally major capital investments, and the large customer demand for machine tools built to customary units.

• But 36 percent of machine tools in this country are now imported. Japanese-built machine tools are of a quality comparable to domestic products, generally cheaper than American equivalents, and backed up by excellent delivery, service, and repair. Since Japanese and other imported machine tools are normally hard metric, although they have customary unit capability, the total stock of metric machine tools in U.S. industry is increasing more rapidly than the outputs of the U.S. machine tool manufacturers would indicate. THIS WILL TEND TO ELIMINATE THE RESISTANCE TO METRIC TASKS WHICH COMES FROM LACK OF FAMILIARITY.

• THE SERIOUS DECLINE OF THE U.S. SHARE OF THE WORLD MARKET HAS BEEN SOMEWHAT MASKED by the fact that the dollar volume of American overseas sales has increased. American companies now rank a poor sixth in share of sales, far behind West Germany and Japan. The world market is four times as large as the domestic market. Since the large backlog of orders has largely disappeared, there is new interest in international marketing efforts, and this overseas market should be more vigorously pursued.

• THE GENERAL EFFECT OF A STRONGER WORLD MARKET ORIENTATION WOULD LIKELY BE TO SPUR METRICATION. Several large U.S. manufacturers have recently introduced metric-capable product lines aimed at the world market, and one major company has introduced a hard metric product line.

• MACHINE TOOL MANUFACTURERS DO NOT SEE CONVERSION TO METRIC USE AS AN IMPORTANT ISSUE. It does not promise to solve their problems, but much of the early fear of and resistance to metrication has faded.

• THERE ARE COMPLAINTS ABOUT THE LACK OF EXPLICIT FEDERAL POLICY regarding metrication. Government procurement policy, including Department of Defense procurement policy, is a source of confusion and dissatisfaction.

• DEFINITION OF TERMS MUST BE EXPLICIT WHEN ASSESSING METRICATION. Especially when the assessment involves self-reporting by industry, it is essential that terms be carefully defined. A machine that is designed in metric units and built from metric-dimensioned stock and components is "hard-metric." It may still have some customary-unit components. A metric-capable machine tool is one that can form or cut to metric dimensions regardless of the dimensioning of its components. A machine designed and built in customary (inches, feet, pounds) can be made metric-capable by attaching metric dies and tooling, by use of metric molds, by dual readouts or settings, or by translating metric instructions into customary units. Numerically-controlled (NC) machines have for over a decade provided both customary and metric capability.

• BECAUSE OF THE PAUCITY OF DATA, ASSESSMENT OF METRIC STATUS IN SPECIFIC INDUSTRIES CANNOT BE HANDLED THROUGH ECONOMETRIC MODELING OR AGGREGATION OF MASSIVE AMOUNTS OF STATISTICAL DATA. The data which exists is often confused and conflicting because of varying interpretations of basic terms or because the data are considered proprietary. Surveys using in-depth discussions with practitioners in the factory, supplemented by qualitative descriptive analysis of the behavior of representative companies, is an appropriate and relatively low cost approach to status assessment. Such studies can produce information of practical value to the industry and to public sector decision makers.

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ABBREVIATIONS USED IN THE REPORT

AISI - American Iron and Steel Institute

ANMC - American National Metric Council

BEA - Bureau of Economic Analysis (Department of Commerce)

BLS - Bureau of Labor Statistics

CGPM - Conférence Générale des Poids et des Mesures (General Conference on Weights and Measures)

CIM - Computer-Integrated Manufacturing

CNC - Computer Numerical Control

DOD - Department of Defense

DODISS - DOD Index of Specifications and Standards

EEC - European Economic Community

FMS - Flexible Manufacturing System

GAO - General Accounting Office

GATT - General Agreement on Tariffs and Trade

GNP - Gross National Product

GSP - Generalized System of Preferences

I-O - Input-Output

ISO - International Standards Organization

MAPI - Machinery and Allied Products Institute

MFN - Most Favored Nation

MSG - Metrication Steering Group

MVMA - Motor Vehicle Manufacturers' Association

NATO - North Atlantic Treaty Organization

NBS - National Bureau of Standards

NC - Numerical Control

NGT - Nominal Group Technique

NMTBA - National Machine Tool Builders' Association

SI - Système Internationale des Unites - The International Metric System Units

SIC - Standard Industrial Classification

CHAPTER I

INTRODUCTION, FINDINGS. AND RECOMMENDATIONS

This report describes the use of the metric system of measurement in the American machine tool industry. The U.S. Metric Board, established to help U.S. industry with voluntary conversion to the metric system, is required to report annually to the President and the Congress on the status of metric use in the United States. One of the concerns of the Metric Board has been the development of improved ways of measuring or evaluating that status. The study reported here was designed both to contribute to knowledge of the status of metric use in American industry and to test and illustrate useful techniques for futher assessments of the same kind.

The test of any method lies in its ability to yield useful information in an application. The application area selected in this study was the machine tool industry. That industry was selected because it is critical to all of manufacturing. The machine tool industry makes the machines that make other machines: automobiles, aircraft, weapons, farm and food processing equipment, construction equipment. The machine tool industry might therefore be the key to what happens elsewhere. But this study revealed that the machine tool industry is not leading the move to metrication, but being pulled along by its customers.

The assessment of metric use in the machine tool industry was an exploratory search rather than exhaustive research; but it provides some substantive information not previously available.

The U.S. Metric Board, as sponsor of the study, will be the primary and first user of this report in making its annual reports to the President and the Congress. The information provided by the study should be useful to users in the private sector and in other government agencies.

Objective information about industry use of metric measurements and about either benefits or problems associated with conversion to metric has been lacking until recently. Even the definition of metric use or metrication has often been confused and confusing. The findings of this study have inferences about future data and research needs. and technical assistance services that should be used in program planning by the Metric Board and other government agencies having a role in industrial revitalization and foreign trade.

The machine tool industry, individual companies, and the trade associations serving them, still have mixed feelings about metrication, and little information or consensus about its future. This report provides information about what is going on wi respect to metrication, and what the interim results have been in those cases where metrication has been introduced. Companies have had mixed experiences with respect to the need for metric products in exports, and they have mixed observations on what is happening in the import situation. A status report on the extent to which metrication has assisted in penetrating foreign markets is of great interest to industry planners and management. At the same time this information can help policy makers identify possible needs for legislation, administrative barriers that could be removed, and gaps in information needed to make good public policy decisions. Finally, the report provides a projection of some likely future developments affecting machine tools which sounds an alarm about the competitive health of this essential industry.

This report has a dual purpose: (1) to provide a report on the status of metric use in the machine tool industry, and (2) to test the extent to which various ways of measuring that status will yield useful information. The conduct of the study required a continuing cross-walk between fact and method. The information about major forces at work in the industry came from extended discussions and consultations with those in the industry, not from books or earlier studies. Those consultations, in turn, suggested the use of graphic methods of portraying how those forces interacted. Those methods, and others which the study team had identified in earlier work for the U.S Metric Board (see Chapter VII), in turn suggested the need for numerical data that may exist only in proprietary form. This suggested the use of input-output analysis, but the data and the coefficients needed for projection had to be estimated by the industry experts. Each step in the analysis required a sharpening of definitions of metric, status, use, and the machine tool industry. Each step also required the coöperation of the industry, and innovation in adapting methods to fit assessment needs.

THE METRIC SYSTEM - DEFINITION

The metric system is defined in the Metric Conversion Act of 1975 (P.L. 94-168) as "the International System of Units as established by the General Conference of Weights and Measures in 1960 and as interpreted or modified for the United States by the Secretary of Commerce."[1] The international body known as the General Conference on Weights and Measures (Conférence Générale des Poids et des Mesures--CGPM) adopted this "Système International d'Unites" in 1960, and has subsequently updated it. The amendments of SI for United States usage, announced by the Assistant Secretary for Science and Technology of the Department of Commerce in two Federal Register notices in 1976 and 1977, [2] are inconsequential for this industry--for example, the unit of length is spelled "meter" instead of the English "metre." For the machine tool industry, the metric system primarily means measuring length in meters and millimeters; and measuring weight (mass) in kilograms and grams, rather than the English units of measure: the inch, foot, yard, and pound.

The process of conversion to the metric system is often called "metrication." The National Bureau of Standards has defined metrication as "...any act tending to increase the use of the metric system (SI), whether it be increased use of metric units or of engineering standards that are based on such units." [3]

It is easy to translate from one measurement system to the other, e.g., one inch to 25.4 millimeters. This, a simple way to convert to use of the metric system would be simply to relabel all dials, scales, and readouts from their former customary notations to the new metric notations. Engineering drawings, handbooks and catalogs could be similarly modified, and no physical difference could be seen in the finished workpiece. This kind of conversion to metric is called "soft conversion" and is often accepted as being a reasonable solution to the requirement for delivering a "metric product." Many producers of machine tools regard themselves as having metricated because the sell numerically-controlled (NC) or computer-numerically-controlled (CNC) machines that have an inch-millimeter selection switch and a corresponding dual readout scale.

The use of both metric and customary units on the same drawing is called "dual dimensions." When dials or gages show both metric and customary units, this is "dual indication." At the other end of the scale is "hard metric" conversion; i.e., the physical dimensions of the workpiece are changed so that it measures some multiple of metric units rather than a multiple of customary units -- e.g., 50 millimeters (1.968 inches) rather than 2 inches (50.8 millimeters). Equipment that has a mixture of components, some in customary and some in metric units, are called hybrids.

In the machine tool industry, a distinction is made between a "metric-capable" machine tool and a machine tool of metric design and fabrication. A metric-capable machine tool is one that can cut or form metal to metric dimensions. A machine tool that is built from all customary components, but has NC controls is "metric-capable." Even "hard metric" machine tools made in the U.S. typically still use fasteners (bolts, nuts, and screws) that are dimensioned in customary units. Their gears, hydraulic systems, and electrical systems are normally customary as well.

There are still some differences in the usage of these various terms--"soft metric," "hybrid," and "hard metric," since there is no published standard definition of these terms in the industry. This has distorted the interpretation of results of some earlier studies of metrication. This study made special efforts to avoid this confusion.*

The companies contacted in this study often criticized the lack of clarity in government procurement intentions concerning metric purchases. They report very little positive guidance, even from the Defense Department, that is useful to them in their corporate planning.

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* In this study, each company representative who was interviewed described his company's progress toward the use of metric measurements and components in his own words, either in face-to-face discussions or in question-and-answer exchanges. This made it possible to describe Company XYZ's metric status in precise and detailed ways. Based on these discussions a profile of measures of the extent of metrication for each company was developed, and these were then projected into a set of measures of the extent of conversion of the machine tool industry as a whole. Privileged information has been protected from disclosure in this report.

THE FINDINGS

- The American machine tool industry is slowly moving toward conversion to the metric system; it will continue to do so.

- The industry has so far satisfactorily met the demands of both domestic and foreign customers for metric machine tools by providing either metric-capable machines or NC and CNC machines with dual selection switches and dual readouts.

- Evidence strongly suggests that sales of metric-capable products in the industry average about ten percent of total sales. The range appears to be 0-30 percent. Several companies have introduced hard metric product lines and intend to introduce others.

- There is a significant, growing demand for metric-capable machine tools in the domestic market, especially in the automotive, construction, and farm machinery industries. This demand is probably the strongest factor pulling the industry toward metrication.

- Other significant forces driving toward further metrication are the increasing interest in the export market, and decisions by multinational corporations to make domestically produced machines compatible with the machine tools and components produced in their overseas subsidiaries.

- The major force that has retarded conversion to metric in the machine tool industry is the very large volume of domestic sales without any requirements for metric measurement. Other inhibiting factors are: the backlog of domestic orders, now decreasing; the long life of machine tools; some residual concern about costs of metrication; and occasional to frequent limitations on supplies of metric materials and components.

- Metrication proceeds by selective introduction of new product lines with metric dimensions. Retrofit of old product lines is unusual except that numerical control may be added. Some retrofitting occurs but not extensively.

- The U.S. machine tool industry has a declining share of the overseas market, which is four times the size of the domestic market. The decline in overseas market share has been partially masked by the fact that the dollar value of machine tool exports has continued to rise.

- The most serious threat to the U.S. machine tool industry is Japanese product lines, which are metric designed and built but usually "customary-capable," and which are of comparable quality to the American product and less expensive than their counterparts, and are backed up with excellent service, maintenance, and speed of delivery.

- Metric conversion will not solve these problems. There is some indication, however, that some countries may strengthen their requirements for metrication in imports in the future. Some, but not all, industry participants believe that metric capability makes American products more attractive in overseas markets. Most doubted that hard metric would noticably enhance sales.

- New manufacturing technologies such as FMS (flexible manufacturing systems) robotics, and new materials do not necessarily entail an accelerated transition to use of the metric system. But adoption of these technologies may be accompanied by a simultaneous adoption of the metric system in new product lines. Japan is a major competitor in supply of all of these technologies.

- The metrication issue is regarded by the industry as of secondary importance. Attitudes toward metrication differ widely, from indifference to mild enthusiasm, to disappointment that it has not come rapidly, to hostility. Most, however, agree that the industry will be thoroughly metricated within a generation. "Metricated" here usually means metric capable rather than hard metric.

- Data on metric conversion in the machine tool industry has been almost non-existent until this study. The same is probably true for most subsectors of U.S. industry. A wide variety of analytical techniques are useful in assessing the status of metric conversion, but because of the paucity of data, informal surveys of industry participants are probably the most useful and cost-effective approach.

- Companies need better information on the status of metrication within their industry, the status of metrication in supplier and customer industries, and the implications of that status for the industry's competitiveness in domestic and world markets. At present, corporate decisions about metrication are made in the face of considerable uncertainty and lack of information.

• In some metric studies folklore and hearsay have been converted to numbers. In any future study of metric use there should be careful definition of what is meant by metric. Questionnaires, while useful, can provide misleading and unactionable information in this area. Personal interaction with industry experts is essential. Anecdotes about the extent of metrication that had been accepted as true failed to survive pointed questioning in discussions with experts. The true market value of metrication is not yet known.

• Government policies leading to a revitalization of industry, and to increased export promotion are needed quickly. Although this broader concern was not an assigned topic, the questions related to metric were all dominated by these larger issues, and there was a large majority of experts who felt that this urgent need should be reported.

RECOMMENDATIONS

1. Assessments of the status of metrication in important industries should continue and should be made widely available to companies within that industry and in related industries.
2. Government policy concerning metric conversion should be clarified and publicized. The Federal government should in particular make known timetables and plans for use of metric standards in government procurement, especially DOD procurement.
3. The relationship between metrication and U.S. competitiveness in foreign markets needs further exploration. If a strong positive effect can be shown, the government should consider incentives, or a positive mandate, to speed conversion to metric.
4. The development of improved indicators and techniques for evaluating the metric conversion status of individual industries merits further effort. However, relatively simple and low cost techniques demonstrated in this study can provide information valuable to both government and industry.

CHAPTER II

INDUSTRY EXPERIENCE WITH METRIC USE

Preview: This chapter describes the study approach and summarizes the results of in-depth discussions with one hundred people in the industry.

"Metric status" is best evaluated by using multiple indicators, including:

- Explicit statements of company policies or decisions to take specific conversion actions.
- Management attitudes about metric usage.
- Company activities relating to metric usage, such as the existence of a metric coordinator or committee, surveys of suppliers or customers having or wanting metric products, etc.
- Metrication of company product lines, stock, and capital equipment.
- Volume of sales of metric-dimensioned items.
- Metric status of customers.
- Metric status of suppliers.

Since metrication is itself a process, parts of which are reversible, evaluation of metric status includes histories, current thrusts, trends, decision rules, and forecasts of future actions under various assumptions.

Research techniques used in this study included:

- Review of published literature on conversion to metric by U.S. industry to abstract data on the machine tool industry,
- Collection of data from a variety of government and industry sources
- Structured discussions, using nominal group techniques, with industry representatives on the American National Metric Council (ANMC),
- Extensive unstructured telephone consultations with representatives of the industry, its suppliers and customers, and trade associations.
- Telephone discussions with university professors who train managers and engineers for the industry,
- A series of analytical and forecasting procedures using the data gathered during the above steps.

The results of the discussion and consultations are reported in this chapter. The results of the literature review are reported in Chapter III. Chapters IV, V, and VI report additional data and our further analysis.

INDUSTRY SPOKESMEN: American National Metric Council (ANMC)

The November 18, 1981 meeting of the American National Metric Council's Machinery Sector Committee in Chicago offered an attractive opportunity to build on the collective judgments of the industry experts in defining the scope of an assessment of metric use in the machine tools industry.

Twelve committee members representing the machine tool builders, the machinery industries that are the main consumers of machine tools, and manufacturers of tools and tooling participated in an informal but structured discussion of the problems of measuring the status of metric use in the industry, and then in a Nominal Group Process Technique session which captured their own evaluation of metric status.

As a result of discussions with the committee, the study was more sharply concentrated on SIC codes 3541 and 3542,* to achieve focus within the limited time and resources allocated. The project was not limited to hard metrication since the industry provides metric capability when needed through the use of metric tooling or dual readout NC and CNC machine tools. The study should examine a number of forces favoring and retarding the use of metric capable machine tools, and machine tools having metric design. Commonly used definitions of metric use, metric conversion, hard and soft metric, and similar terms should be carefully refined (committee members themselves used the terms in slightly different ways). Several possible indicators of metric conversion status were suggested, such as volume of sales, statements of company policy, etc., but committee members had no hard recommendations on this subject.

The nominal group session encouraged the committee members to arrive at collective judgments about metric conversion within their industry. These are summarized below; it should be noted however that opinions on each of these points were not necessarily unanimous.

Customers of the machine tool industry, rather than the industry itself, will determine how far metric conversion goes. The customer decision on what to buy is guided primarily by (a) the need for the machine tool, (b) the quality of the machine, (c) the price and delivery date, and (d) the availability of spare parts and service.

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* Standard Industrial Classification (SIC) 3541 includes companies whose major products are metal cutting machine tools. SIC 3542 includes companies whose major products are metal-forming machine tools.

Metric needs are adequately handled by delivery of metric-capable machine tools. Requirements for either hard metric or metric design do not exist at present. Exports may need to be accompanied by metric documentation.

Forces favoring the domestic use of metric capable machine tools and metric design machine tools are:

-- multinational corporation design and production, *
-- export market opportunities,
-- the need to meet competition from imports,
-- the need to meet domestic competition,
-- government requirements,
-- long term reduction of costs.

Forces retarding the introduction of metric capable and metric designed tools are:

-- lack of domestic demand for metric products,
-- lack of standards for metric design,
-- unfamiliarity with metric units,
-- lack of executive/management interest,
-- lack of active interest in exporting,
-- perceived excessive conversion costs,
-- fear of import penetration,
-- slow obsolescence rate of existing machines.

With reference to metric design (hard metric) especially strong forces are:

favorable	inhibiting
- influence of multinationals	- perception of costs
- international compatibility	- lack of availability of metric components
- licensing ability	- lack of standards, handbooks
- customer demands if they exist	- lack of government mandate or purchase
- new technology	- long product life
	- human resistance

* Forces listed in this section are explained and discussed in later sections.

In the future, three developments could strongly encourage metric conversion: increased emphasis on worldwide marketing, increasing competition where metric capability gives an advantage, or "foreign developments," such as GATT agreements or European resistance to customary or soft metric products. Other developments that would favor metrication are demand for metric capable tools by major industries, and government incentives, rules, or regulations.

TELEPHONE CONSULTATIONS

Machine tool manufacturers were identified using the NMTBA* 1982 Membership Directory. This list was supplemented by selecting organizations listed in The American Register of Exporters and Importers, 1978. Of the 18 companies with whom extensive telephone discussions were held, 15 were members of NMTBA and 3 were not. All of the six largest manufacturers were included and three of the six next largest. The manufacturers that provided information for this study produce 45% of the shipment value of machine tools in the United States. Six small companies (the smallest had 15 employees) and three medium-sized companies were also included. Care was taken to include both metal-cutting and metal-forming companies, and companies having both special order machine tools and production models. Finally, the list included both multinationals and producers with a domestic market only. Information was obtained from engineers, plant managers, and marketing personnel.

The ANMC Machinery Sector Committee members had suggested that discussions should be held not only with the machine tool builders, but also with manufacturers of tools, dies, jigs, fixtures, and perishable tooling.** Accordingly, five firms that manufacture products in the 3544 and 3545 SIC codes were chosen, as well as representatives of five of the trade associations in those industry groups -- Cutting Tool Manufacturers Association, American Machine Tool Distributors' Association, Diamond Core Drill Manufacturers Association, the Metal Cutting Tool Institute, and the National Tooling and Machining Association.

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* National Machine Tool Builders' Association.

** Perishable tools are accessories used in conjunction with the machine tools, such as drills, chucks, and reamers. They are called perishable because their lifetime is short compared to the machine tool in which they are used.

The ANMC Committee had also suggested that the customer and supplier groups be included since they help determine whether and how the use of metric components is made. Accordingly, telephone discussions were held with staff members of the Motor Vehicle Manufacturers Association, the Farm Equipment Manufacturers Association, and the Food Processing Machinery and Supplies Association, and with representatives of each of the three largest automobile manufacturers, a large truck manufacturer, and a large off-the-road construction equipment manufacturer.

The Department of Defense coordinator of metric activities and several armed service contracting officers provided information on their policies and purchase practices.

Approximately twenty officials in the Department of Commerce, the National Bureau of Standards, the International Trade Commission, the Office of the United States Trade Representative, and the Bureau of Labor Statistics contributed to the study. The BLS provided a special computer projection of the machine tool industry, its suppliers, and its customers to the year 1990 for this study. Trade representatives of Japan, the European Economic Community, and the United Kingdom provided information from the point of view of the overseas community.

Finally, two of the largest producers of steel and two small steel producers provided information on their perception of the needs and purchasing behavior of the machine tool builders.

In order to provide a forward view of what the university graduates in machine tool design are learning, two outstanding university professors were interviewed.

In all, approximately 100 persons in the machine tool industry or connected with it as customer, supplier, distributor, regulator, analyst, teacher, and trade association staff, contributed to this study.

Telephone discussions typically lasted for 30-45 minutes, some for over an hour. Persons contacted gave freely of information concerning their company; except in a few cases when company privileged information had to be refused - e.g., for some of the companies, the volume of sales of metric products.

The discussions were by design an interactive, two-way activity, so as to capture full understanding of the implications of the responses, and to lead to new areas that may not have been foreseen. Copies of the draft final report were reviewed by the Metric Board staff, nine industry experts, and five government experts.

A note on terminology: the word "customary" has been used in this report to mean the customary English units such as inches and pounds. This terminology is not standard in the machine tool companies, and most respondents tended to use the phrase, "English" units or "inch-pound" measures.

ATTITUDES TOWARD METRIC CONVERSION

Ten years after the NBS report, and seven years after the passage of the Metric Act, some of the persons questioned still had strong, even emotional, feelings about metric conversion. However, many declared the metric question to be less important than five or ten other issues affecting the industry. If metrication should prove to be of even marginal value in solving important problems such as competing with Japanese imports, increasing general sales, changing depreciation allowances, or modifying interest rates, it would be of some concern. Otherwise, many wished the metric question would go away forever.

Despite this, those questioned offered relatively strong and contrasting statements concerning the role of metrication in the industry and in their companies. These ranged from unswerving commitment to metric because "it is the wave of the future," or "the handwriting is on the wall," to declarations that neither the respondents nor their company saw any need to proceed any further than NC and dual readouts. In general, even where company policies are increasingly pro-metric, those questioned were negative toward any major movement toward hard metric. But a vocal minority were frustrated at the foot-dragging in the industry, and in their companies.

Several felt that the federal government should take a stronger leadership position in promoting the conversion to metric, in order to increase competitiveness in export markets. Others showed some relief that government policy was either "non-existent," "ambiguous," and "inconsistent." The DOD Directive 4120.18 and DOD Instruction 4120.23 were unknown to most respondents. Most saw little hope for an expanding capital goods activity in the United States over the coming months. They worried about the Japanese import competition but drew no implications about metric conversion.

THE PRODUCT LINES

Companies that were in the process of metric conversion tended to do it by introducing a new product line. Descriptions of the product line metrication given by the 18 machine tool discussants are summarized in Exhibit 1.

The industry has been relatively successful in meeting the demand for metric-capable machine tools through providing metric-capable and NC dual readout products. Machine tools are beginning to appear that are "harder metric" than previously. Most of the new lines are in market growth areas.

It appears that some metric components are now reasonably available--lead screws and fasteners being mentioned most often. Metric steel--bar stock and others--were said not to be needed or not to be available on the required schedule, although some steel service centers provide metric stock. Metric castings can be obtained. Hydraulics, gears, and electrical components were typically in customary units. Nearly all respondents had always used metric ball bearings and customary unit roller and tapered bearings. The NC and dual readout feature was said to satisfy most customers' needs for a metric machine tool.

METRIC SALES VOLUME

The volume of sales of metric products should be a significant measure of the extent of metrication in that industry, but it was sometimes regarded as proprietary or confidential information, and in many other cases the numbers could be obtained only by going back to and adding up individual orders. Ten respondents offered "an educated guess" for their companies. These ranged from 2% to 100% of overseas orders, and up to 30% of all orders (50% for one company) but with no general perception of a trend. In all cases responses meant "metric capable", not hard metric.

Exhibit 1

Product Line Metrication

No.	Extent of Metrication
1.	Introducing hard metric machine tools, with hard metric components wherever possible. Use metric fasteners whenever possible. Substitute English modular components when the supplier system cannot provide metric parts.
2.	All new machines to be hard metric. Some machine tools introduced 25-30 years ago still being manufactured in customary units.
3.	5 vertical lines metric. Machine tools metric designed; metric stock painted yellow. One machining center line redesigned from English units to metric. All lathes in customary units.
4.	5 metric lines.
5.	10 product lines designed in metric. Plastic machinery hard metric. English hydraulic and electrical components.
6.	Manufacturer of special order machines; prefer metric, but will build to customary if asked.
7.	Plastic machinery metric. Metric ball bearings, English roller bearings. Nearly all machine tools hard inch, but with dual capability for many years.
8.	All lead screws English, but with an even metric pitch. Provide metric gears if wanted. English stock and bolts. First hard metric machine out late in 1982. Dual readouts.
9.	Dual dimensioned drawings. Special tools in customary units, but precision measuring equipment in metric. ISO tolerances on internal screw threads too large for this company.
10.	Hard English machines, soft conversion.
11.	All NC machines dual readouts; 1% of lead screws metric.
12.	Engineering drawings metric. Use microprocessor on machines and conversion tables in manufacturing to convert to English units. Bolts, nuts, and hydraulic systems English.
13.	Provide NC; otherwise no need for metric.
14.	Customary unit design; NC dual readouts for last 5 years.
15.	No metrics; all machine tools switchable.
16.	No need for metric; all machine tools customary.
17.	One line dual dimensioned. Put metric scales on exported machines. Catalogs give dual dimensions.
18.	Drawings English. 90-95% machines have NC, which are dual.

Several respondents noted an increase in metric orders 2-3 years ago, but no further noticeable increase. They guessed that their customers had briefly expected a national conversion to metric. It was clear that several companies had analyzed their metric sales data for internal purposes, but were reluctant to share the information.

PERCEPTIONS OF THE CUSTOMER DEMAND

Many respondents said, "If the customer wants metric, he will get it. We are a customer-pulled industry." They distinguished between "special order" machine tools, built to customer specifications, and a standard product line. Respondents were asked about their perception of customer needs. The 16 responses are given in Exhibit 2. The responses reflect the feeling that NC, dual readouts, and metric cutting and farming capability are sufficient to satisfy all but the most demanding customer. Some responses indicate that the much advertised metrication of some of the domestic automotive, earth-moving, farm machinery, and construction machinery industries did not impose any special demands on the machine tool industry to change its ways, but industry perceptions are conflicting. Only a few detect an increasing demand for more metrication in their product.

The discussions also brought up some "horror stories" about confirmed orders for machine tools in customary dimensions that were rejected at Australian customs posts, for example. These were counter-balanced by other stories about Australian customs waivers of metric requirements. There were also numerous suggestions about unfair trade practices by foreign companies and their governments, but when these observations were checked with the International Trade Commission or the Office of the Special Trade Representative, there was the instant request that any such cases be brought to their attention. It is possible that some company may not have paid attention to the import rules of the country in question, and has itself to blame, or there may be systematic problems which need further examination by industry associations.

Exhibit 2

Customer Perceptions of Customer Demand As Reported by 16 Respondents

1. The Europeans want metric capability, not design. France may be a little stickier. Domestic markets need metric capability. My guess is they don't cut in the metric mode more than 5% of the time when they do have the capability.
2. There is no customer demand for metric machines, and I don't expect any. Caterpillar and others who have gone metric, like the automotives and construction machinery people, allow us to translate all their metric dimensions into an English equivalent.
3. The automotive industry is not asking for metric machines.
4. Overseas customers do not demand metric machines.
5. Some Europeans demand metric machine tools--the French, Scandanavians, and to a somewhat lesser degree, the Germans. Others prefer, but do not demand, metric. Some customers, e.g. in Latin America, are now asking for metric fasteners in the machine tools. Overseas machines are operated in the metric mode about 75% of the time. Automotive industries do not require metric fasteners.
6. There is no need for metric in any way; we have only one European competitor, and we both keep well supplied with orders.
7. The aerospace industry wants dual-capable machines with NC.
8. Deere, Caterpillar, and the automotive industry are just not ordering anything, metric or otherwise.
9. Caterpillar wants metric-capable machines; the aircraft industry does not want them. There is no requirement for any large metric conversion.
10. We expect the automotive industry to set the standards they want of machine tools, and they are not saying anything. There is no domestic demand for metric. Our overseas customers are asking for metric capability only.
11. Overseas customers prefer metric machines; domestic purchasers, including automotive, prefer English.
12. Anything sells overseas.
13. Rarely does a USA customer ask for a metric-capable machine.
14. We have no complaints from overseas customers on our English unit machines.
15. Automotive sales are going metric-capable, but that could reverse again.
16. Caterpillar designs in metric. There is no overseas demand for metric fasteners, although they want metric capability.

PERCEPTIONS OF THE IMPORT THREAT

Would metrication of the machine tool industry improve the international trade competitiveness of the American manufacturer? The judgment of the respondents was that metrication might improve the ability to sell overseas, but some added,"not much." This question evoked lively responses. Some companies felt relatively unaffected by imports from abroad, although they had heard of difficulties in "run-of-the-mill production line machines." Others, however, had felt directly the impact of foreign producer sales; one company declared that its sales volume had been reduced by 25% due to Japanese sales. There is a large potential ground-swell of resistance to imports, especially Japanese imports, and to a lesser extent, German and Scandinavian imports.

There was some protectionist advocacy. Sobering evaluations came from the six largest companies, whose business felt this competition. Their judgments about Japanese machine tools were nearly unanimous:

- The machine tools are equivalent to American products in quality, sometimes better and sometimes not quite so good;
- The Japanese machine tools are less expensive--some estimates were 10-15% less;
- Delivery is faster than that of American counterparts, an advantage that has become pronounced with decreased backlogs for American manufacturers;
- Installation time is faster;
- Response to trouble-shooting requests is faster;
- The long-term durability of the machine tools, and their vulnerability to other factors, is so far unknown.

The fact that Japanese tools are metric was not considered important. They are generally hard metric with English perishable cutting tools and English readouts.

Industry respondents frequently observed that the Japanese government provides considerable encouragement to their machine tool industry, while the American government not only does not help, but

has not noticed that there is a problem. U.S. government officials, however, are well aware of the problem, and actively searching for constructive ways of dealing with it. They acknowledged the helpful inputs of NMTBA, the trade association. but said individual company inputs on specific violations would be helpful.

TOOLS, DIES, AND PERISHABLE CUTTING TOOLS

Machine tool manufacturers are convinced that their machines can be made metric-capable through the use of metric tools, dies, taps, and perishable cutting tools, such as drills. The extent to which the SIC code 3544 and 3545 industries are selling more metric tools could be a warning signal that the machine tool industry itself needs to "go metric."

In 1974 the National Tool, Die & Precision Machining Association made a survey of its member companies on the extent of planned metrication [4] and in 1981, the successor organization, the National Tooling and Machining Association, made a similar survey.[5] In the first survey (949 returns), 31% of the respondents indicated that they had received inquiries for contract work in metric products, and 27% saw a competitive advantage in early metrication. Over 70% planned to pace their transition to meet customer needs, while 8% planned a rapid changeover.

The comparative results of the two surveys are displayed in Exhibit 3.

Exhibit 3

Metric Sales of Contract Tooling and Machining

Exhibit 3 . Metric Sales of Contract Tooling and Machining

Item	1974 Survey		1981 Survey	
	Number	Percent	Number	Percent
Total respondents	949	100	100	100
Customer industries				
With metric demands				
Electronics		31		32
Automotive		27		39
Aerospace		15		24
Consumer goods		13		
Optical/photo		7		
Appliances		4		
Military		3		18
Metric work as percent of total output				
None		55		12
Under 10%		40		52
10-25%		4		29
25-50%		0.7		6
Over 50%		0.1		1

The results of these surveys suggest that there is an increased purchase of metric tools from contract organizations.

In this study, similar questions were asked of five manufacturing associations. One trade association in the drill manufacturing area estimated that about 25% of domestic and foreign products bought were metric, while a drill manufacturers association said that their earth-drilling companies probably had no metric sales. The Cutting Tool Manufacturers Association reported low metric sales, and projected only soft conversion, while the Metal Cutting Tool Institute reported that "metric is coming," with international trade and General Motors acting as strong pulls.

For the five 3544/3545 production companies contacted in this survey metric sales varied from 100% for one company to less than 10% for the others. One of the respondents had decided to invest heavily in metric tooling at the time the automotive industries announced their metric plans, but sales failed to match their expectations.

In the SIC 3544/3545 industries regarded as a forerunner of metrication in the machine tool industry, there is some qualitative and quantitative evidence that metrication is under way, but it is by no means overwhelming.

THE CUSTOMER INDUSTRIES

Telephone conversations with purchasers of machine tools included representatives of the three largest automotive manufacturers, a truck manufacturer, an off-the-road construction vehicle manufacturer, and the Motor Vehicle Manufacturers' Association, the Farm Equipment Manufacturers' Association, and the Food Processing Machinery and Supplies Association. Information from two auto manufacturers is not reported, at their request.

General Motors regards itself as being about 95% metricated in new automotive product lines. Chrysler is 80% or more metric in its front-wheel drive autos since 1978, but customary measures are still used for rear-wheel drive vehicles and trucks. Ford is increasing its metric production, but estimates only about 50% metric use by 1985. In these companies, machine tools having a metric capability are regarded as satisfying the requirements of the industry. However, one manufacturer indicated a strong preference for design of dies, fixtures, and gages that are metric-dimensioned.

Two manufacturers volunteered the information that they purchase foreign machine tools from EEC and Japan. One company indicated that it was finding it increasingly necessary to go to imported machine tools to get certain performance capabilities. A second manufacturer indicated disappointment with the innovativeness of their machine tool suppliers, to the extent that they have designed some of their own new machine tools, and were debating the possibility of doing more such production, if only to "provide some leadership to the machine tool industry." A different automotive manufacturer indicated that they used to build some of their own machine tools, but had switched to purchase instead. The criteria used in their "make/buy" comparison is regarded as confidential.

The MVMA indicated that they had no data on metrication of the machine tools used by their members, nor were they aware of any releasable studies on the question. They assume that the machine tool industry is satisfactorily responding tc the metric movement in the automotive industry, because they had no complaints.

The one truck manufacturer contacted still uses the "standard" (customary) system. Although there is no corporate policy on metrication, their purchases of machine tools in the past several years have been dual-capable machines, and they, too, occasionally build their own machine tools. About five years ago they purchased some foreign-built machine tools, but couldn't get replacement parts when needed, and so have limited their search for machines to the domestic producers.

The manufacturer of off-the-road construction equipment has "gone metric." They require from machine tool suppliers only metric capability. Foreign manufacturers of construction equipment are beginning to provide some competition to them.

The Farm Equipment Manufacturers Association recently submitted the ANMC Conversion Guidelines draft document to their members, and received a fast response from 131 member companies that was interpreted as "not enthusiastic." Of the 131 respondents, 23 companies were producting farm machinery with metric dimensions; 43 planned future conversion. Their response also indicated an inability to find metric steel and fasteners. Their export market, including Canada, is said to be buying equipment without reference to the measurement system used in the equipment. Their membership of 440 companies does not include the "big 7" tractor companies.

The representative of the food processing machinery industry indicated that some years ago there was a a surge of interest in metrication which had died down. Some members, e.g., FMC, are now fully metric.

At the Department of Defense, the Under Secretary of Defense for Research and Engineering issued, on 7 March 1980, a Memorandum indicating a target date of 1 January 1990 for the availability of a complete spectrum of metric specifications and standards.* The primary rationale is interchangeability with NATO countries. A DoD Metrication Steering Group (MSG) has issued a set of Guidelines for preparing standardization documents: 6/

- industry, and not DoD, is to determine the pace of metrication and the sequence of changes that occur;
- the weapons system program manager will determine whether it is in the best interests of national security for a new procurement action to be metric, and, if so, how far,
- if the decision is made to procure a metric system, the most cost-effective choice will be made, including the life-cycle cost basis, and
- if industrial producers can provide metric components less expensively than the customary unit counterpart, DoD will procure the metric alternative.

  The Defense Acquisition Review Council is considering a possible addition to the procurement policy documents to require the use of metric in purchases exceeding $2 million, unless it can be shown that the use of the metric alternative is not cost-effective.

DoD will continue to prepare standards for items that the private standardization sector is unlikely to handle, so that the 1990 target date can include all items on the DoD Index of Specification and Standards (the DODISS). Metric standards for machine tools are regarded as of secondary importance.

One of the assignments of DoD's MSG is to prepare an annual metric status report. The first has not been released.

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* See DoD revised directive 4120.18, 22 Jan. 1980, "Use of the Metric System of Measurement." Also Change #1, 18 June 1980, establish a DoD Metrication Group, and directive 4120.23, 18 May 1981, the Metrication Plan.

Telephone discussions with contract officers in the armed services revealed some variety in attitudes. Nearly all observed that they have no authority to prefer or require metrication, this being the prerogative of the program officer. Two indicated that in machine tool acquisition, they had difficulty in their own minds in justifying a conversion to metric.

FOREIGN PURCHASES

Machine tool manufacturers indicated that soft conversion of machine tool drawings, instructions, and scales, plus a metric-cutting capability, had been adequate in the past to satisfy foreign purchasers. One or two felt that additional steps in going "hard metric" might be advantageous, but had no real evidence. Exporters partially confirmed the judgments of the machine tool builders, but they also felt that making further gestures in the direction of hard metric is an asset in marketing products.

A document from the Japan Machinery Importers' Association says:

"Suppliers must also adopt the metric system and guarantee rapid and reliable after-delivery service and quick and easy access to such expendable spare parts as electrical and hydraulic parts."[7]

The European Economic Community (EEC) directives also suggest that there will be increasingly tight demands on metrication of machine tools. The Council has directed that EEC Member States (United Kingdom, Federal Republic of Germany, France, Luxembourg, Belgium, Denmark, the Netherlands, Italy, and the Irish Republic), should adopt the metric system by 21 April 1978.[8] The question of prohibition of use of English units has been deferred.[9]

In an attempt to provide guidance to exporters on how these directives would be interpreted, both the Department of Commerce and the American National Metric Council [10] counseled exporters to use SI units at least on labels and shipping documents, as well as other places required by individual countries and purchasers. ANMC noted that internal components and fittings would probably not have to comply with the EEC directives, and noted that such topics as dual-dimensioning would be a determination of each country.[11]

Metrication in the United Kingdom is now in limbo. The Conservative government's Department of Industry abolished the Metrication Board and declared adoption of the metric system to be voluntary.

METRIC COMPONENTS AND MATERIALS

Shortage or unavailability of metric-dimensioned materials and components was reported in some metric studies to be a barrier to the manufacture of hard metric machine tools. Three of the eighteen machine tool manufacturers contacted in this study reported this problem, especially with respect to bar stock. Metric fasteners have at times been in short supply, but are increasingly available. Reports on the availability of other steel stock differed. Metric castings appeared to be available as needed. Most respondents agreed that electric motors and electrical systems; hydraulic power units, pumps, and cylinders; motor controls; gears, belts and drives; valves; needle and tapered bearings; hydraulic tubing; gasketing; O-ring stock; electric wire and sleeve bushings would continue to be in customary units, even in hard metric machine tools. Items such as non-ferrous pipe and tube fittings were reported as not being available in metric.

In this study, four steel mills (two very large, two small) and one service center were contacted. One commented, with respect to metric-dimensioned steel, "We're trying to fight it like everyone else," and this was implicitly echoed by the others. The Steel Service Center indicated it had sheet, bar, and hex stock on hand.

The American Iron and Steel Institute (AISI) reported that in 1979, metric sales were 4.9% of the volume reported to them, and in 1980 it had grown to 7.9%. The AISI survey sample covered about 63% of industry sales in 1979, and 73% in 1980.

The steel mills report that they can satisfy metric orders. One of the giants reported that 3% of their volume was metric, and the other that it was less than 20%. One small supplier reported 2% sales volume in metric, the broker reported some sales, and the service center reported a small but growing volume of metric sales. One large mill indicated that they would not convert their lines to metric until the volume of orders reached a 50% level, and in the meantime would

satisfy metric orders by turning out the equivalent size in English units. Four of the five respondents had expected metric sales to move faster. The steel mills' primary customer is the automotive industry; the machine tool manufacturers are proportionately very small purchasers. Machine tool orders for steel are in very small quantities--typically one to five tons--but a minimum size roll is a 5-ton ingot, and the rolling stands cannot be economically changed if the order is less than 10 tons. A typical automotive order is 180 tons. Machine tool makers usually want bar and tubular stock and mills report that there are no general metric standards for this.

THE UNIVERSITIES

One indicator which reflects the status of metric use in the machine tool industry is the degree of training in metric of the machine tool designers in universities and technical training schools. Metric training of engineers in machine tool design courses was discussed with professors at the University of Michigan, the University of Wisconsin, and The Ohio State University.

Engineers who become machine tool designers typically get an undergraduate degree in mechanical engineering with a major in machine design. The University of Cincinnati, California/Berkeley, Georgia Tech, Illinois, University of Massachusetts, Michigan, Minnesota, Northwestern, Ohio State, Purdue, Stevens Tech, and Wisconsin are leaders in this kind of training. Universities reported that recruiters from the machine tool industry have not shown interest in having metric training.

Many courses are taught using metric at the University of Michigan because of its closeness to the automotive industry. At Ohio State, the local industry still works predominantly in customary units and courses are taught in customary units. At the University of Wisconsin, about half the courses use metric and the other half customary units. Textbooks and handbooks are still primarily based on customary units of measurements. One metals handbook gives metric dimensions first, and customary units second. Machinery's Handbook, on the basis of a survey of Handbook users, decided to provide metric thread sizes, but otherwise not move to a stronger metric content.

RETROFIT

One further measure of the extent of metric use is the rate of conversion (retrofit) of existing machine tools to metric, since machine tools have a long life. Retrofit could include changing lead screws from customary to metric components, a relatively low-cost choice. More likely would be the addition of dual-readout scales, or incorporation of dual-dimension NC or CNC controls.

One large manufacturer indicated that it did not retrofit its own products, but it did supply retrofit kits. The volume of demand for them was small. Two other companies that offer retrofit services also report low demand. NMTBA believed such conversion to be relatively small, a judgment echoed by other manufacturers and automotive companies. One truck manufacturer was reported to be planning a massive conversion, but this has not been confirmed.

CHAPTER III

A REVIEW OF THE LITERATURE PERTAINING TO THE USE OF METRIC IN THE MACHINE TOOL INDUSTRY

Preview: During the 1970's there were several studies of the progress of metrication in the U.S. Most of them produced only incidental information about the machine tool industry since they dealt with more inclusive categories of industry. This chapter culls, codifies, and compares the scant information related to the machine tool industry from these earlier studies.

NBS: U.S. METRIC STUDY

The National Bureau of Standards (NBS) carried out a three year study, reported in 1970, of the advantages and disadvantages of increased use of the metric system compared to the alternative of promoting use of customary measurements in international trade. 12/ The report, which was pro-metric, contained much survey data and careful analysis. There was a sub-report on the manufacturing sector, 13/ in which the machine tool industry and most of the machinery industries were analyzed as part of a larger group of companies manufacturing such products as automobiles, aircraft, and appliances.

The general fundings of the NBS study were:

- 9-12% of the companies used metric units or engineering standards in at least some part of their operations,
- these companies represented about 30% of the work force in their industry group,
- larger companies and those with international connections used metric more than smaller companies and those with domestic plants only,
- there had been a modest increase in the use of metric units in design, R&D, and catalog listing of products between 1965 and 1970,
- about 5% of companies that used metric did so exclusively, the rest using dual dimension, and
- most respondents expected some accelerated use of metric in the next five years (1970-75).

Modest advantages in competing for foreign markets were reported along with some difficulties in obtaining metric-sized stock, duplications and dual inventory costs, and training. Two percent of companies reported an increase in foreign competition for their metric-dimension products and 3% reported a decrease in domestic sales.

The advantages of a single system for worldwide manufacture and mating with standard design components were the most important factors encouraging metric use. Other factors were the expected increase in foreign sales and possible economies of manufacture. But most companies did not expect to see increased export markets as a result of metrication. About 10% were strongly pro-metric, 16% were strongly against, and 39% were neutral. Small companies had more extreme positions than large ones.

There was wide dispersion in estimated costs of metrication, which appeared to be due to the difficulty of making good estimates and the use of different assumptions.[14/] Estimates of increased costs ranged from 5.3% to 65%.

How many machine tool manufacturers were included in NBS analyzed data is not now known. [15/] The NBS evaluation included a separate study of possible effects on international trade of conversion to metric, which indicated relatively little effect--possibly a 3.2% increase between 1970 and 1975.[16/] This study included some machine tool manufacturers. Most of them designed and produced their product line to customary dimensions but 20% designed and produced "at least part of their exports in both customary and metric units." Most avoided bidding on orders that specified metric production, but about 50% of machine tool shipments were in dual dimensions--i.e., built in customary units but described in labels, packages, drawings, and catalogs in metric units. Ten percent had metric components and 40% were hard customary unit machines. Conversely, most imported machine tools in 1970 were built in metric units but modified to show customary measurement units in scales, etc.

THE NATIONAL TOOL, DIE, AND PRECISION MACHINING ASSOCIATION SURVEY

The Association's 1977 survey showed that 51% of those responding had some of their machine tools equipped for metric capability and 66% reported that future machine tool purchases would have full metric options.

GAO: GETTING A BETTER UNDERSTANDING OF THE METRIC SYSTEM

The General Accounting Office (GAO) issued a report on metrication in the U.S. in 1978, based on extensive surveys, interviews, and literature review.[17/] GAO noted that there was a pervasive - but incorrect - perception in industry that Congress had mandated conversion to metric.[18/] Nearly half of the Fortune 500 companies questioned had appointed either a metric conversion coordinator or a metric committee, and nearly 40% had published some policy statement about metrication. This was the major

quantitative difference between the GAO report and the NBS report nearly eight years earlier. The tone of the two reports was markedly different.

GAO's report had one chapter on machine tools, based on discussions with NMTBA, the Tool & Die Manufacturers Association, and some industry personnel. Conclusions were that the status of metrication in the industry was mixed, and that the industry was most concerned about the need for dual inventories. Most believed that metrication would not materially affect either imports or exports.

U.S. METRIC BOARD REPORTS

The U.S. Metric Board issued Annual Reports in 1979 and 1980. The 1981 Report is not yet available. The annual reports and other studies funded by the Board are a source of general information about metric conversion activities. Several are described below.

KING RESEARCH (U.S. METRIC BOARD): 1979 SURVEY OF SELECTED LARGE U.S. FIRMS AND INDUSTRIES

King Research, Inc. in November 1979 conducted a survey of metric use among the Fortune 1000 Companies[19] under the sponsorship of the U.S. Metric Board, using a random sample of 200 companies in five major industry groups. Among all of these companies, the study found that 32% of sales were metric, including 21% soft metric, 5% hybrid metric, and 6% hard metric.[20] (See Ref. 20 for definitions used in the study.) Products for export were about 48% metric while manufacture for domestic consumption was about 29% metric. These results are significantly higher than the NBS findings in 1970. Sixty-three percent of manufacturing establishments reported selling at least one metric product, and only 30% reported that they had no metric capability. Twenty-six percent had some manufacturing equipment that could produce to metric dimensions.[21]

The results of this study were generally consistent with the GAO study except that a larger number of firms were reported to provide metric training for employees. Reasons given by firms producing metric products were primarily international acceptance (40%) and customer demand for metrics (36%). About 20% of the companies had no intention of buying any metric-capable equipment in the foreseeable future but 80% were planning to obtain metric-capable equipment, although only half of them within the next five years.

These findings relate to a spectrum of manufacturing companies. A review of the questionnaires and data sheets used in the study indicates that respondents included four large machine tool manufacturers. Two had appointed metric coordinators in 1972-73 and one a metric committee a year later. One reported no metric sales; a second reported that 3% of U.S. sales and 20% of overseas sales were hybrid equipment (some metric components); a third claimed an unspecified amount of metric sales, and the fourth refused to provide such information. One company had no new product designs in metric, two reported that 10-20% of new designs were hybrid. The fourth company reported a mix: 4% hard metric, 1% hybrid, 15% soft metric, 80% customary. From 10% to 80% of production in these companies was "metric-capable." All four companies said that there was no real demand from their customers for any further metric capability, but three said that most of their acquisitions in the next several years would be metric-capable, although not hard metric. To the question of when these companies would be metricated, the responses were 12,20,25, and 30 years. The two reasons for going metric were customer demand, which they did not see at present, and sales to metric countries, which could be handled at present with metric-capable products.

The four machine tool companies included in the Fortune 1000 study were also contacted for this study. All have continued along the path reported at that time; that is, a cautious movement toward metric use by three companies, and no movement by the fourth.

These four companies were further advanced than the larger industry group in the sample in terms of calculated consideration of whether and when to go metric, although their sales volumes and current capabilities matched well with the larger group. None of the companies indicated concern with legal or other perceived barriers; their pace was set by perceived customer demand.

DAMANS AND ASSOCIATES: SURVEY OF SMALL BUSINESSES: ISSUES IN METRIC PLANNING AND CONVERSION

Damans and Associates, Inc. studied the status of metric conversion in small businesses, also under a contract from the U.S. Metric Board.[22/] The study was based on a survey of a probability sample of 2500 small businesses, distributed as shown in Exhibit 4, with a response rate of 55%, heavily weighted

Exhibit 4

Survey Sample

SIC Code and Industry	Number in Sample	Number Responding
15 Building Construction General Contractors	170	65
24 Lumber and Wood Products	88	35
28 Chemical and Allied Products	38	16
34 Fabricated Metal Products	110	55
35 Machinery, except Electrical	178	99
36 Electrical and Electronic Machinery	54	26
42 Motor Freight Transportation	180	72
50 Wholesale Trade - Durable Goods	779	352
52 Retail Trade - Building Materials	269	135
55 Automotive Dealers	634	240
Total	2500	1097

toward wholesalers and retailers. There were some slight differences in definitions of metric use in this study as compared to studies discussed above, and Damans and Associates correctly noted that differences in definitions of metric status trouble all assessments in this field. The report noted that "Very few of the 'converted businesses' had more than 25% of their total products in metric units....the concepts of conversion and metrication could benefit from increased specificity in future research."[23/]

In spite of this problem, the survey results were reasonably consistent with earlier findings. They found somewhat more hard metric products than other studies had indicated - 23% of respondents designed, manufactured, or sold metric products - but little customer demand for further metric products.

DEPARTMENT OF COMMERCE INDUSTRY SPECIALIST INFORMATION

Industry specialists at the Department of Commerce in 1980 prepared reviews of the status of metric conversion in a number of industries. The summary for the machine tool industry (SIC 354)[24/] notes the following:

- Partially converted to both hard and soft metric
- Impact of conversion would be moderate
- Major bottlenecks to conversion are equipment change, the need for dual inventories, and supplier resistance
- Industry typically is sophisticated, capital-intensive, and labor-intensive
- 3 standards-setting organizations servicing the industry, and about 50% of standards are in metric
- Ten to thirty companies with overseas operations
- Export shipments of companies range from zero to 37%
- No industry cost of conversion estimates available
- No studies showing benefits of conversion available
- Increased export possibilities expected to be a benefit of conversion

With respect to metric status in the various sectors, the industry analysts concluded:

- 3541/3542 - "The industry is taking metric conversion in its stride; metric is an opportunity to be more competitive in the world market." A major obstacle is the availability of metric components and raw materials. Appoximately 20 firms have foreign operations, largely manufacturing facilities in Europe to improve access to the EEC markets; 2 or 3 have Canadian operations.

- SIC 3544 - "The tool and die industry is ready for metric conversion," since these items can be produced to either customary or metric dimensions, as the customer requests.

- SIC 35451 - "Industry currently manufactures and exports tools to metric standard, fully statisfying domestic and foreign demand at present." The industry is demand-driven, and the heavy involvement in metric of many customers, such as automotive, appliance, and farm equipment industries would have a pulling effect.

The Commerce analysts for the consuming industries also noted the trends in their sectors, as follows:

- SIC 3523 - Farm Machinery - At present, most companies are ordering their machine tools in soft metric, although most manufacturers accept hard metric as inevitable. Deere, International Harvester, Ford Tractor have large foreign subsidiaries.

- SIC 3532 - Construction Machinery - "The industry is very active in ANSI and ISO (metric) standards activities. The international standards are metric. There are many multi-national companies in this industry and therefore have a great deal of experience in metric applications. The industry is actively introducing metric, both hard and soft in design and production. One new plant in the industry was designed metric and the finished machines are hard metric."

  "The conversion at present is both hard and soft. Consider Caterpillar Tractor Co. which accounts for over 30 percent of industry sales. Caterpillar takes a pragmatic cost/benefit approach to hard conversion. Metric module standards are adopted only if they result in product advantages in costs, availability, and service-ability. Caterpillar has many large foreign manufacturing facilities. Metric sizes are used for drills and ball and cylindrical bearings. Soft conversion for tapered and needle bearings, fasteners, spring pins, seals, hydraulic fittings and tubing. In most cases other standards have been soft-converted.

- SIC 3711 - Automotive - "The passenger car manufacturers have all decided to convert gradually. For the most part, truck manufacturers will also convert over the long-term. As new major components and new cars are being developed, they are designed to a considerable degree in metric. Also much

emphasis is being placed on using metric fasteners. GM's Chevette and Chrysler's Omni and Horizon are predominantly metric. Also, the new engines being developed and introduced are metric.... For passenger cars, the conversion is expected to be complete by the early 1990's; for trucks several years later."

- SIC 372/376 - Aerospace - "Aerospace industry conversion to metric is inevitable.... Changeover, however, will take place through normal attrition on an evolutionary basis." "The machine tool industry is providing aerospace sufficient tools to make orderly flow as old machines are phased out.

The Commerce analysts therefore paint a picture of a gradually converting machine tool industry, being pulled by a dedicated conversion decision in the automotive, farm, and construction industries. They also paint a picture of metric supplier shortages.

The Commerce industry analysts for the primary supplying industries made the following observations about their metric status:[25/]

- SIC 3312 - Steel - "The steel industry is committed to meeting the requirements of its customers. As such, it has since 1970 undertaken planning for metrication. The industry is currently accepting orders in metric terms for many rolled products." "Over two-thirds of the steel industry's product shipments are destined for the automotive, construction, and producer durable goods industries. The pace of metric conversion in those industries will in large part determine conversion in the steel industry."

- SIC 332 - Iron and Steel Foundries - "The industry is already shipping to metric standards where customers require, i.e., automotive and machine tool castings." "Ferrous castings are components of nearly every machinery system and the industry can only respond to its markets, not lead them," "Automotive is going metric as are machine tool customers."

J.F. COATES, INC.: THE SEARCH FOR SMALL BUSINESSES WITH INVESTMENTS IN METRIC PRODUCTION

A 1981 study by J.F. Coates, Inc., for the U.S. Metric Board found the nation's small manufacturers offer a widespread capability to produce metric products at low cost and with little difficulty.[26/] Of the 686 small manufacturers contacted, 30% produce products to metric dimensions. Metric often accounts for less than 5% of their total production. The metric capability has cost small manufacturers little. Less than 4% of small manufacturers working in metric spent over $10,000 converting.

The study also found:

- Small manufacturers convert because their customers request metric, almost never to seek or compete in foreign markets.
- Small manufacturers respond to metric orders by converting them into customary "inch-pound" dimension.
- Small manufacturers do not make major purchases for metric, but order new equipment with dual capabilities.
- Few small companies make plans to convert; it occurs as a natural outgrowth of shifting customer demands.
- Repair, modification, or rebuilding foreign machinery spurs conversion of small machine shops.
- Few small manufacturers feel that metric has increased their business; it did help them meet the needs of current customers.

THE AMERICAN NATIONAL METRIC COUNCIL

The American National Metric Council (ANMC) is a private, non-profit organization that provides:

- an industry forum for voluntary conversion to metric,
- a vehicle to assist sector-wide planning, and
- feedback to government on problems.

The Council disseminates information on metric facts and issues, and publishes the Metric Reporter. It maintains a group of some 40 industry sector committees, including a Machinery Sector Committee, 2.06. This committee, one of the more active, meets several times each year. It has drafted a set of suggested guides for conversion in industries that manufacture machinery and machine tools. The guidelines are being revised.

THE MACHINERY AND ALLIED PRODUCTS INSTITUTE (MAPI)

The Institute issued memoranda to its constituency in 1975 and 1979,[27] which reported that a large number of U.S. multinational corporations had converted to metric. They also noted the results of a survey of the Fortune first and second 500 companies made by the University of Wisconsin's Department of Engineering and Computer Science, which reported that over 50% of the respondents had either "switched to metric or were planning to switch."

CHAPTER IV

THE PROCESS OF CHANGE

Preview: This chapter describes forces at work to increase or decrease metrication in the machine tool industry. Some possible future scenarios are explored, most of which would accelerate the use of metric.

The evidence from this study suggests that the process of change to metric in the machine tool industry is primarily in response to customer demand. Until now, this demand has been basically satisfied with metric-capable machine tools, even in those industries and countries that themselves operate in metric. There is also the very large domestic demand for which the use of metric-capable machine tools is immaterial. Machines built in customary units may be less expensive and backed up by larger supply systems of repair parts. It has been demonstrated that change to metric is not cost prohibitive but that cost is still a major consideration in determining whether a new product line should have extensive metric characteristics.

Change to metric is being accomplished on a company basis, rather than on a sector-wide basis. Concern for antitrust litigation is still strong but perhaps unwarranted. Industry competitiveness also protects some metric decisions from outside viewing until the machine tools themselves appear on the market. Most major metric introductions are in a product line, rather than across-the-board.

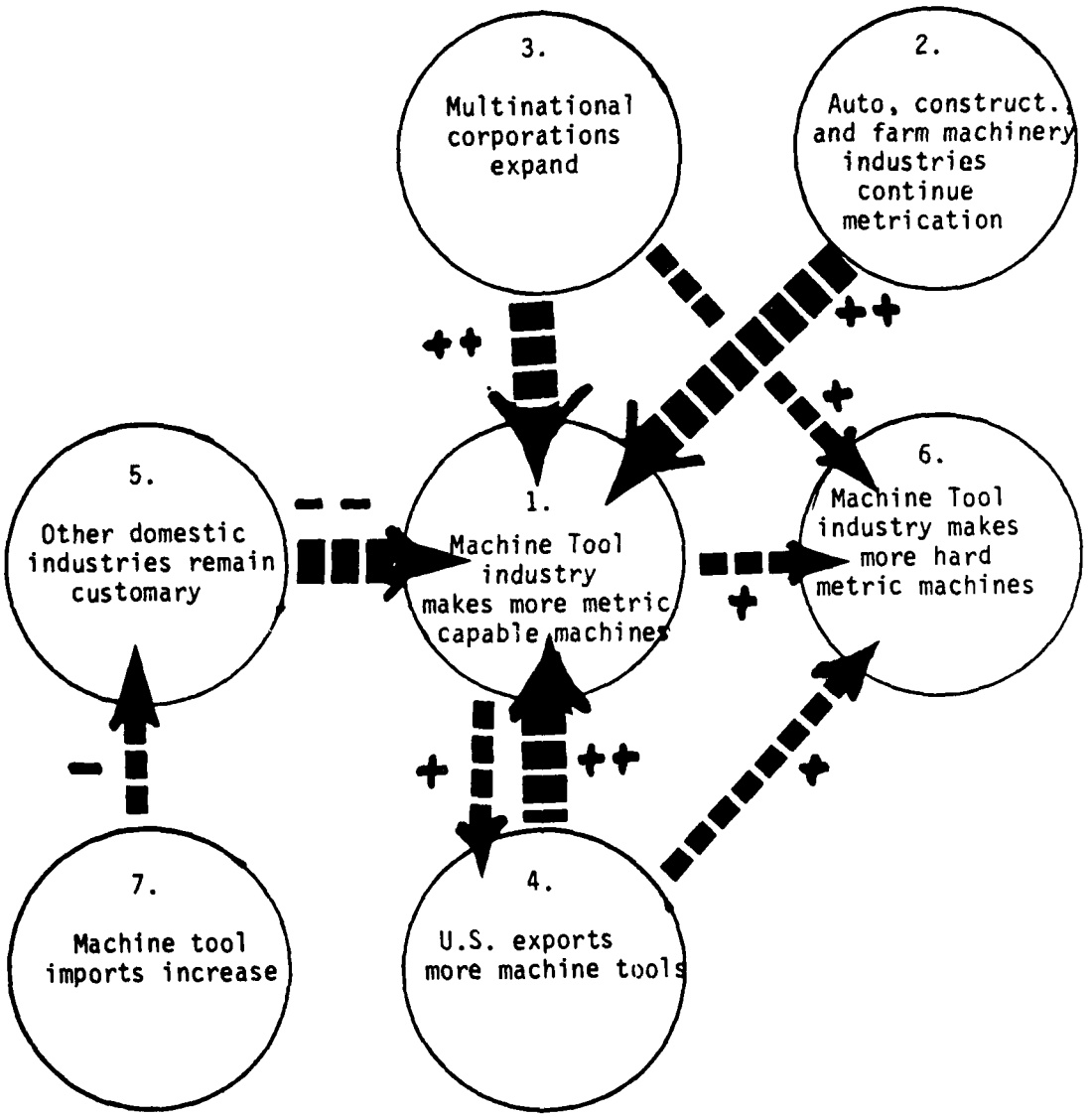
Conversion to metric in this industry is a central management decision, with implementation sometimes delegated to the plant manager or the plant engineer.

A METRICATION DIGRAPH

Analysis suggests that three major factors and a number of minor factors contribute to the growth of metrication in the machine tool industry. These first-approximation findings are shown in Exhibit 5. The figure can be called a "graph" of the major forces at work to cause further increase of either soft metrication or the production of metric-capable machine tools. The three major factors are the move toward metrication in the auto, farm, and construction machinery industries in the U.S.; the growth of the multinational corporation with overseas subsidiaries; and growth of the U.S. exports.

Exhibit 5

Simple Digraph of Metrication in the Machine Tool Industry



With sufficient data, this signed digraph would become an econometric model. Each of the driving factors exerts a strong and direct positive force on the extent and speed with which metric conversion occurs in the machine tool industry. That force is partly counterbalanced by the negative effect of another factor, the extent to which other industries continue to produce in customary units. A mathematical model would show the interacting effects of these forces, but data at that degree of detail would be proprietary.

The digraph shows a reinforcing relationship between metric-capable and hard metric machines, i.e., hard metric production to a very limited extent nudged by the production of metric-capable machines for multinationals seeking interchangeability with their hard metric overseas manufacturers, and for export. This encourages the feeling that a hard metric machine tool might increase the overseas appeal of American-produced machine tools. However, this relationship on the basis of the present research, appears weak. Metric-capable tools are used as a substitute for hard metric. Some machine builders think that a hard metric product would enhance their overseas market, but they also think that proof would be hard to come by.

To repeat, the conclusion that stands out in high relief is that there are strong pulls from three major customer groups to make the machine tool industry more metric-capable. The pull is partly counterbalanced by the large volume of domestic consumers who do not require, and in some cases, do not want, metric.

Other factors are at work with effects that are less pronounced. These forces are tabulated in Exhibit 6. A more complete digraph, showing other forces and their pulls, is shown in Exhibit 7.

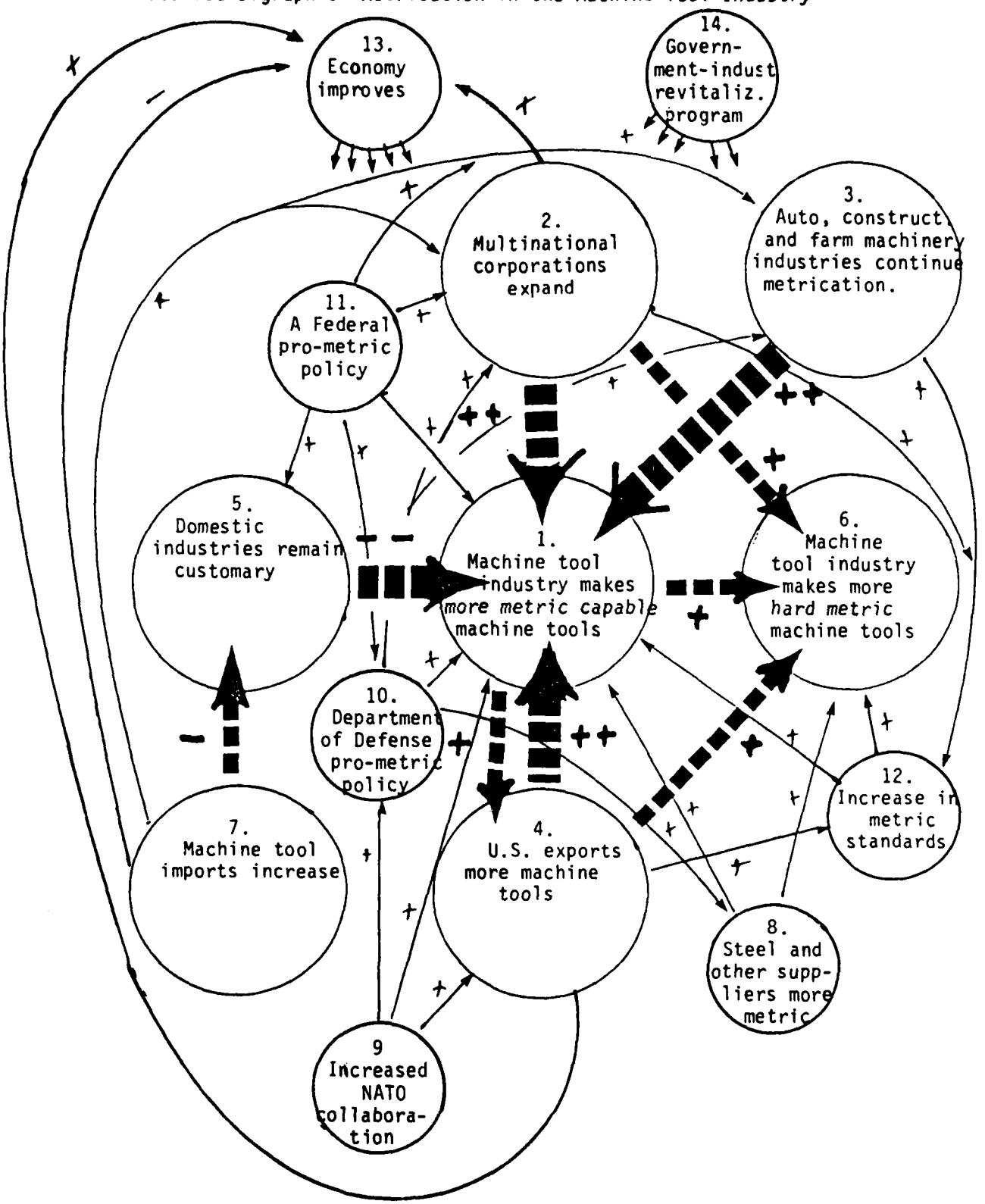
Exhibit 6

Other Forces in Metrication

Circle No. on Exhibit 5	Description	Effects
8	Steel and other supplier industries increase metric use.	Helps machine tools move more to hard and metric-capable production.
9	Increased mutual force equipping with NATO.	Increases metric exports, increases metric machine tools; encourages faster DOD conversion.
10	DOD takes strong metric standards and procurement actions.	Machine tool and other industries more metric-responsive.
11	U.S. government takes pro-metric stance.	Encourages all others to move metric faster.
12	Increase in metric-dimensioned machine tool and component standards.	General movement toward metric everywhere.
13	American economy improves.	Affects all other activities; because more machine tools would be ordered, might increase metrication.
14	Government revitalization of industry programs.	Affects all other activities because more machine tools would be ordered, might increase metrication.

Exhibit 7

Detailed Digraph of Metrication in the Machine Tool Industry



PROJECTIONS OF METRIC STATUS: SOME SCENARIOS

Projecting the future of any aspect of machine tool characteristic has always been difficult. The Encyclopedia Britannica of 1904 noted several machine tool innovations and their potential, but declined to estimate the rate and extent of their future use. For example,[28/ 29/]

> ...Sir J. Whitworth ... has achieved such success that in his workshop measuring machines a difference of 1/10,000 of an inch is readily appreciable.
>
> ...holes have been carried to a depth of 24 feet with a variation of less than 1/100 of an inch in the diameter.
>
> Another formidable rival to steam has now sprung up in the shape of electricity, and the results from it which are promised to us--and which indeed seem likely to be obtained--will go far towards revolutionizing all our ideas as to the difficulty of transmitting power to a distance, and will work a complete transformation in the aspect of the machine tools of the future.
>
> ...a more widely applicable remedy (to forging metal evenly), and one which will doubtless come into general use for heavy work, is the substitution of hydraulic or other pressure for the force or impact....
>
> It is therefore mechanically preferable to keep the work at rest when it is large or heavy, and to give all the requisite movements to the tool. This view is now gradually gaining favour, and the makers of some recent machines have adopted a form of construction...which has the advantage of enabling cuts either horizontal or vertical to be taken from any piece of work which can be secured to the base-plate, so that its full size is almost immaterial.

Other portions of the same article contained observations similar to the findings of this study: the customer industry required new performance (artillery pieces), and hence "pulled" the industry; and progress was made product-line by product-line. The only forecast that was made was that "The days of

mill-burning and implement-breaking mobs are indeed past...."[29/]

Today, it appears possible to offer some qualitative, and partially quantitative projections concerning the use of metric in the machine tool industry.

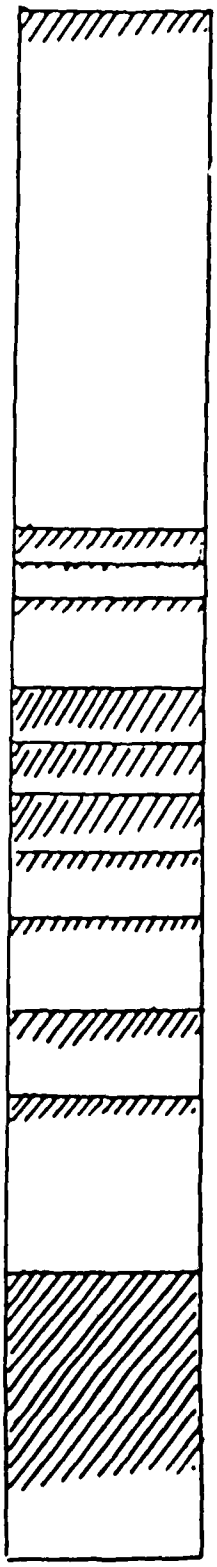
Exhibit 8 reflects the purchases of machine tools made by various consuming industries, shaded to show industry trends toward metrication. It is apparent that the greatest demand for machine tools comes from customers who are now asking for metric-capable machine tools, and are likely to increasingly demand those products in the future. Alternative future developments could include those indicated below.

(1) The baseline projection

If present trends continue, the transition of machine tools with a metric capability will characterize most American products. There will be a slowly increasing demand for 3544/45 tooling in metric dimensions. Imports of machine tools manufactured abroad will increase and stabilize at a level above the present volume. The EEC and Japan will gradually increase their requirements for machine tools in metric dimensions, and may require hard metric components such as fasteners for production-line machines. Special machine tools will still be accepted in customary units with metric capability. The 3541 and 3542 sector companies will slowly introduce new product lines with increasingly metric specifications. Use of metric dimensioned bar steel will still be the exception, as will metric gears, hydraulics, and electrical systems. More machines will be CNC. There will be a significant increase in the demand for robots and flexible machining systems. Limited metrication will become the rule with some companies specializing in more limited customary-unit product lines. The machine tool industry will become increasingly competitive. Some of the smaller producers will convert, be absorbed by larger companies, or fail. There will be little, if any, real growth in the early 1980's, although some companies will continue to expand. There will be a smaller inventory of machine tools in use, and a gradual increase in metric-capable machine tools. The accumulated volume of imports will support a number of small companies specializing in the repair of hard metric machines.

Exhibit 8

Relative Proportion of Machine Tool Sales
to Various Manufacturing Sectors



All Other Manufacturing Purchases

Photographic and Optical Machinery
Metal Can Machinery

All Other Special and General Machinery

Farm Machinery

Construction Machinery

Aerospace

Heating and Refrigeration

Electrical Machinery

Screw Machine Manufacturers

Machine Tool Industry

Automotive Industries

Key:
Proportion of the Using Industry converting to Metric Products

This projection is the most plausible general summary of what will happen if present trends and forces at work continue. Against this projection, it becomes possible to explore in a series of scenarios the effects of different assumptions or of different actions that could be taken.

(A) The U.S. government adopts some "revitalization initiatives" for American industry, perhaps tax incentives and accelerated depreciation allowances. The results are likely to be a slightly lower volume of imports, with slightly accelerated metrication in the machine tool industry. This could provide some growth in the industry.

(B) International customers become more demanding about metric components of machine tools, as outlined in the EEC plans and the Japanese requirements for metric characteristics of machine tools. The industry will move more quickly to metrication, with more failures of companies that do not provide metric machines.

(C) The U.S. government adopts a more positive attitude toward metrication, by policy statement or by acceptance of a DoD timetable. Metrication in the industry would accelerate. Some producers would begin introducing metric product lines. The steel industry would increase the availability of metric bar and other stock.

(D) U.S. foreign assistance programs increase their emphasis on third-world industrialization. This would cause slow increase in metrication in the machine tool industry.

(E) The United States is involved in war preparation that requires reactivation of the lay-away production base. There would be increased demand for machine tools in customary units, and an increase in CNC and NC conversion kits. If there is intense collaboration with NATO countries there would be increased demand for metric-capable machine tools on a rapid delivery schedule.

(F) Robotics, new materials, and flexible manufacturing systems spread rapidly. This would first affect large companies, most of whom have made some commitment to metric-capable machine tools.

(G) The United Kingdom and Canada back off from their metric programs, or a strong "Buy America" movement develops. The trend toward metrication in the industry would slow, with perhaps a halt in conversion plans for future product lines in some companies.

Of the above scenarios, only the most extreme, (E) and (G),

suggest any slowing of the gradual movement toward metrication in the American machine tool industry. The general inference from this study is that the machine tool industry is moving toward metrication, will pause momentarily at the production of metric-capable machine tools, but will gradually make the transition to hard metric. The study has not revealed any major impediments to this movement, other than the lack of domestic demand and the inertial friction of changing an industry whose product lifetime is several decades.

(H) Still another scenario is possible but not likely--that of sector-wide planning for metrication. There might be industry participation in the development of metric machine tool standards, but it appears unlikely that the industry would significantly embrace anything except a general statement of intent, and then probably only if the U.S. government took a strong initiative in asking for it.

There may be some advantages in preparing and using a "business management game" to forecast for the industry, the effects of possible government or customer industry actions. However, such a game should be targeted on the question of the viability and competitiveness of the industry and not narrowed to the metrication question. Except for the question of the likelihood or extent of increases in exports from increased metrication, this study has not identified any high priority research questions associated with metrication in this industry. There are, however, several top priority research questions that have metrication overtones. Answering these questions might show that metrication could provide some tactical leverage in solving some problems of the machine tool industry. An attractive research agenda could include the following questions:

(1) What combination of public and private initiatives might stimulate a more internationally competitive American industry?

(2) What are the probable future developments in the various major American industries? What future machine tool demands do they imply? To what extent do American producers have an inherent competitive advantage in satisfying those demands? And in which areas will imports be more attractive to the consuming industries?

(3) In what ways could an American foreign assistance program for industrializing the newly developing nations also help the American machinery industry?

(4) How will the future of the multinational corporation affect the American industrial scene?

(5) To what extent are American machine tools capable of penetrating foreign markets?

(6) To what extent might foreign machine tool products displace American producers?

(7) To what extent does the long development and production cycle for machine tools affect the ability to produce military materiel in emergency conditions? How much accelerated delivery is possible?

(8) What is the role of metrication in each of the above questions?

(9) What would be the consequences of a positive federal pro-metric (non-voluntary) policy?

(10) What effects might arise from the interface between a partly-metric American industry and a fully-metric foreign industry?

CHAPTER V

THE OUTLOOK FOR THE MACHINE TOOL INDUSTRY

Preview: This chapter describes the machine tool industry, its structure, and its products. It provides information from the National Machine Tool Builders' Association, the Census Bureau, the Bureau of Labor Statistics, and other sources. A brief examination of some industry trends and innovations completes the chapter. Readers who are familiar with the industry may wish to go directly to Chapter VI.

Machine tools are power-driven machines, not portable by hand, that are used to cut, form, or shape metal. They are the tools that make mass production in industry possible. The machine tool industry is a small but very important part of the larger category, manufacturing industries. Several metric use studies have dealt with the manufacturing industries (see Chapter III),but have given scant attention to the machine tool industry.

The most useful general way of describing the industry is by the use of SIC (Standard Industrial Classification) codes.* The primary focus has been on SIC codes 3541 and 3542. The National Machine Tool Builders' Association spans these two SIC codes with its membership and services, and generates much of the data used by the world at large. 30/

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*SIC codes, defined by the Office of Management and Budget, are described in terms of the number of digits they contain. For example, the two-digit SIC code 35 includes all kinds of machinery -- farm, construction, oil field, food processing, textile, paper, printing, office, pumping machines, and the machine tools. The three-digit SIC code 354 is reserved for the metal-working machinery subdivision of SIC 35. SIC 354 includes metal-cutting machine tools, metal-forming machine tools, special dies, tools, jigs, fixtures, perishable cutting tools, power-driven hand tools, rolling mill machinery, and a group of miscellaneous kinds of metal-working machinery. The further subdivision SIC Code 3541 includes those establishments which make the large metal-cutting machine tools. SIC Code 3542 includes the establishments which make the metal-forming (shearing, bending, stamping, pressing) machine tools. Further detail is obtained by using 5- and 7-digit codes. For example, SIC 35415 are metal-cutting lathes.

As noted in earlier chapters, a metric-capable tool can be created from one built in customary units by inserting a metric drill, die, or tap into the machine tool. Thus, although the machine tool industry itself is defined by SIC codes 3541 and 3542, those machine tools can be made partially metric by the use of tools, dies, molds, and other accessories, which fall under SIC codes 3544 and 3545. For purposes of measuring the status of metrication in the machine tool industry, it is important to measure the extent of metrication in perishable cutting tools and dies as well.

There have been no extensive studies of metrication in the machine tool industry. NBS and Metric Board studies described in Chapter III included a very small number of 3541 and 3542 companies in their surveys. American Machinist, which makes in-depth surveys of metalworking equipment, has not included metric questions in its comprehensive tabulation,[31/] and has no plans to include such questions in the next survey for 1983,[32/] although they do include counts of NC and CNC machine tools.

THE STRUCTURE OF THE INDUSTRY

The machine tool industry provides critical metalworking tools for nearly all manufacturing establishments in the nation. Because machine tools are usually expensive items of capital equipment that must serve the demands for high productivity over periods of 30 years or more, they are built with precision and quality of performance in mind. The requirements of industrial purchasers are at least as strong a factor as the new technologies of the machine tool industry itself in determining where the machine tool industry is going. Indeed, much of the inventiveness in the machine tool industry is provided in response to outside stimuli or novelties. For example, computer-numerically-controlled machine tools or the substitution of lighter-weight plastics for metal parts of an automobile have caused major changes in the industries. A common saying in the industry is that "we can build whatever the customer wants," and this customer "pull" also

applies to metrication; toolmakers say: "when the customer wants metric, he gets it," or "we've always made metric machine tools when they are ordered."

Because of this responsiveness to the capital expansion needs of the manufacturing sector, the machine tool industry has boom periods and recession periods. This cyclical history in net new orders is very pronounced. It can produce a doubling or a halving of demand over a year or two.[33/] The industry has recently been extremely sluggish with net new orders in 1981, 35-40 percent lower than in 1980. However, this is not necessarily true of individual companies. Several of the companies contacted for this study were enjoying an unprecedented boom in business at precisely the same time that most other companies were having trouble.

Thus, the health of the machine tool industry is heavily dependent on a number of economic factors well beyond its own immediate control. Orders will drop if the using industry is operating at a low level and rise if the using industry has a congested production line. Most machine tools become part of the depreciable capital equipment of an industry. Their purchase can require borrowed capital, and the prevailing interest rates bear heavily on the decision to purchase. Finally, confidence in the future growth of the economy has an important bearing on machine tool orders. With the present high interest rates and gloomy forecasts about the economy, the machine tool industry has suffered cutbacks in new orders. The success of foreign producers, especially the Japanese, in penetrating the American market has added to the problems of the domestic machine tool manufacturer. In spite of this, many industry representatives are buoyantly optimistic in the recession year 1982.

Some machine tools are production line items -- turret lathes, grinding machines, etc. Still others are specially designed and built, one-of-a-kind machine tools. The production time for machine tools is typically measured in months; for a special purpose machine tool it may be a year or more. In 1980, delivery lead times on new orders averaged 13-15 months. This order backlog helped to smooth over slow periods in late 1981,

but order backlogs now average 6-8 months. Long lead times produce customer dissatisfaction; a part of the success of foreign machine tool manufacturers in recent years can be attributed directly to their delivering products more rapidly than their American competitor.

The machine tool industry is relatively small. The 1977 Census of Manufacturers counted 919 metal cutting and 426 metal forming establishments. Of these, 306 metal cutting and 163 metal forming establishments had work forces of 20 or more employees. The metal cutting tool industry had a workforce of 59,000 employees, and the metal forming industry only 24,000.[34/] About one-fifth of the employment and one-fifth of the shipments in each came from the four largest establishments, while the 20 largest establishments provided slightly more than half the employment and total dollar shipments.[35/] The SIC 3544 industry had 7,033 establishments with 106,000 employees, and the SIC 3545 (perishable cutting tool manufacturers) has 1,271 establishments with 54,000 workers.

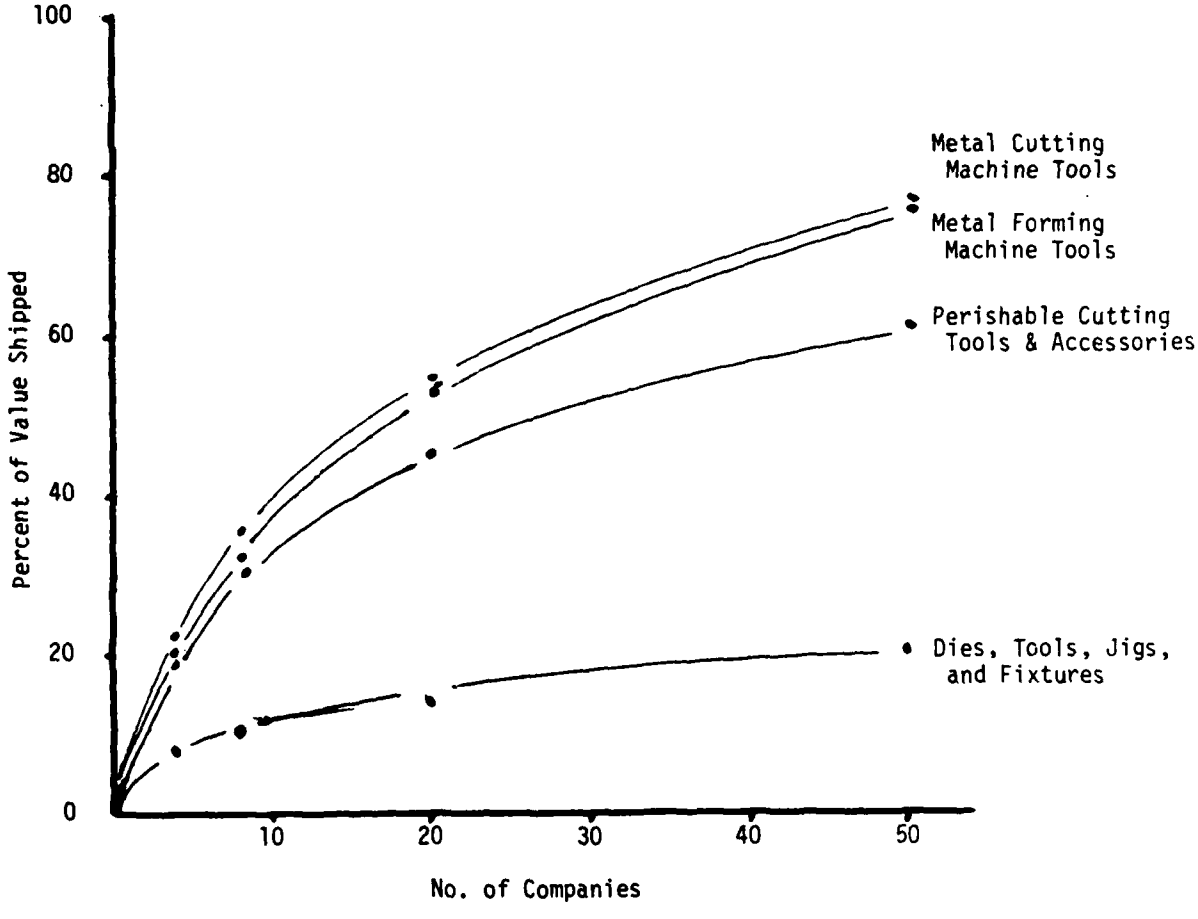
The concentration ratios for the industries are shown in Exhibit 9. There are a few large establishments and a very large number of small companies. The perishable cutting tool manufacturers are somewhat less concentrated than other parts of the industry, and die makers are even less concentrated, with only a small number of large producers.

Most of the manufacturers with 20 or more employees are corporations; partnerships and proprietorships are rare.

Manufacturers in the metal cutting industry tend to be highly specialized, and very few other manufacturers have penetrated the field. Two ratios are used in Exhibit 10 to describe these characteristics. The specialization ratio is the percent of shipments from a four-digit SIC code industry of products which fall within that SIC code. As shown in Exhibit 10, SIC code 3541 manufacturers have not significantly diversified into other product types, and conversely, 92% of all metal cutting machine tools come from SIC 3541 companies (the coverage ratio).

EXHIBIT 9

Concentration Ratios, 1977
(Percent of Value of Industry Shipments)



Source: Bureau of the Census, 1977 Census of Manufactures, Concentration Ratios in Manufacturing, MC77-SR-9, issued May 1981, pages 9-47, 9-48, and 9-107.

EXHIBIT 10
Specialization and Coverage Ratios 35/

SIC Code	Specialization Ratio	Coverage Ratio
3541 Metal cutting	87%	92%
3542 Metal forming	90%	87%
3544 Tools, dies, jigs, and fixtures	94%	79%
3545 Perishable tools and accessories	89%	88%

This concentration is even more pronounced when it comes to individual product lines. Exhibit 11 shows the concentration for the six major five-digit cutting machine tool classes. The top 8 producers of gear-cutting machines held 92 percent of the 1977 market. This concentration means that if a major manufacturer makes an important innovation in his product line, it could be a highly significant event for the entire industry. If a large manufacturer decides to convert one major product line to metric, it may have great impact.

THE BEHAVIOR OF THE INDUSTRY

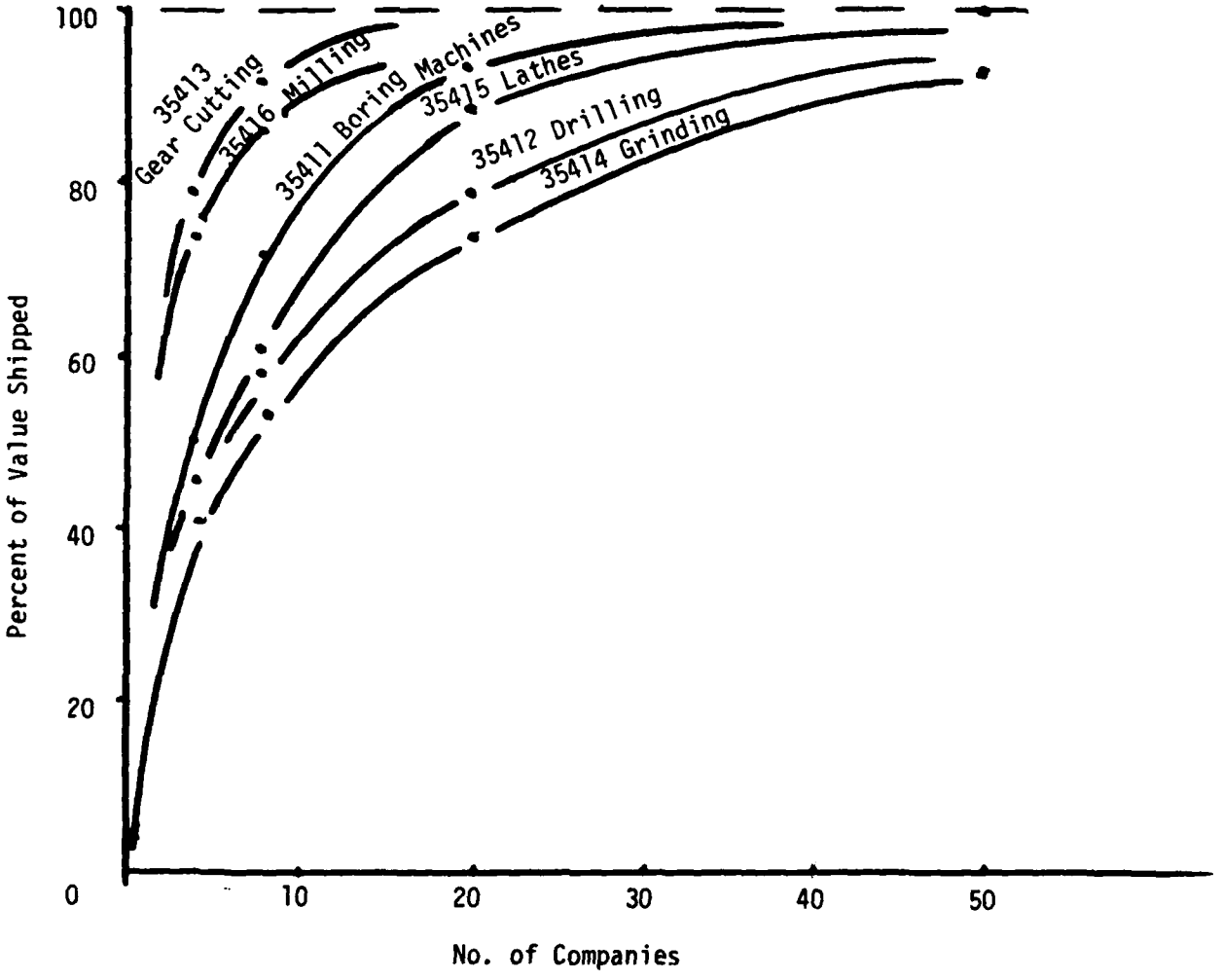
The dollar value of shipments of machine tools from domestic manufacturers has been increasing dramatically in recent years, as can be seen in the graph of Exhibit 12. The rise in dollar values, however, conceals two important negative factors. A significant portion of that most recent growth is due to shipments of previously ordered equipment, part of a 12-14 month backlog of unfilled orders that began disappearing in the summer of 1980, and has been dropping consistently ever since. The backlog is now below the 8-month point. The behavior of the backlogs is shown graphically in Exhibit 13. Some manufacturers have begun stretching out delivery schedules in an attempt to avoid worker layoffs. The drop in net new orders is shown graphically in Exhibit 14.

The second negative factor is inflation. The values or shipments shown in Exhibit 12 are in current dollars and, therefore, include inflation. Exhibit 15 below shows the inflation correction factors. Inflation has been larger in the metalworking industry than in manufacturing in general, or in the GNP.

When the industry shipments shown in Exhibit 12 are divided by the metalworking machinery inflation deflators (Exhibit 15), a cyclic pattern results (Exhibit 16). The cyclic nature of the shipment volumes clouds the ability to measure systematic detectable growth or decay. However, NMTBA has constructed a similar graph using 1967 constant dollars and quarterly intervals of time,[36/] which is consistent with that in Exhibit 16. Added to this exhibit is a projection by the Bureau of Labor Statistics showing high and low estimates of the volume of machine tool shipments for 1990.

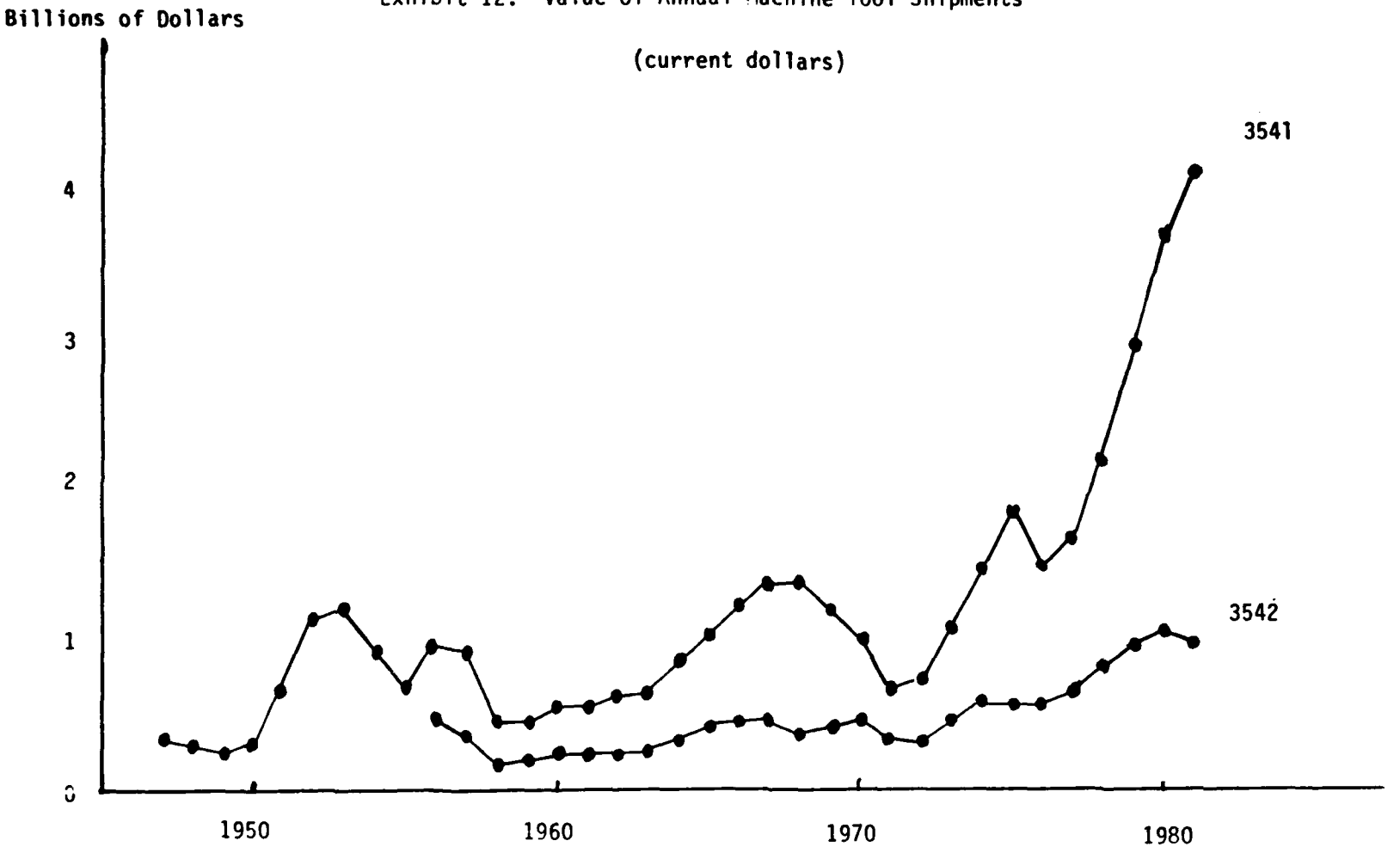
EXHIBIT 11

Concentration Ratios, 1977
For Classes of Machine Tools
(Percent of Value of Industry Shipments)



Source: Bureau of the Census, 1977 Census of Manufactures: Concentration Ratios in Manufacturing, MC77-SR-9, issued May 1981, pages 9-224 and 9-225.

Exhibit 12. Value of Annual Machine Tool Shipments

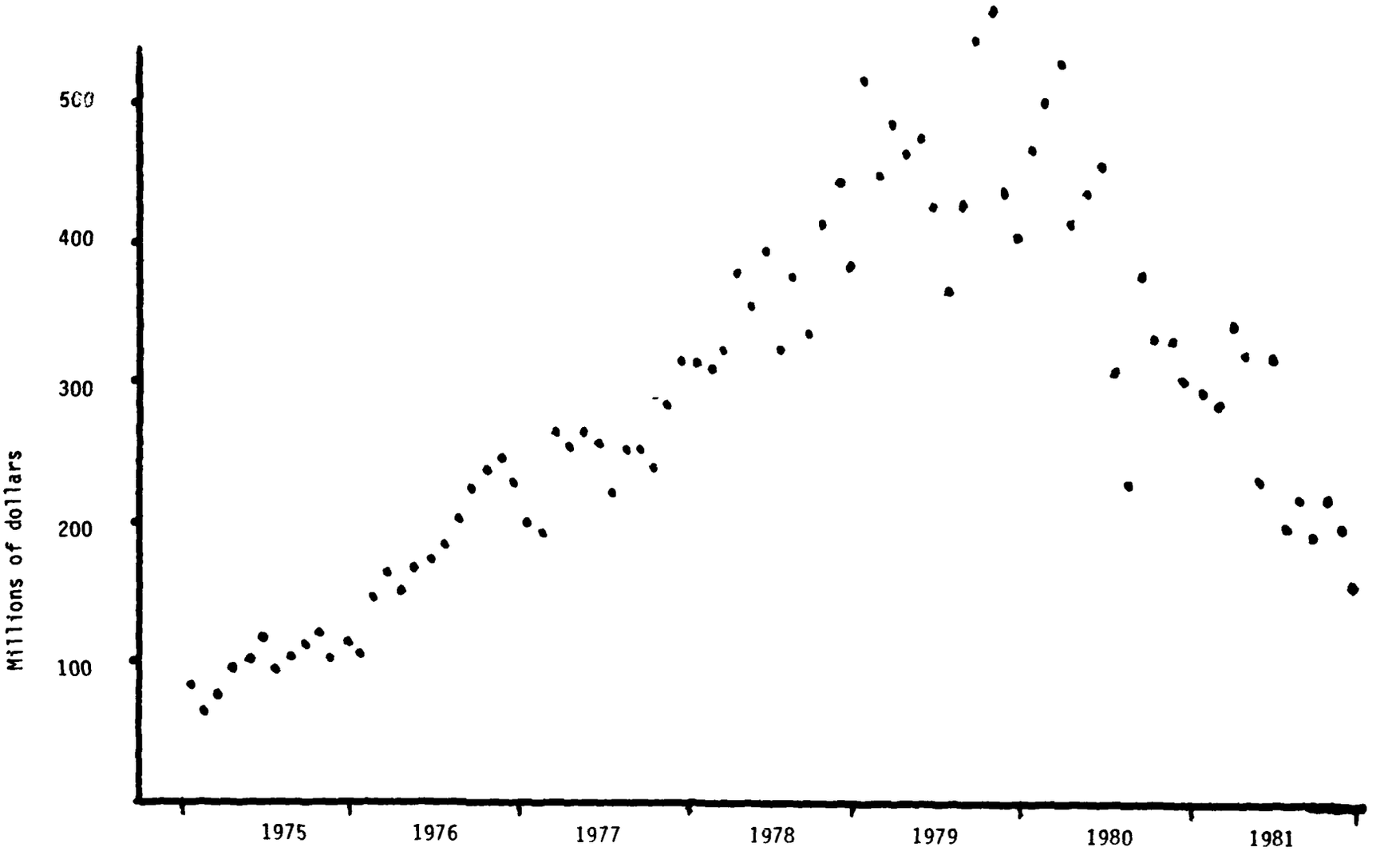


Source: National Machine Tool Builders' Association, Economic Data, 1981-82, page 42.
Data for 1981 taken from statistical report provided by NMTBA.

Exhibit 13. Backlog of Unfilled Orders
SIC 3541 and 3542

Source: National Machine Tool Builders' Association, Economic Data, 1981-82, page 37. Data for 1981 provided in special preliminary report by NMTBA: discontinuity is due to a redefinition in SIC 3542 backlogs.

Exhibit 14. Net New Orders for Machine Tools (Monthly)



Source: National Machine Tool Builders' Association, Economic Data, 1981-82, page 36.
Data for 1981 provided by NMTBA Statistics Department.

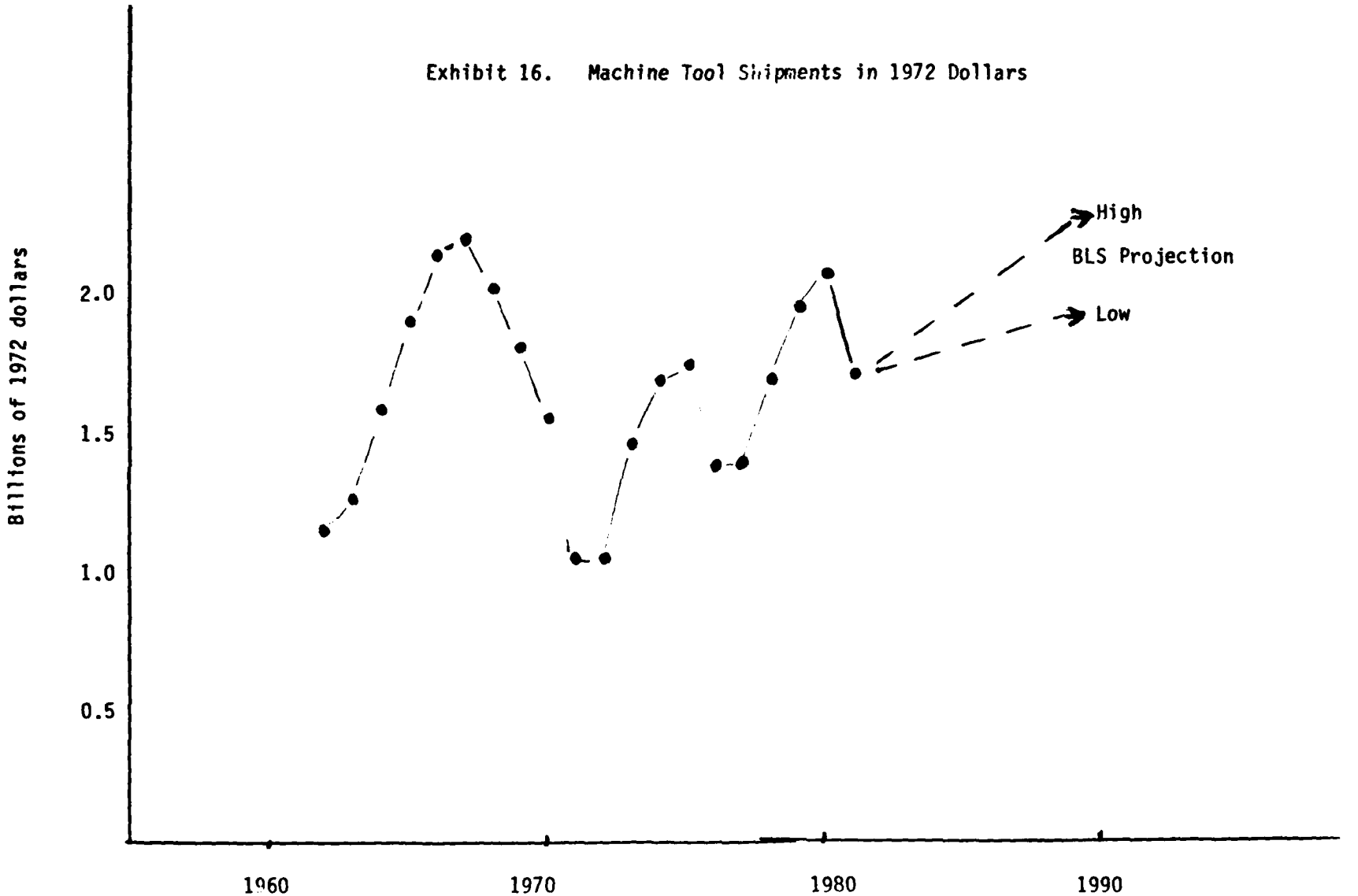
Exhibit 15

Price Deflators
1972 = 100.00

Year	GNP	Durable Equipment	Metalworking Machinery
1962	70.6	79.4	72.6
1964	72.8	80.1	74.3
1966	76.8	82.1	79.8
1968	82.5	87.2	86.5
1970	91.4	93.2	94.8
1972	100.0	100.0	100.0
1974	114.9	109.3	122.2
1976	132.1	133.9	152.2
1978	150.1	150.1	180.5
1979	162.8	159.7	200.7
1980	177.4	170.1	228.2

Source: National Machine Tool Builders' Association, Economic Data, 1981-82, page 7.

Exhibit 16. Machine Tool Shipments in 1972 Dollars



Source: National Machine Tool Builders' Association, Economic Data, 1981-82, pp. 7-42. Data for 1981 provided by NMTRA. Projections for 1990 are based on the assumption that 14% of 1990 machinery sector outputs projected by BLS are for SIC 3541 and 3542, i.e., excludes 3544 and 3545.

America's inventory of machine tools in use is nearly twice as large as that of any other western industrial nation. Its inventory is also the oldest among those of seven major western countries, with the smallest proportion of machine tools younger than 10 years and the largest proportion older than 20 years. See Exhibit 17.

Partly because of this aging stock, industrial productivity increased in the United States have trailed those of other countries.[37/]

The long service life of a machine tool and the slow replacement process means that innovations take time to permeate the system. Numerically controlled (NC) machine tools made their appearance during the 1950s; yet, by the time of the 1978-79 American Machinist Inventory, only 53,000, or 20%, were NC.[38/] By 1980, the total shipment of NC machine tools in the United States was 8,000 units. This still represented only 3% of the total number of units shipped, although it was 34% by dollar value, as shown in Exhibit 18. Imports of machine tools are predominantly NC. Japan, our largest foreign supplier of machine tools, shipped 4,600 NC machine tools to the U.S. in 1980, valued at $348 million, approximately 73% of the value of all machine tools arriving from Japan.[39/]

NC machine tools have become important in the metal cutting industry, some 20-25 years after they first appeared. About 4% of tools used by machine tool manufacturers themselves are NC machines (dollar value not available). Insofar as NC machine tools are metric-capable, then 3-4% can be regarded as a lower limit in estimating the extent of metrication capability in machine tools. Adding to that is the capability of inserting a metric drill, die, or tap into a conventional unit machine. Most of the machine tools in the United States are capable of cutting to metric dimensions.

INPUTS AND OUTPUTS

A good way to understand how an industry fits into the economy is by looking at its inputs and outputs, as in Exhibit 19. The machine tool industry buys steel, castings, industrial controls, and other materials. In turn, they sell the machine tools to other manufacturing sectors --

Exhibit 17

Age of Machine Tools in Use

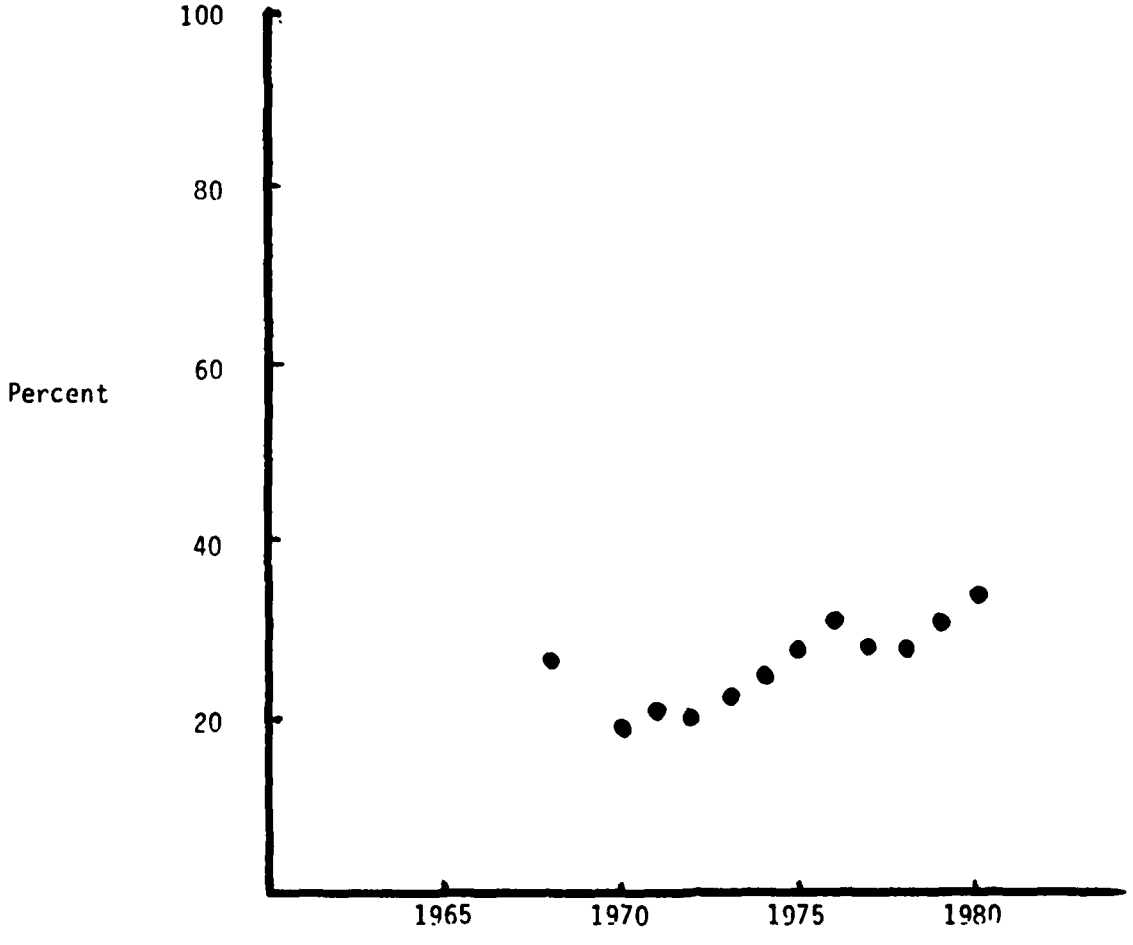
Country	Percent of Machine Tools by Age		
	Less than 10 Years	10-20 Years	Over 20 Years
United States	31%	35%	34%
West Germany	37%	37%	26%
United Kingdom	39%	37%	24%
Japan	61%	21%	18%
France	37%	33%	30%
Italy	42%	30%	28%
Canada	47%	35%	18%

Source: National Machine Tool Builders' Association, Economic Data, 1981-82, page 257. Their sources included McGraw Hill, American Machinist, and Verein Deutscher Werkzeugmaschinenfabrik, e. V.

Exhibit 18

Proportion of NC Cutting Machines

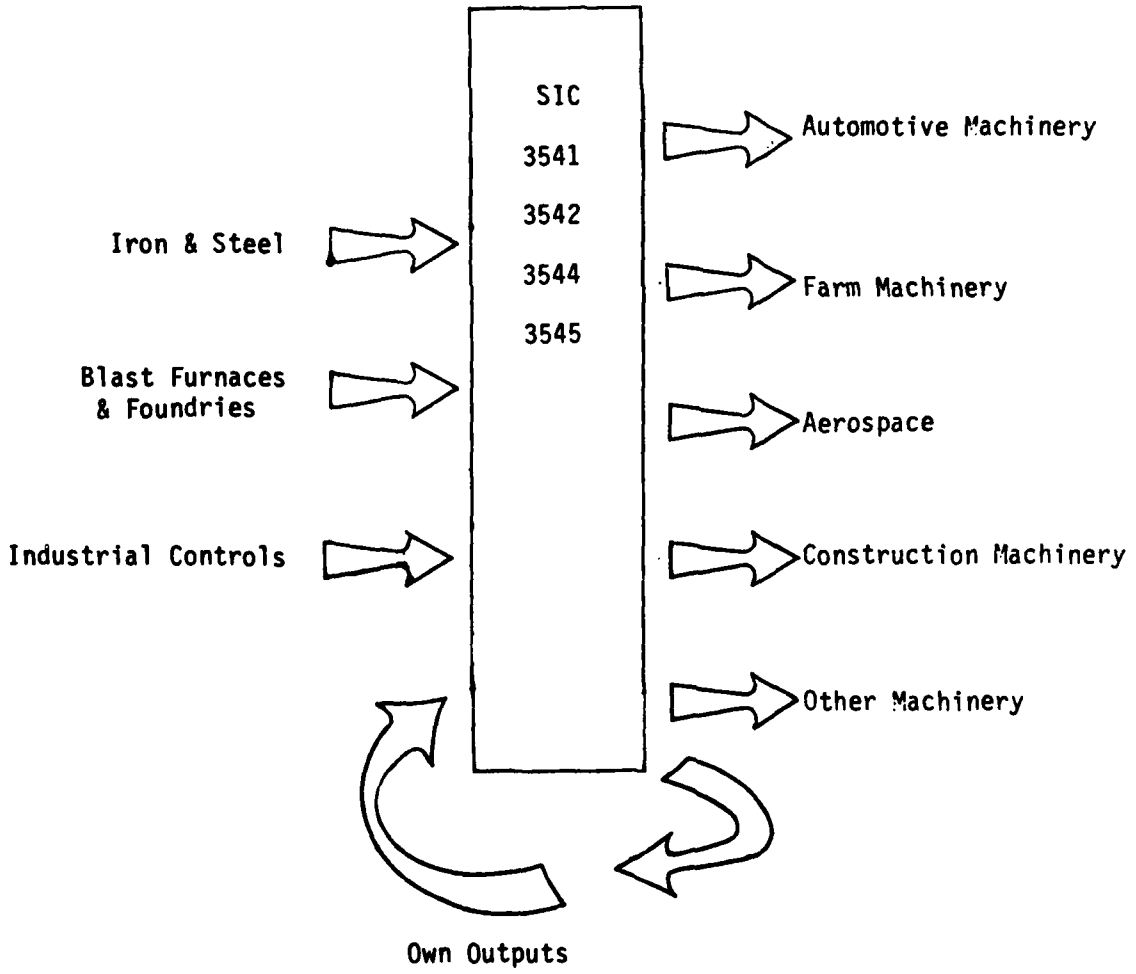
(Percent of Dollar Value of Shipments)
by the U.S.



Source: National Machine Tool Builders' Association, Economic Handbook 1981-1982, pp. 100-101.

Exhibit 19

Industry Inputs and Outputs



automotive, farm machinery, aerospace, construction, and other machinery, and to themselves.

The extent to which industries affect each other can be described in mathematical economics terms by using an input-output (I-O) model. (See Appendix A for a discussion of the use of I-O analysis in this study. The appendix includes detailed lists of inputs, outputs, coefficients, etc.)

The machine tool industry draws heavily on inputs from blast furnaces and steel mills, iron and steel foundries, castings, and industrial controls. The inputs to the industry include heavy purchases of its own outputs, pumps and compressors, motors and generators. Capital inputs show additional purchases of their own outputs, as well as investments in buildings, computers, motor vehicles, and materials handling equipment. The outputs of the machine tool industry are thus distributed widely among the various manufacturing consumers, both in terms of expensed items and capital flow transactions.

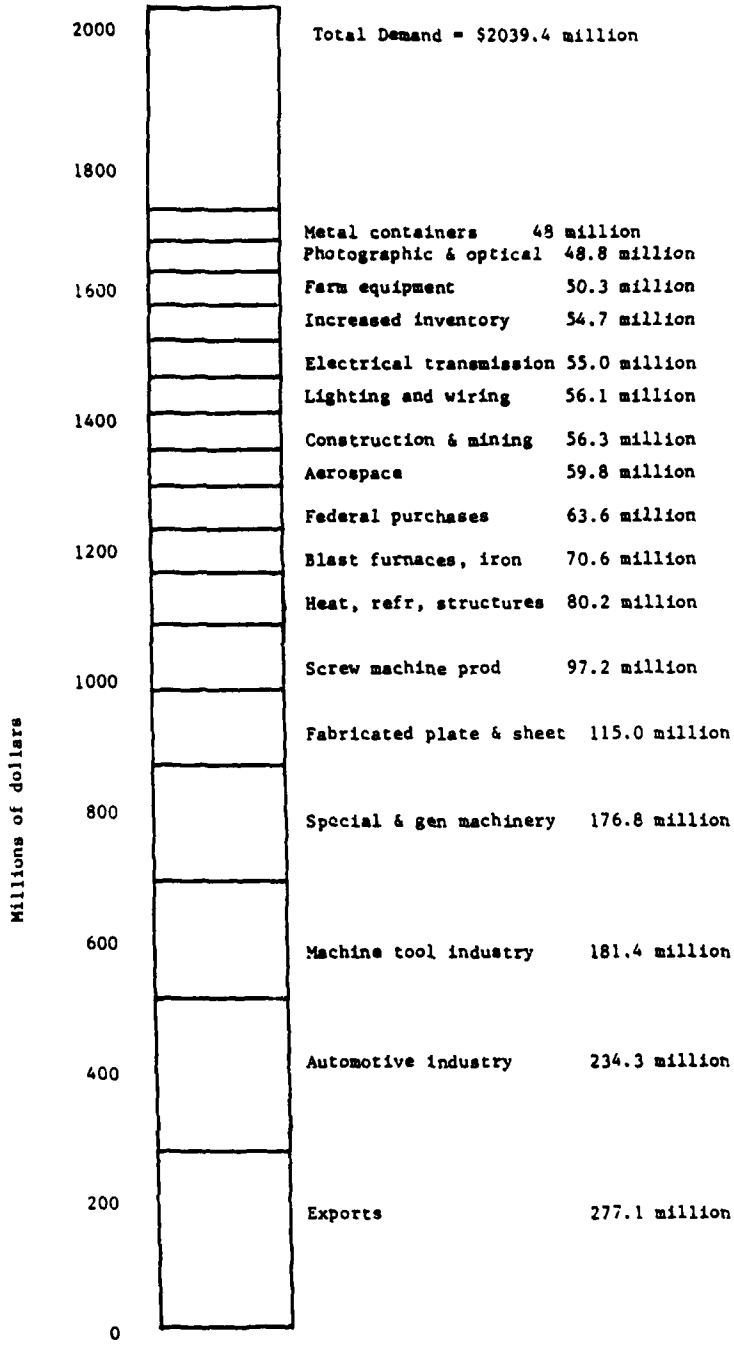
In an earlier BEA analysis, direct government purchases of machine tools (in 1972) accounted for 15.7 percent of the metalworking industry output, but federal purchases from other sectors may prompt another 1.6 percent of industry sales.[40/] Thus, each federal dollar spent in income transfer or public assistance programs has a "pulling effect" of 0.2 mill on the machine tool industry; the expected result of a one billion dollar federal expenditure on such social programs would be the purchase of one $200,000 machine tool.

The bar chart of Exhibit 20 summarizes the I-O data. Of the total demand for machine tools in SIC codes 3541 and 3542 in 1972, slightly more than 85% went to 17 user groupings, the largest of which was exports. The automotive industry was the largest single user. This chart was used earlier in the report to show the extent to which the customers of the machine tool industry are converting to metric use; here it merely indicates roughly the proportional customer demand on the industry.

As a special courtesy to this project, the Bureau of Labor Statistics made a computer run of projections for the machine tool sector through 1985 and 1990, using its most recently corrected coefficients. These

Exhibit 20

Total Shipments of Machine Tools by User Industry
(For 1972)



Source: BEA Input-Output Tables in Appendix A

coefficients are still being improved, and the projections should not be regarded as authoritative. The projections used three sets of assumptions: a low general growth rate in the economy and two variants of a high growth rate (see Exhibit 21).

Given these assumptions, the projections showed increased demands on the machine tool industry by their customer sectors at rates of annual increase of real growth (not due to inflation) averaging 4% per year, but with some sectors as low as 2% and others above 10% (see Exhibit 22).

The very large customer classes now buying from the machine tool industry continue to grow at about 4% per year, but some new customer classes are beginning to emerge at significant levels -- electronic and scientific instrumentation and computers, and machining of non-ferrous metals other than copper and aluminum. Also, aircraft manufacturers have overtaken the automotive purchasers.

There is a major defect in these projections. Import growth is estimated at 4% per year, and the export growth at 6% per year, with the average overall growth rate between 1972 and 1990 slightly less than 4% per year. The volume of imports projected for 1990 has already been exceeded in 1981. The formula used to project imports in the model was based on trends of the early 1970's, before the exponential growth of Japanese sales in the U.S. Later versions of the model will be adjusted to reflect the new situation.

The Bureau of Industrial Economics (Department of Commerce) makes projections for shorter periods of time.[41/] For 1982, these projections, now in press, show a surge of about 30% in new orders for machine tools. Longer term prospects are for an estimated growth rate of 9.6% through 1986. These optimistic projections are guarded with the observation that the growth rate depends on American use of new technology to compete successfully with foreign manufacturers. NMTBA also had an optimistic sales forecast for 1982 of 5% real growth.

Exhibit 21

Assumptions for 1985-1990 Projections (annual rates of growth)

Factor	Low	High I	High II
Employment Increase	1.4%	1.9%	1.5%
Growth in GNP	2.8%	4.0%	4.1%
Productivity Increase	1.8%	2.5%	3.0%
Durable Equipment Sales	5.0%	8.1%	8.1%
Defense Purchases	2.0%	1.5%	2.1%

Source: Norman C. Saunders, "The U.S. Economy through 1990--An Update", Monthly Labor Review, August 1981, 18-27.

Note to Reader: Low and High I projections tend to reflect a range of expected values. High II corresponds to a realization of the Administration's goals.

Exhibit 22

Projections of Machine Tool Sales to 1990

Using Sector	1990 Projection (millions of 1972 dollars) Low Growth	High I Growth	Percent Increase of Low 1990 over 1972 (18 year total)
Ordnance	$41	$44	53%
Plastics	153	178	122%
Blast Furnaces	245	289	27%
Iron and Steel Foundries	98	120	38%
Copper and Copper Products	78	91	43%
Aluminum and Al Products	140	164	22%
Other nonferrous metals & prod.	96	109	691%
Metal containers	39	42	59%
Fabricated structural metals	125	144	82%
Screw machine products	141	169	54%
Metal stampings	93	113	149%
Cutlery, hand tools, hardware	56	65	74%
Fabricated metal products,nec	114	134	56%
Engines, turbines, generators	97	121	79%
Farm machinery	90	115	113%
Construction, mining, oil field	215	276	123%
Materials handling equipment	35	46	233%
Machine tools	704	919	74%
Special industry machinery	116	153	61%
General industry machinery	195	247	96%
Nonelectric machinery, nec	159	191	100%
Computers	115	148	561%
Service industry machinery	43	53	117%
Elec industrial apparatus	99	123	96%
Household appliances	49	57	315%
Electrical lighting and wiring	53	62	59%
Radio and communication eqpt	102	113	102%
Electronic components	107	129	365%
Electrical machinery nec	61	75	146%
Motor vehicles	266	339	105%
Aircraft	335	357	212%
Railroad equipment	32	44	88%
Scientific and control instrum.	51	62	372%
Exports			205%
Imports			105%
Total output of machine tool industry			88%

Source: Special Computer Run made by Bureau of Labor Statistics for this Project, March 1982.

Note: The figures are shown in 1972 dollars, i.e., inflation does not appear. Percent increases are for the "Low 1990" projection and "High I" projection. This projection is only for the expensed portion of the inter-industry flows. Therefore this chart should be compared with the 1972 data in Appendix A, and not the capital flows, for which the 1990 projections were not detailed.

The American Machinist's economic forecast for the first half of 1982 was gloomier, with a real growth rate of only 2% over 1981 in production and little likelihood that the large volume of new orders foreseen by the optimists will in fact occur.[42/]

One way to stimulate the purchase of new machine tools is through the use of various tax incentives provided by the Economic Recovery Tax Act of 1981. These include tax credits of 25% for R&D expenditures over past levels, and 5-year depreciation of capital equipment. Economists hypothesize that innovations in the machine tool industry typically accompany the purchase of new equipment, rather than the retrofitting of older equipment.[43/] The introduction of NC machine tools is cited as an example. These new incentives may or may not be exercised to advantage in the next several years.[44/]

NEW TECHNOLOGY

A full treatment of the possibilities of new technology in the machine tool industry is well beyond the scope of this report, but it is important to summarize some of the more important possibilities affecting the future status of the industry.

The U.S. Industrial Outlook: 1982 points out that new technology will be an important factor in determining whether the American machine tool industry can maintain or improve its competitive position. Among the imminent improvements judged to be important are flexible manufacturing systems (FMS) and robotics.[45/] The FMS is a set of CNC machine tools with automatic tool-changing capabilities and automated workpiece transfer. Robots are reprogrammable manipulators that can be used in repetitive operations such as materials handling, tool changing, paint spraying, and other operations, especially in hazardous environments. Both are available from both American and foreign manufacturers, but the Japanese have taken a strong lead.

Innovation in machine tools has tended to be pushed from outside, especially from user industries.[46] A Machine Tool Task Force report[47] sponsored by the Air Force Systems Command concluded that future innovations were likely to come from the automotive, aircraft, and construction machinery industries.[48] Requirements in those industries included:

- the ability to cut novel materials such as magnesium, powdered metals, titantium, polymers, and laminates;
- use of thinner workpieces, which require new kinds of cutting tools and holding fixtures;
- lighter automobiles which require meshing parts with tighter tolerances; and
- energy conservation, implying closer tolerances in surface finishes.

Further conversion to the metric system was not mentioned. All of these new technologies would be workable in either customary or metric units.

The Task Force pointed out that the economics of an innovation determine whether it becomes a production line reality. Governments of other nations promote their machine tool industries in ways not even considered in the United States; for example, special depreciation allowances in Japan for companies using new NC machines with capacity greater than 60,000 bits, and special robot leasing arrangements for small- and medium-size manufacturing companies.[49] A quarter of all West German machine tool R&D is government funded. There are machine tool R&D institutes in both East and West Germany, the UK, Japan, France, Belgium, Yugoslavia, Czechoslovakia, and Canada. The Task Force noted that the health of the machine tool industry, a customer pulled industry, depends very strongly on government policies on innovation, depreciation, tax allowances, interest rates, and inflation.[50] It reported industry complaints both that government policies are a barrier to growth, and that there is a lack of information on what the policies are.

The Task Force report noted that, increasingly, there would be a systems-orientation in the use of machine tools, in which all the pieces of a problem or workflow are treated as interacting and subordinate components of the total process. For example, in machine tool use, a major

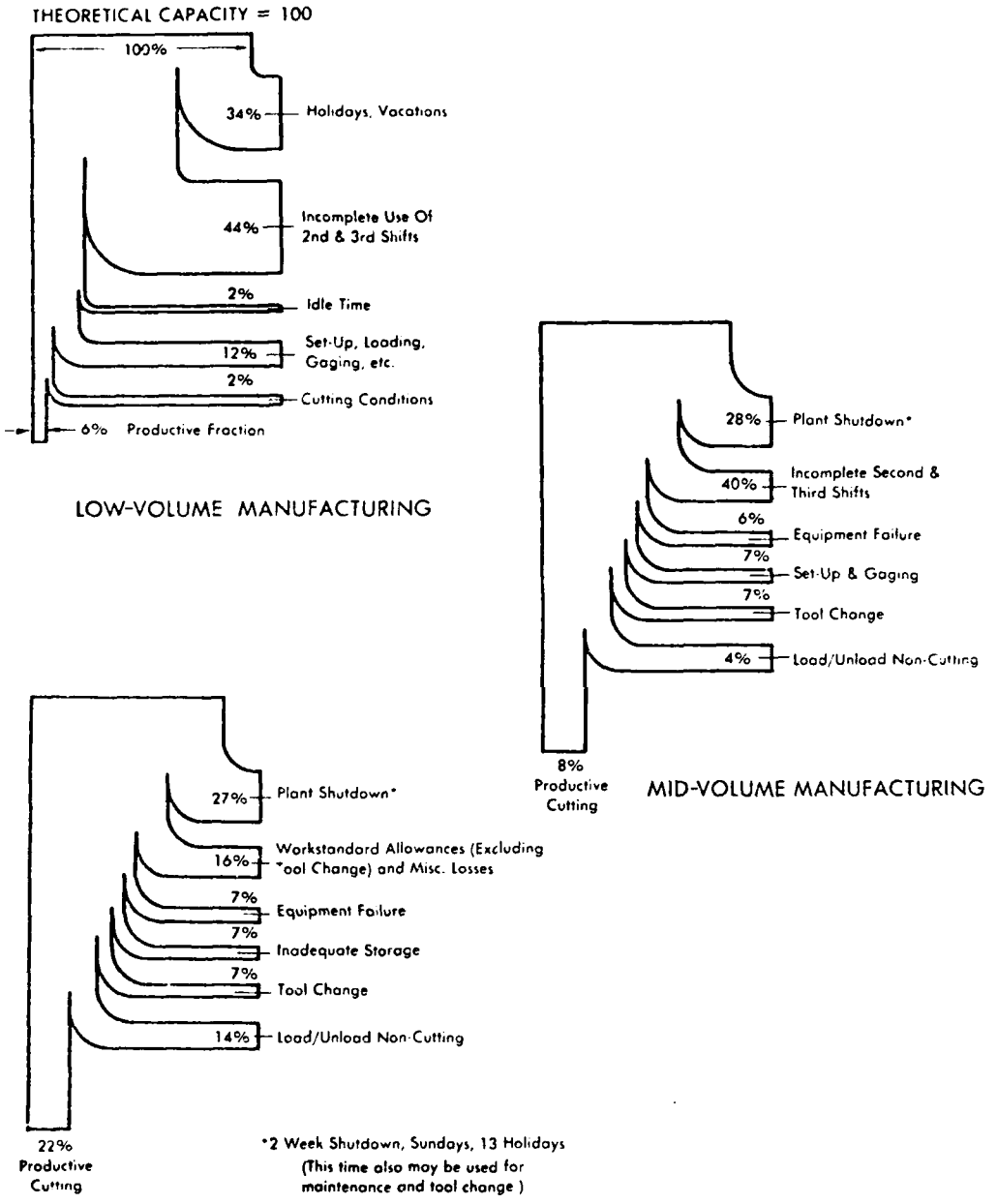
portion of the cutting time of a tool is sacrificed to non-productive activities. These are illustrated in Exhibit 23 from the Task Force Report. [51] A systems approach would call for finding different ways to improve total productivity, not just improvements in cutting speed, for example.

Increasing precision requirements have interesting repercussions internal to the machine tool industry. For example, increased precision in forging can create workpieces on which no cutting operation other than finishing is required.[52]

American Machinist also sees major advances in robots, automation, new materials, and computer-integrated manufacturing (CIM) as important in 1982 and shortly thereafter.[53]

Exhibit 23

Utilization of Machine Tools in Low, Mid, and High Volume Production



Source: Machine Tool Task Force, "Machine Tool Systems Management and Utilization," volume 2 of the series, Technology of Machine Tools, Lawrence Livermore Laboratory, University of California, October 1980, page 32.

CHAPTER VI

THE THREAT TO THE MACHINE TOOL INDUSTRY

Preview: This chapter describes the import and export activity in machine tools, and projects an increasingly unfavorable future for the American manufacturers. An aggressive overseas marketing strategy is suggested.

In 1980, world production of machine tools was valued at $26.5 billion. The United States produced approximately one-fifth of this amount, and was also the largest single buyer of machine tools, and purchased about one-fifth of the world production. The Soviet Union, West Germany, Japan, the United Kingdom, Italy, and France were the next largest consumers by dollar volume. Of the world production of machine tools, nearly half crossed international boundaries to reach their users.[54/]

These proportions are reflected in Exhibits 24, 25, and 26.

Exhibit 24

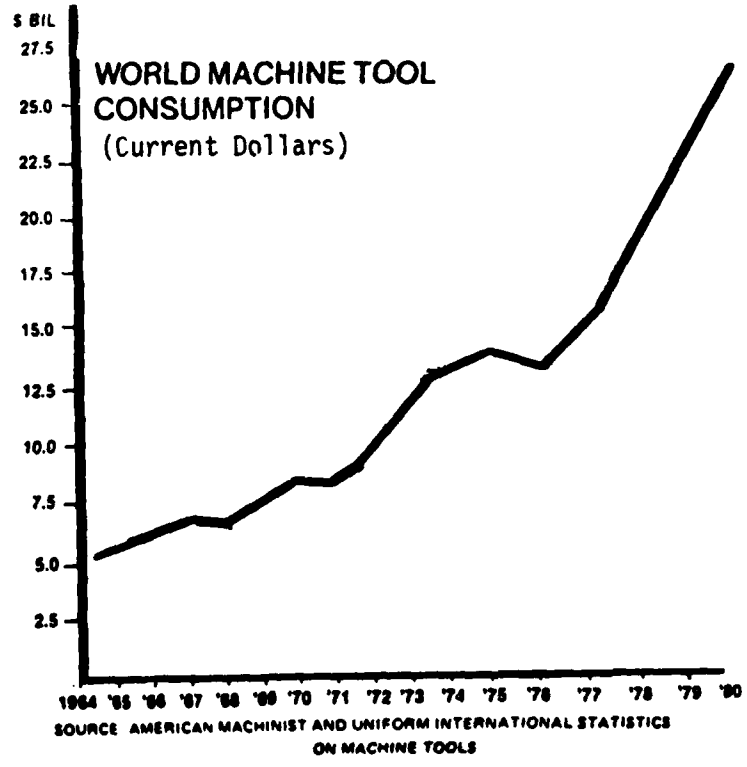
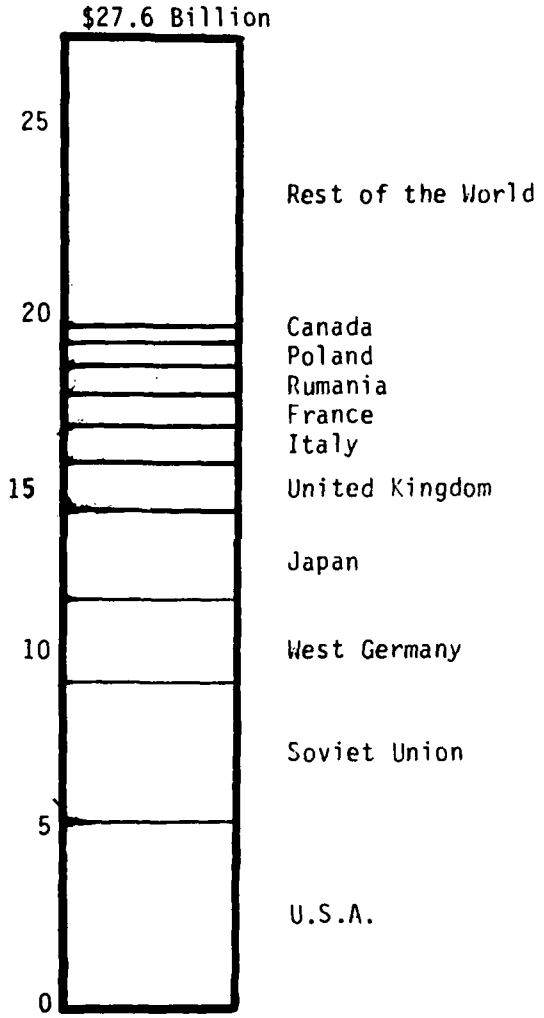


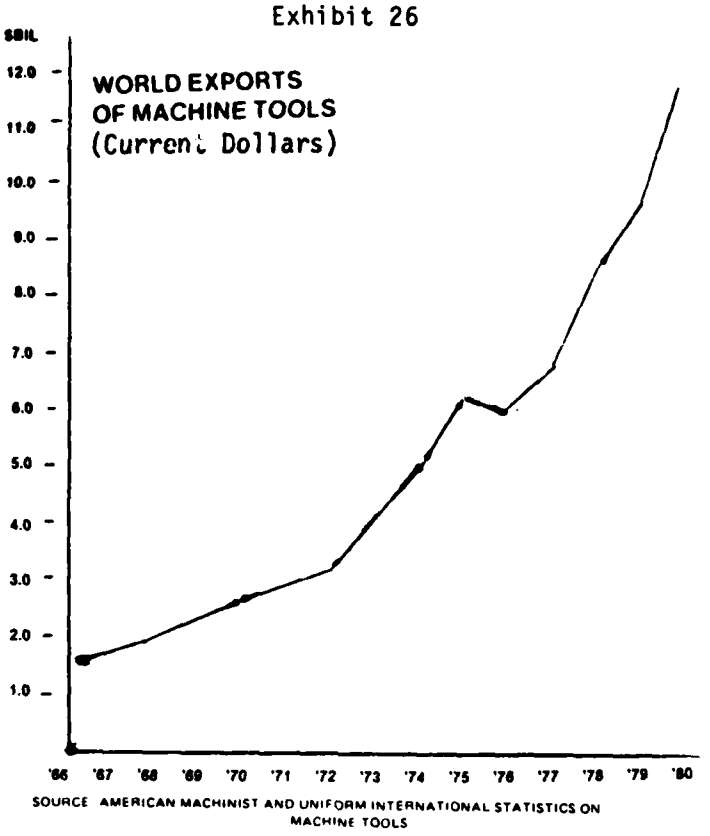
Exhibit 25

Country Purchases of Machine Tools, 1980
(Current Dollars)



Source: National Machine Tool Builders' Association, Economic Handbook 1981-1982, p. 163.

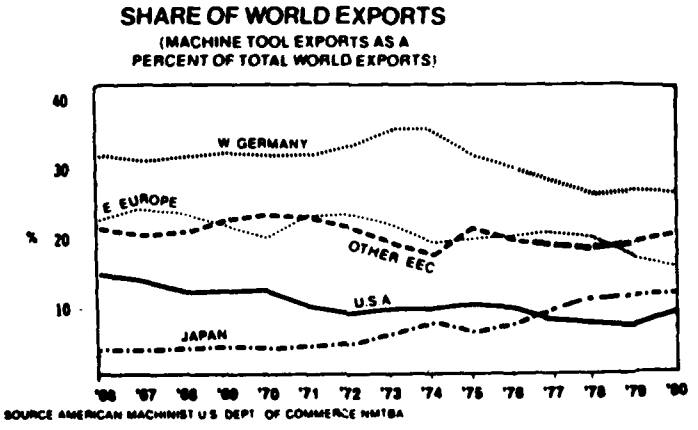
Exhibit 26



SOURCE AMERICAN MACHINIST AND UNIFORM INTERNATIONAL STATISTICS ON MACHINE TOOLS

The United States has a significant, but small, proportion of the world export market at present. Japan and other EEC countries have become the newest competitor, as shown in Exhibit 27.

Exhibit 27



SOURCE AMERICAN MACHINIST U.S. DEPT OF COMMERCE NMTBA

The United States, which until 1978 had a very favorable balance of trade in machine tools, switched to an increasingly unfavorable balance, as shown in Exhibits 28 and 29. The cutting tool industry has suffered the largest deficit, with the metal forming machine tool industry showing a slight trade advantage in 1980. Preliminary NMTBA estimates for 1981, however, show a sharp drop in metalforming tool shipments to foreign purchasers to $166.9 million, which could lead to an unfavorable balance of trade in that sector as well. Preliminary Census data from three sources--Current Industrial Reports MQ-35W, Import Reports IMI46, and Export Reports EM522--covering the first six months of 1981, also reflect a worsening of the trade balance.

Exhibit 28

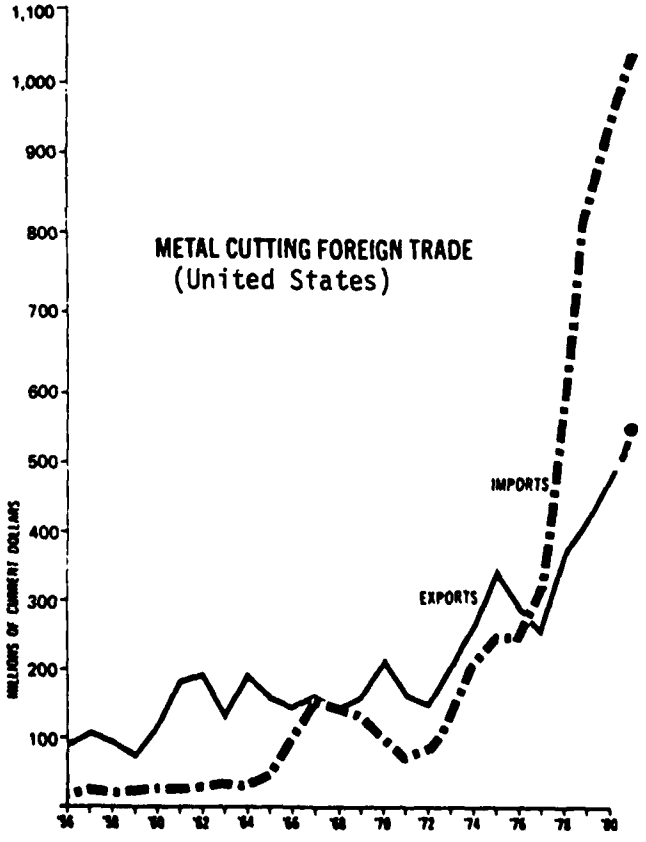
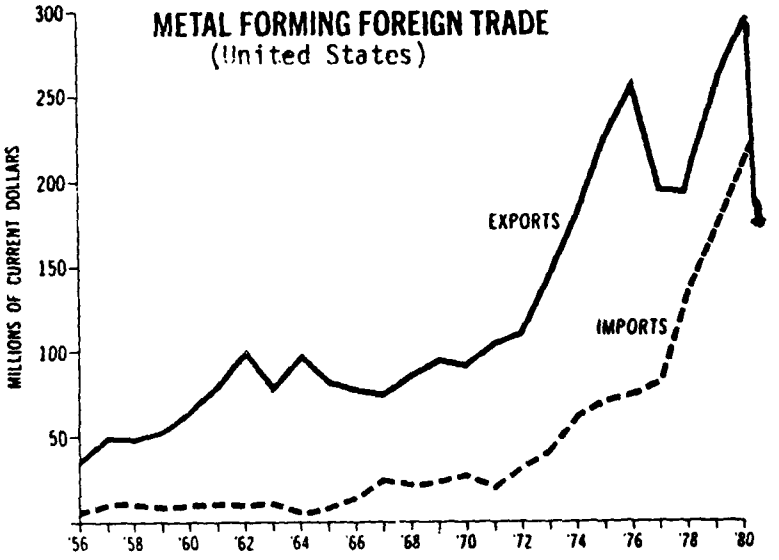


Exhibit 29

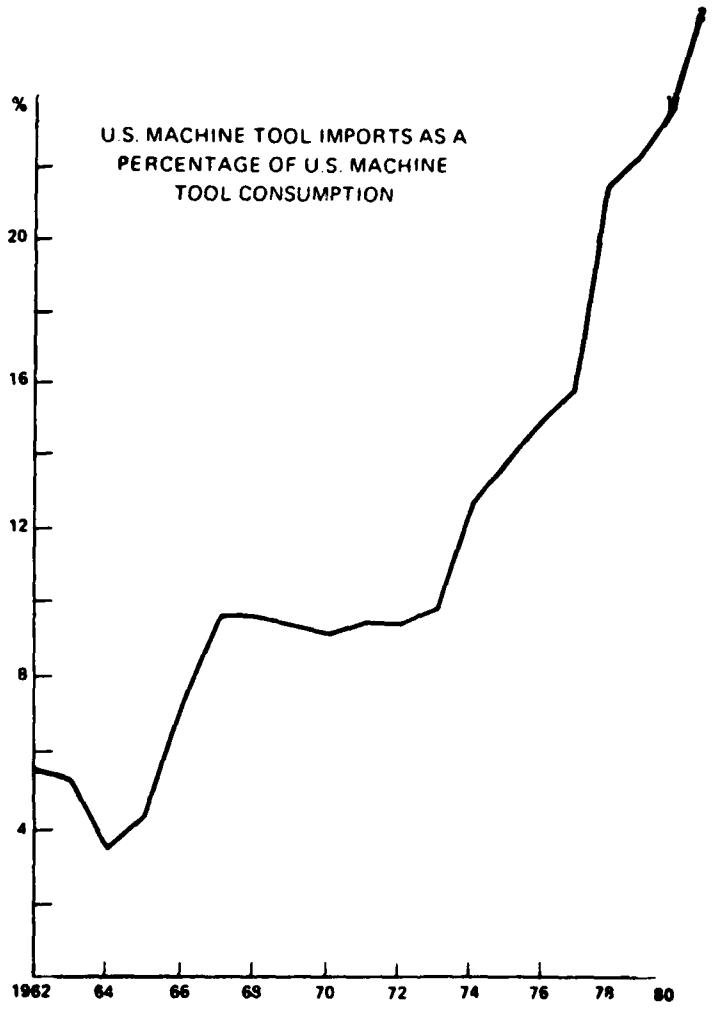


A significant part of the imbalance in metal cutting tools can be attributed to the large volumes of CNC machining centers and CNC turning machines ("the heart of U.S. machine tool production") sold by Japan in the United States.[55] In 1980, the United States produced some 8800 NC machine tools, valued at $1.25 billion.[56] Japan produced 22,000 NC machine tools, valued at $1.5 billion. Of those NC machine tools, some 4650 valued at $350 million were shipped to the United States.[57] In that total were 3000 lathes and 1300 machining centers. A new marketing target in the U.S. is the CNC turret punching machine.

The most recent import summary available, that for the second quarter of 1981, reports imports to the United States from all foreign sources of $210 million. More than 50% of the apparent American consumption of gear cutting machines, NC turning machines with small and medium horizontal spindles, non-NC turning machines, and NC thread-rolling machines were imports.[58]

Machine tools of foreign origin have been increasingly a part of the American manufacturing scene, as Exhibit 30 shows. Preliminary tabulations for 1981 show the upward trend continuing, with 36% being the probable percentage. See Exhibit 31.

Exhibit 30



Nearly all machine tools imported from abroad are designed in metric and built with metric components. However, since American customers typically order customery units, the foreign supplier often provides "customary capability" or NC duality in the machines shipped to the United States.

Although American manufacturers continue to be optimists about future domestic capital goods purchases, a number of machine tool builders are increasingly considering possible foreign markets. World trade flows of machine tools are shown graphically in Exhibit 32. In that chart, the relative size of production in each of the major nations and nation-groups is proportional to the height of the solid bar. American machine tool builders are currently operating at about 74% of capacity, so there is potential for higher production.

Exhibit 31

CONCENTRATIONS OF IMPORTS

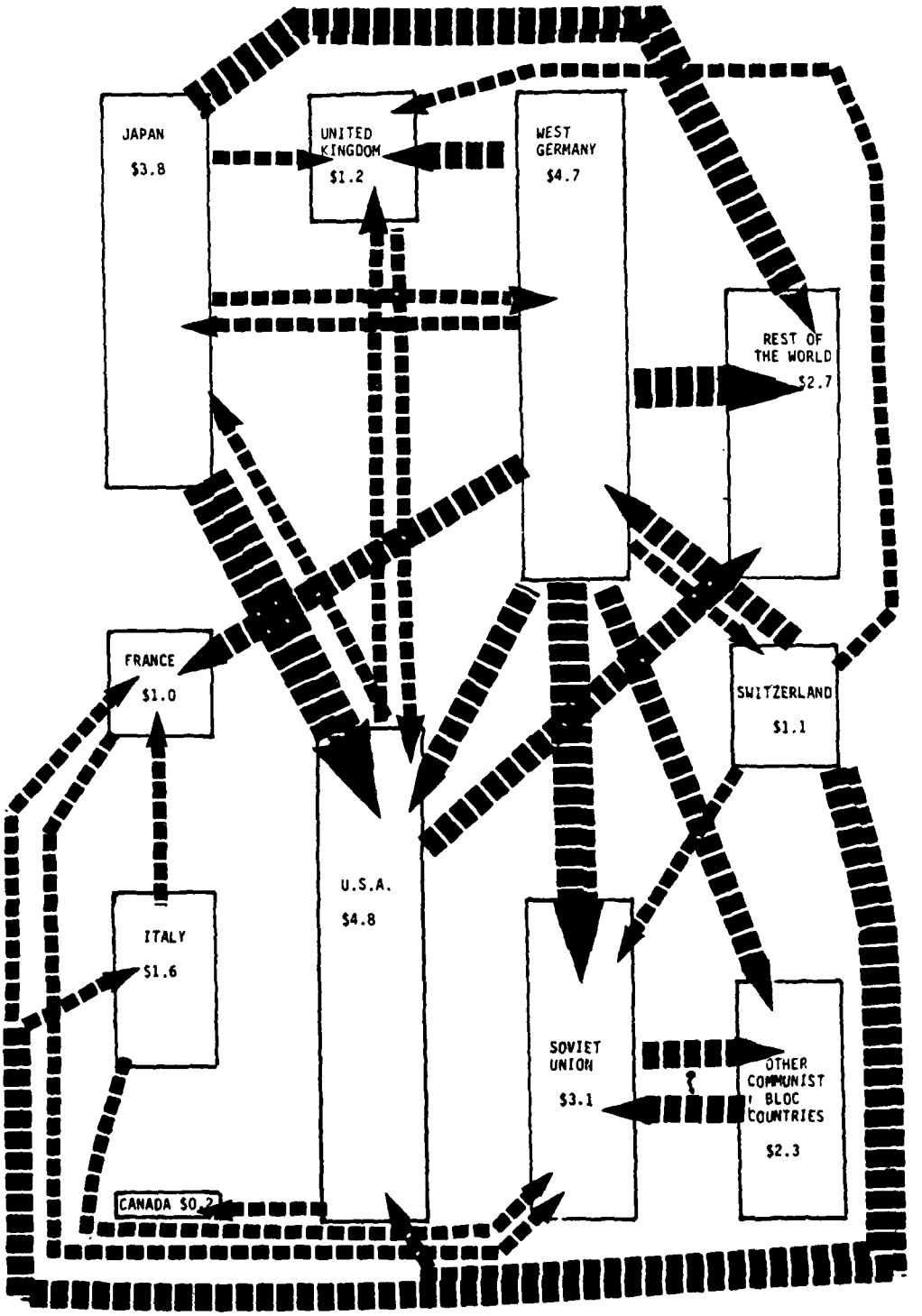
BY

TYPE OF MACHINE TOOL
Second Quarter, 1981

SIC Code	Machine Tool Type	Percent of Imports to Apparent Consumption (Based on dollar value)	Total Apparent Consumption (in millions of dollars)
Cutting Machine Tools			
35411 11 and 15	Horizontal boring, drilling, and milling machines	48%	$21.8
35412	Drilling machines with numerical controls	22%	27.6
35413 12 and 31	Gear cutting machines (hobbers and shapers)	77%	5.6
35413 54, 71, and 99	Gear tooth finishing, bevel gear generators, all other gear cutting machines	25%	14.2
35414	Grinding machines with NC	23%	174.6
35415 11 and 12	NC turning machines (lathes) with small or medium horizontal spindle	50%	136.1
35415 13	NC turning machines with large horizontal spindle	30%	30.9
35415 24 and 26	NC vertical spindle turret lathes and turning machines	21%	28.4
35415 14, 22, 23, 25, 29, and 37	Non-NC turning machines	62%	35.0
35415 63 and 65	Automatic lathes: (single spindle) chucking machines	18%	7.8
35415 68	Automatic lathes (multiple spindle) bar (screw) machines	10%	28.0
35415 67	Automatic lathes (multiple spindle) chucking machines	16%	6.4
35416	Milling machines, NC	26%	128.1
35417 09	Machining centers (multifunction NC) vertical mill, drill, and bore, Y-axis travel over 26"	27%	20.1
35417 11, 13, and 15	Machining centers, horizontal mill, drill, and bore	13%	82.2
35417 xx	All other metal cutting machines, n.e.c., with NC (Broaching, sawing, spark erosion, tapping, etc.)	27%	83.8
Metal-Forming Machine Tools			
35421	Punching and shearing machines, NC	25%	44.4
354211	Bending and forming machines	25%	39.6
35422	Presses except forging presses	2%	128.8
35422 56 and 57	Hydraulic presses (vertical single action)	17%	9.2
35422	Hydraulic presses (other)	37%	13.6
35423	Forging machines	34%	11.3
35423	Die casting machines	41%	9.5
35423	All other metal-forming machines, n.e.c., with NC (thread rolling, riverting, and others)		

Source: Bureau of the Census, Current Industrial Reports: Metalworking Machinery, MQ-35W(81)-2, Second Quarter 1981 Issued September 1981

Exhibit 32
World Trade Flows of Machine Tools
(billions of dollars)



Soviet bloc countries are linked together in this chart. The "Rest of World" component includes some of the medium-sized producers of machine tools, as well as the smaller developing countries. There is a large volume of bilateral flow of machine tools. Some bilateral flows, such as that between the US and the UK, are roughly in balance. Others, such as at between the US and Japan, are strongly one-directional. The major producing nations are diversified in their markets. But there is practically no flow of machine tools from the United States to the Soviet Bloc, although there is a very large volume of flow from EEC nations to the Soviets. Data on flows between the Soviet Union and the Satellites are uncertain; the most recent data available is for 1977.

A comparison of the sources of machine tools going to the "other nations" is given in Exhibit 33.

Exhibit 33. Sources of Machine Tools for Other Nations, 1979

Nation Importing	Total Imports From 14 Major Nations (Millions of Dollars)	Imports From USA	W GER	JAPAN	ITALY
Brazil	187	24	95	22	15
Venezuela	88	46	8	4	21
Mexico	121	70	20	7	8
Argentina	64	9	24	2	10
Korea (Rep)	376	34	85	212	4
India	74	5	26	8	3
China (CPR)	112	9	34	30	4
Spain	95	5	42	2	22
Turkey	40	2	13	-	6
Saudi Arabia	47	15	11	8	6
USSR	635	7	315	47	78
Poland	187	3	56	40	16
Romania	243	7	58	23	52
Czechoslovakia	82	-	54	1	3
Hungary	62	1	44	-	3
Yugoslavia	186	5	98	8	24
	2,599	242	983	414	275

The West Germans and, to a lesser extent, the Italians, have clearly established an international market in machine tools. The United States has a significant share of the Mexican, Venezuelan, and Saudi Arabian markets. Some attractive market areas, such as Turkey, Spain, and the remainder of Latin America, do not show up as business for U.S. companies.

From 1973 to 1979, the export market share of all the major producers of machine tools except for Japan have tended downward.[59/] The U.S. share of overseas markets has also been downward except in sales to the U.K. and the relatively small Swiss market.

TARIFF AND NON-TARIFF FACTORS

In 1974 the U.S. Tariff Commission prepared an extensive report describing the many tariff and non-tariff issues affecting imports and exports.[60/] It noted that the major determinants of international trade were the GNP performance of a nation, the international monetary system, the diffusion of technology, and the commercial climate created by the policies of the various nations. In addition to an ad valorem duty assessed against an imported item, non-tariff barriers that affect international trade are:

(a) *quotas*
(b) non-tariff charges
(c) government participation in trade
(d) standards requirements
(e) customs procedures and administrative practices, and
(f) discriminatory ocean freight rates.

Duties on metalworking machine tools coming in to the United States vary by type of machine tool and country of origin,[61/] but are being gradually reduced as a result of the Kennedy and Tokyo rounds of negotiations on GATT (General Agreement on Tariffs and Trade), currently scheduled to be completed on January 1, 1987.. Communist countries have not benefitted from these reductions, but MFN (Most-favored Nation) treatment has been granted by the President to Communist China, Hungary, Romania, Poland, and Yugoslavia. The Trade Act of 1974 also provided for a Generalized System of Preferences (GSP), under which Presidentially-designated developing countries can ship machine tools and parts to the United States duty-free until January, 1985.

Products of the least-developed developing countries (LDDC) are dutied at the rates that will not be reached by the other GATT agreement signatories until 1987. Duty rates for imports to the United States, using these categories of nations, are shown in Exhibit 34.

Exhibit 34. Rates of Import Duty (United States)

Machine Tool	GATT 1981/Rate	LDDC Rate	Old (1960) Rate
Gear-cutting	9%	5.8%	40%
Boring, drilling, milling	5.6%	4.2%	30%
Other machines	6.7%	4.4%	30%

Thus, for most countries selling machine tools to the United States, the duty is that of the GATT rate, which will be gradually reduced to the LDDC rate.

For U.S. manufacturers shipping to other nations, the customs treatment also varies by type of machine tool and the country of destination. Comparisons of U. S., EEC, and Japanese import duties at the rates in effect in early 1981 are shown in Exhibit 35.

Exhibit 35. Comparison of Rates of Import Duty

Machine Tool	US Rate 1981	US Rate Final	EEC Rate 1981	EEC Rate Final	Japanese Rate 1981	Japanese Rate Final
Gear-cutting						
NC machines	9.0%	5.8%	4.7%, 7.3%	3.8%, 5.3%	6.9%, 7.9%	5.8%, 7.2%
Non-NC machines	9.0%	5.8%	4.3%, 6.5%	3.5%, 4.9%	5.0% 6.4%	4.2%, 5.4%
Boring, drilling, and milling						
NC machines	5.6%	4.2%	4.7%, 8.9%	3.8%,- 5.5%	6.4%- 7.9%	4.0%- 7.2%
Non-NC machines	5.6%	4.2%	2.4%- 7.3%	2.2%- 5.3%	4.7%- 6.4%	4.2%- 5.4%

Note that higher duties are levied on NC machines arriving in the EEC and Japan, in contrast with the flat rate in the United States.

The International Trade Commission has investigated four complaints of unfair trade practices alleged to have an effect of producing substantial harm to an industry. These relate to certain NC machining centers, automatic crankpin grinders, turning machines, and surface grinding machines.[62/]

Each nation has its own preferences for machine tools, and to some extent has developed connections with overseas suppliers that reflect confidence in their products. Japan, for example, has developed a policy of "positive economic administration in order to expand its import policy by increasing the economy concentrated on its domestic demand.[63/] In part, this means that Japan will place more emphasis on sending missions to other nations to help them respond better to the Japanese need. With respect to machine tool sales in Japan, it is useful to quote from a guide published by the Japan Machinery Importers' Association.[64/]

> ... Japanese machine tools rank at the top level in the world today, both in technology and output of production. They are strong sales competitors with respect to price and delivery time.
>
> Consequently, ... one must conduct very thorough market research on the particular machine that one intends to sell.... it is more advantageous profitwise for newcomers to establish reliable agent in Japan.... from among these trade companies.... the agents must meet the following conditions: They should have experienced salesmen with special technical knowledge; they must be well-acquainted with the customers' trade and enjoy the customer confidence; furthermore, they must have the capacity to perform the after-delivery service that is indispensable in the field of machine tools....
>
> Customers purchasing machine tools have recently welcomed the sales that include manufacturing know-how concerning the products that will be produced by the purchased machine. Furthermore, customers make strict demands regarding operational quality, safety and such pollution measures as those concerning noise and vibration of machines, as well as measures for chip disposal. Suppliers must also adopt the metric system and guarantee rapid and reliable after-delivery service and quick and easy access to such expendable spare parts as electrical and hydraulic parts. Customers welcome the use of parts that are manufactured domestically in Japan....

The safety regulations for machinery are described in a separate brochure, "Japan's Industrial Safety Regulations: Machinery."[65/] Not only metric capability, but also very strict operator safety requirements must be met in many overseas markets. Compatibility with manufacturing equipment already in factories is also important.

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A number of U.S. machine tool builders have overseas subsidiaries, which produce to both overseas and U.S. specifications. A number of foreign investors have acquired or otherwise invested in machine tool factories in the United States, but over the past several years, such investments have been small compared to the total known value of foreign investments in the United States. Examples of such acquisitions are given in Exhibit 36.

Exhibit 36: Foreign Acquisitions of U. S. Machine Tool Firms

Date	Investor	Activity
1977	Preci Tools, Canada	New $600,000 metalworking machinery plant in Vermont; 30 U.S. employees
1977	Roxboro Investments, Canada	$2.9 million acquisition of Skil Corp, metalworking machinery in North Carolina, 4268 U.S. employees
1978	LVD Co., Inc of Belgium	New subsidiary with 60 employees in Connecticut
1978	Osawa Screw Grinding Co of Japan	New plant in Georgia (Sossner Tap and Tool Co), with 125 employees
1978	Lead Industries Group, Ltd, of UK	Joint venture, Fry's Metals, Rhode Island, 25 employees
1978	Martin Brothers Toolmakers, Ltd of UK	New plant in Alabama
1978	Jaegers Leopold of West Germany	$2 million acquisition, Burlington Engineering Sales Co., North Carolina, 60 employees
1978	Stihl Andreas Maschinenfabrik of West Germany	New $5 million plant in Virginia, 250 employees
1978	Robert Bosch GMbH of West Germany	Acquisition of Suretran Co of Michigan, 33 employees

Source: U.S. Department of Commerce, International Trade Administration, 1977 and 1978 Lists of Complete Transactions, and Foreign Direct Investment in the United States: Transactions Activity," for 1980 and for the first half of 1981.

Foreign nations sometimes provide incentives for U.S. investments or impose performance requirements on U.S. companies. The most recent survey, based on 1977 data, showed that 20% of the U.S. companies investing abroad received some kind of tax concession, 8% received tariff concessions, and 9% received some kind of subsidy.[66/] There was a wide variation among countries: Ireland granted incentives to 70% of its U.S. affiliates. South Korea, Israel, Taiwan, and Brazil helped some 40-50% of U.S. investors. Japan granted incentives to only 9% of the U.S. investors. Manufacturing companies received more benefits than other categories.

Two percent of U.S. companies abroad were required to export a minimum amount of product, 3% were limited as to the amount imported, 8% were required to use some amount of local labor, and 3% were required to have local contracts. The incidence of performance requirements was highest in the developing countries (30-50%).

In summary, the most serious threat to the U.S. machine tool industry is Japanese product lines, which are metric designed and built but ususally "customary-capable," and which are of equal or better quality and less expensive than American counterparts, and are backed by superior service, maintenance, and speed of delivery.

CHAPTER VII

THE METHODS FOR ASSESSING THE STATUS OF METRIC CONVERSION

Preview: This chapter evaluates the methodological approach used in the study and draws out lessons learned for guiding future status assessments.

Early in 1981 the U.S. Metric Board contracted with J.F. Coates, Inc. to study better ways of evaluating the status of metric use,[67/] to improve the technical content of the status reports delivered to the President and to the Congress.

The methods report urged that status assessment of metric use include not only a snapshot of the present status, but also a projection of the future status of metric use. This required a better understanding of the dynamics of change.

The report also urged that status reports:

- be targeted on questions important to diverse users as well to the Metric Board,
- be useful in formulating policy and in government program planning,
- identify both data sources and gaps in data, and hence research needs,
- be useful to the industry in its planning and operation.

Otherwise, status reports run the risk of being dust-gathering museum pieces or expensive investments in gathering data that contributes nothing substantial to the decision process. A status measure should include a mixture of qualitative and quantitative indicators to give a profile of progress rather than a single number such as "30 percent converted."

The report suggested that a broad range of techniques such as morphological analysis, modeling, input-output analysis, substitution analysis, and case history development could be useful in furthering understanding of how conversion occurs, in measuring the extent of conversion or use of metric, and in projecting the future.

The present study had two purposes: (1) to use some of the methods suggested in the earlier report to develop an assessment of metric use in the machine tool industry, and (2) to evaluate the usefulness of the methods in making that status assessment.

Nominal group techniques (NGT) were used in structuring the problem and in capturing the wisdom of experts. The technique

provided a first approximation answer to some questions and raised other questions to be addressed. Future metric status assessments would benefit from early use of NGT.

The study relied heavily on the testimony of experts and experienced practioners. The mini-survey was intended to answer a limited set of questions, but by encouraging open-ended responses and spontanious comments the survey opened richer sources of information than might be indicated by the relatively small number of respondents.

The study made some use of case histories available in trade literature. While they suffer the limitation of being company or situation specific, they also contain rich detail which suggests wider generalizations.

Simple scenarios were used both in telephone discussions and in advisory meetings. They proved to be especially helpful in evoking discussions of how the future might unfold under "what-if" conditions Scenarios on a much larger, fuller developed scale would be especially useful for both government and industry in developing strategies to meet the problems that have been uncovered in this exploratory study. Indeed, the use of a management simulation game could be a particularly productive way of exploring these problems. Respondents were always able to respond to scenario situations in imaginative ways to generate their own forecasts of the future of metrication in the machine tool industry.

The study used simple cross-impact analysis to identify major interactions. Relationships among parts of the problem were identified, and the conclusions of the study are largely based on tying those pieces together.

A simple, limited form of input-output analysis was used. The large econometric models which were examined do not yet have the ability to respond to metrication questions. They require large volumes of data that are not available. Ways of modeling productivity and other changes that might accompany metrication are not yet developed.

Both qualitative input-output logic, to analyze the extent of metric use that may occur in the future, and more formal mathematical projections of the rows and columns associated with the machine tool sector of the BEA and BLS models were useful in illuminating what is now happening in terms of volume of business, and what is likely to happen.

The signed digraph (Exhibits 5 and 7) was especially useful in guiding subsequent analysis. On the other hand, a substitution analysis (e.g., an analysis of displacement of older tools by NC machines) was not possible within the limitations of this project budget. Trends were extrapolated to the extent that the data would allow, but there was little data on the use of metric in the machine tool industry.

Given the present state of knowledge, metric status assessments must place major dependence on informal surveys. This is a valuable method of obtaining data at relatively low cost, and its reliability can be increased by subjecting preliminary results to review by a broad range of industry participants. Submitting the draft report on this study brought additions and helpful modifications.

Future studies of the status of metrication should recognize the following points:

- It is unlikely that much data is available on metrication in any industry. A few companies will have collected and analyzed some data for their own purposes. There are no data bases in the Census Bureau, the Bureau of Industrial Economics, the Bureau of Labor Statistics, or the National Bureau of Standards that can be used for industry-wide projections. Most information is anecdotal, outdated, and not replicable. Thus, each study must collect its own data. The best starting point (and perhaps the most economical stopping point) is consultations with industry experts.

- Definitions will vary widely. This can mislead researchers. "Metric" is a word that should be accompanied by a precise statement of what is included and what is excluded. "Metric" is a sliding scale.

- As an issue, metrication is regarded in most places as of secondary importance and has not been analyzed as a separate topic. But metrication connects with other more important issues and is embedded in larger concerns of industry. Metric status assessment teams must therefore be prepared to analyze metrication as marginal to other issues. In some cases, however, metrication could be the one small competitive advantage that a company treats as proprietary information.

- Surveys should be accompanied by personal interviews. Variations in responses will otherwise defy analysis. The results of many metric surveys are informative but fall short of what is needed for actionable analysis.

- No industry is an island; it pulls, pushes, drives, attracts, and displaces other industries and it is pulled, pushed, driven, attracted, and displaced by its suppliers and customers. Thus, assessments must consider the environment in which an industry operates.
- Metrication is a process, not a snapshot or a balance sheet. Assessments should consider the forces at work. They take into account both the "heavy hand of history" and the realm of possibility -- the future.
- World trade is likely to be increasingly important to many industries. That factor must be explicitly included. This study gathered estimates of the extent to which metrication might increase overseas sales or might open domestic markets to imports, but found no firm numbers. This question is important to consideration of federal policy initiatives related to the U.S. economy.
- Future studies should portray graphically the interactions among the industry, its customers, and its suppliers. They should search for numbers. They should question industry folklore to determine whether it can be verified and documented.
- Assessments should be guided by the question, "Who will use the results and what questions and decisions will be important when the report is issued?"
- Large, multi-year assessments with input-outpout econometric analyses of metrication would not be cost-effective at present, since the requisite data is lacking and the theory to handle capital investments in productivity change through an I-O model needs further development. Further intense research is justified however because the field of metrication is so poorly understood and because the results could be applicable to other forms of innovation. There were many indications in this study that such research on government industrial policies in the national economy would be valuable.

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APPENDIX A

INPUT-OUTPUT ANALYSIS

The most frequently used input-output model is that developed by the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce. The most recent version of the model that has been calibrated against Census of Manufactures data and other sources is the one for the base year 1972. The 1977 model is in the final stages of calibration and validation but is not yet ready for general use. The 1972 I-O model, despite its age, serves as a useful reference point for this analysis.

When considering the machine tool industry, it is important to note that there are two major parts to the BEA I-O model: the "expensed" transactions,* and the capital flows model.* The "expensed" transactions represent the flows of dollars from one industrial sector to another within the year in question, while the capital flows represent capital investments.

The detailed model of expensed inter-industry flows has 494 industries and 491 commodities; the machine tool industry is treated in terms of three major subgroups: metal cutting machine tools (3541), metalforming machines (3542), and the tools, dies, jigs, fixtures, accessories and perishable tools together (3544 and 3545). This grouping also allows rolling mill machinery (SIC 3547) and metalworking machinery, n.e.c. (SIC 3549) to be analyzed separately.

The capital flows study does not have the same degree of detail; it is based on 76 industries and 150 commodities. All the components of the metalworking industries are treated as a unit, but the product class detail described above is preserved. It is possible to tell how many metalcutting machine tools were capitalized by the machine tool industry as a whole to 3541, 3542, 3544/45, 3547, and 3549.

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In the 1972 base year, $672 million dollars was expensed by the metal-cutting machine tool sector (SIC 3541) for materials supplied by other sectors, plus labor and other components of the $732 million in value added. The total 3541 output was rated as $1404 million. Of that output, only $230 million was expensed by the using industries, while $921 million went into the capital flow account. Imports and exports, as well as government purchases, are handled as separate accounts, completing the input-output balance. Eighty percent of the purchases of cutting machine tools can be regarded as "capital investment," and 20 percent as "expensed."

Exhibits A1 and A2 show the dollar flows of expensed items into and out of the machine tool industries for 1972. Only the major ones of the nearly 500 commodities and industries are given here.

Exhibits A3 and A4 show the corresponding capital purchases by the machine tool industry, and the shipments of machine tool products as capital investment by using industries.

EXHIBIT A-1

MAJOR INPUTS TO THE MACHINE TOOL INDUSTRY, 1972
(Millions of Dollars)

INPUTS	USED BY		
	SIC.3541	SIC.3542	SIC.3544-45
Petroleum & Coal	10.2	4.8	24.4
Abrasive Products	6.9	3.6	35.3
Blast Furnace & Steel	61.8	49.5	194.9
I & S Foundries	56.2	31.2	45.3
I & S Forgings	5.1	7.3	7.0
Metal Products, n.e.c.			76.7
Alum. Castings	4.8	1.0	9.2
Nonferrous Castings	11.6	6.4	8.2
Fabr. Platework	14.9	5.8	0.3
Screw Machine	10.0	3.4	9.3
Mach Tool (Cut)	71.3	2.1	16.3
Mach Tool (Form)	0.6	25.1	2.8
Tool & Dies	23.8	7.9	189.7
Pumps & Compressors	27.2	8.5	1.8
Bearings	18.7	6.1	11.5
Power Transmission	8.8	11.1	2.8
Machinery, n.e.c.	40.0	25.8	79.9
Motors & Generators	23.8	8.4	2.4
Ind. Controls	47.5	20.0	2.8
Communications	9.0	2.6	19.2
Electricity	11.0	4.5	28.1
Wholesale Svcs	52.6	24.1	59.2
Credit Agencies	7.1	4.0	35.0
Misc Business Svcs	17.7	7.8	45.9
Misc Professional	14.9	5.8	23.8
Eating & Drinking	16.6	6.5	26.5
Total Intermed. Inputs	671.6	332.7	1195.7
Value Added	732.1	356.1	2428.7
Total Industry Inputs	1403.7	688.8	3624.4

EXHIBIT A-2
MAJOR PURCHASES OF MACHINE TOOLS, 1972
(Millions of Dollars)

USING SECTOR	SALES FROM		
	SIC 3541	SIC 3542	SIC 3544-45
Guided Missiles		0.5	14.2
Plastic Products			69.2
Blast Furnace & Steel	2.6	3.3	87.1
Steel Wire			50.5
Iron & Steel Foundries	1.1		38.1
Iron & Steel Forgings	1.1	1.9	22.6
Aluminum roll			32.5
Alum. castings		2.1	47.6
Metal cans		4.5	19.9
Fabr struct metal	2.7	7.5	9.2
Fabr plate work	2.3	5.6	9.3
Sheet metal work	3.0	4.6	11.8
Screw machine	3.3	1.2	87.1
Auto stampings	2.6	9.0	25.7
Fabr metal prod		4.4	28.1
Steam engines	2.2	0.5	15.7
Internal Comb Eng	4.7		31.2
Farm mach	11.8	2.2	22.6
Construction mach	5.9	3.1	60.9
Oil field mach	2.4	0.4	12.3
Mach tools (cut)	71.3	0.6	23.8
Mach tools (form)	2.1	25.1	7.9
Tool & Dies	16.3	2.8	189.7
Food Products mach	1.4	0.7	7.6
Textile Mach	2.1		5.3
Special Ind Mach	3.3	0.9	12.4
Pumps & Compr	4.3		27.3
Power Transmission	3.5		15.7
Gen. Ind Mach, n.e.c.	12.1	0.5	52.2
Refrig & Heating	2.3	2.4	15.1

EXHIBIT A-2 [continued]

USING SECTOR	SALES FROM SIC 3541	SIC 3542	SIC 3544-45
Motors and generators	2.1	0.6	30.0
Radio & TV	2.1	0.6	47.9
Truck & bus bodies	2.0	0.8	2.3
Truck trailers	2.0	0.6	1.9
Motor Vehicles	5.8	1.7	73.1
Motor vehicle parts	15.8	5.0	94.2
Aircraft	5.0	1.5	35.3
A/C Engines	6.2	0.5	58.1
A/C Eqpt. n.e.c.	3.7	1.1	42.4
Shipbuilding	1.1	4.4	3.1
RR Eqpt.	1.2	1.6	13.2
Total Intermediate Use	230.4	140.4	2297.3
Gross domestic investment	920.7	471.6	1684.0
Changes in inventory	40.7	14.0	43.6
Exports	169.7	107.4	105.7
Imports	-118.9	-38.0	- 93.1
Federal - defense	18.0	6.8	26.6
Federal-non defense	37.2	1.6	12.0
State & local - educ	13.5	0.3	0.8
State and local - other	12.9		
Total Final Demand	1104.9	563.7	1779.6
Total Demand	1335.3	704.1	4076.9
TOTAL	2039.4		

EXHIBIT A-3

CAPITAL PURCHASES BY SIC.354

TYPE OF CAPITAL PURCHASE	Dollars (Millions)
New Ind. Bldgs	37.0
New Office Bldgs	13.7
Ind. Trucks & Tractors	8.0
Mach tools (Cut)	73.6
Mach Tools (Form)	8.7
Tools & Dies	22.8
Spec. Ind. Mach	10.5
Electronic Computers	12.4
Motor Vehicles	13.4
Wholesale Trade	12.3
See Others	56.2
TOTAL CAPITAL PURCHASES	268.6

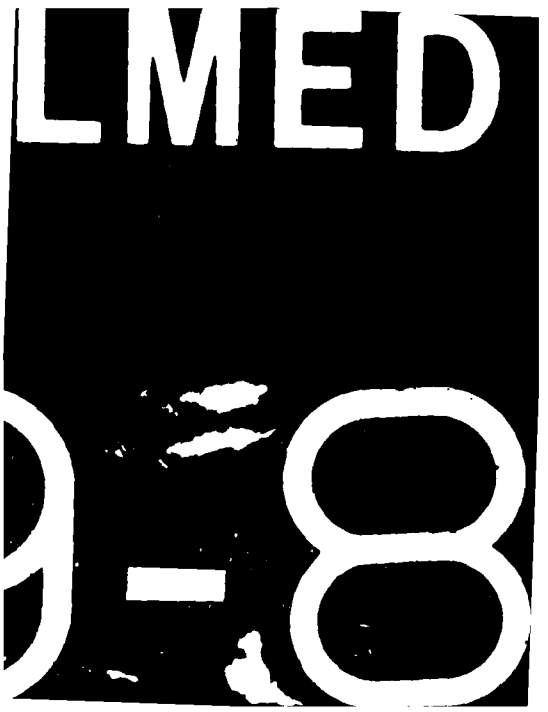
EXHIBIT A-4

CAPITAL SHIPMENTS FROM THE MACHINE TOOL INDUSTRY, 1972

(Millions of dollars)

Using Industries	From SIC 3541	From SIC 3542	From SIC 3544-45
Ordnance and Missiles	11.5	4.3	2.8
Household furniture	3.6	8.4	7.5
Rubber and misc plastics	0.5	0.0	204.4
Stone and clay products	0.4	0.0	96.3
Iron and steel mfg	42.7	17.9	13.9
Nonferrous metal mfg	22.7	9.5	9.0
Mtal containers structural	0.5	43.0	0.0
Heating, plumbing, fabr/metals	31.7	38.3	15.6
Screw machine products	48.1	44.6	19.9
Other fabr metal products	48.8	46.3	22.9
Farm machinery	22.5	13.8	6.9
Construction and mining mach	35.8	11.5	10.1
All metalworking machinery	73.6	8.7	22.8
Special industry mach	38.6	8.2	9.9
General industrial mach	56.0	16.1	0.0
Misc mach, elxcept elec	36.1	5.0	6.3
Computers and office machines	14.9	5.8	25.8
Service industry mach	19.4	16.2	22.4
Electrical transmission eqpt	45.1	6.4	9.6
Household appliances	9.7	12.0	12.7
Electrical lighting and wiring	32.1	24.0	16.1
Radio, TV, communications eqpt	19.6	11.3	33.4
Electrical components	17.7	10.5	25.0
Motor vehicles and eqpt	142.9	46.1	942.2
Aircraft and parts	33.7	7.6	15.1
Other transportation	10.3	3.5	9.7
Scientific instruments	22.8	6.6	5.0
Optical and photographic eqpt	37.7	11.1	25.1
Miscellaneous manufacturing	23.9	25.6	23.9
Total, all users	920.7	471.6	1,684.0

*U.S. GOVERNMENT PRINTING OFFICE: 1982 375-837/1078 1-3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