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**THE U.S. MACHINE TOOL INDUSTRY
AND DEFENSE READINESS:**

An Agenda for Research

Report of the

**Committee on the Machine Tool Industry
Manufacturing Studies Board
Assembly of Engineering
National Research Council**

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

The domestic machine tool industry, though small, is the source of components that are fundamental to the entire manufacturing base of the United States. The Department of Defense, concerned about the economic and technical health of the industry, requested that the National Research Council's Assembly of Engineering form a committee to address the machine tool industry's ability to respond to current and projected defense needs. The Committee on the Machine Tool Industry was constituted in October 1981 to conduct Phase I of an anticipated two-phase project. Phase I had two objectives: (1) to review prior recommendations regarding the machine tool industry and (2) to design a comprehensive study of the machine tool industry's ability to meet military needs, to be undertaken as Phase II.

Phase I was a three-month effort. The committee, its staff, and its consultants reviewed prior studies of the machine tool industry and defense readiness in general, and compiled the relevant recommendations of these studies. The committee met November 23-24, 1981, to formulate hypotheses that could be tested in Phase II and to outline the Phase II study, which would lead to recommendations for improving the domestic machine tool industry's defense preparedness.

This report presents the committee's findings and proposed study plan. Chapter 1 is an introduction to the issues of the machine tool industry and defense preparedness. Chapter 2 discusses the relationship of the Department of Defense and the machine tool industry. Chapter 3 describes the industry's apparent problems from the Defense Department's point of view. Chapter 4 presents the major issues, as raised by the prior reports and discussed by the committee; these represent the committee's judgments, to be tested further by the Phase II study. Chapter 5 summarizes recommendations from prior studies. Chapter 6 outlines the study plan for Phase II.

Committee on the Machine Tool Industry

James E. Ashton (Chairman)
Deputy General Manager for
Research and Engineering
General Dynamics
Electric Boat Division

Margaret B. W. Graham
(Vice-Chairman)
Assistant Professor
Harvard Graduate School of
Business Administration

Arden L. Bement, Jr.
Vice President
Technology Resources
TRW Inc.

M. Larry Billups (retired)
Director of Manufacturing
Advanced Development Projects
Lockheed-California Company

Dale W. Church
Attorney-at-Law
Surrey and Morse

Robert H. Elman
Group Vice President
AMCA International Corporation

Sumner Myers
Director of Technology and
Transportation
Institute for Public Administration

Roger B. Orloff
Vice President
Corporate Finance Group
Girard Bank

Richard P. Rumelt
Assistant Professor
Graduate School of Management
University of California at
Los Angeles

Cedric Lewis Suzman
Educational Program Director
Southern Center for
International Studies

John G. T. Thornton
Regional Editor, Chicago
American Metalworking News

Kurt O. Tech
Management Consultant

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Cincinnati Milacron, Inc.

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Director of Research
International Association of
Machinists and Aerospace
Workers

Leo S. Packer
Consultant

Michael Radnor
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Interdisciplinary Study of
Science and Technology

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Business Administration
Harvard Business School

Alvin Stein
Parker Chapin Flattau and Klimpl

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Corporate Research Staff
The Rand Corporation

Chapter 1 BACKGROUND

The capacity of this nation's "industrial base" for defense has been questioned repeatedly in recent years.^{1,2,3,4} Especially among suppliers of components and subsystems, the ranks of defense contractors have thinned over the past decade, lead times are long, and production of defense systems is often slowed by lagging component deliveries. Thousands of suppliers dropped out of the defense market during the 1970s, and others are reported to be reluctant to gear up for new military production, fearing another slump like that in the early 1970s. The intricacies and reporting burdens of defense contracts are also blamed for inhibiting companies from seeking military business.

The machine tool industry is critical to the success of a defense buildup, yet many question whether the industry is prepared to meet such an event. The weapons, aircraft, and other materiel that may be required by new national policies will contain many parts of complex design and novel materials, which will require new tools and techniques for their effective manufacture. However, there is reason to believe that the domestic machine tool industry will find it difficult to adjust to demands for new technology and that, over the longer term, it will not expand its output enough to meet growing demand.

The machine tool industry in this country, like many other domestic industries, has recently fallen victim to aggressive competition from overseas. In design many U.S. machine tools set world standards, but certain cost advantages, corporate planning, marketing, cooperative efforts, and perhaps higher quality have elevated Japan and several European nations to commanding positions in the world market. Furthermore, over the past decade foreign machine tools have gained shares of the U.S. market that match those taken by foreign automobiles: 23.2 percent in 1980, up from a 1964 level of 3.5 percent.⁵ The underlying causes of these trends that have been adduced by the recent studies range from overconservative management in U.S. companies to an overvalued dollar during the late 1960s and early 1970s. Whatever their causes, the market trends disturb many who are concerned with fostering a strong manufacturing economy in the United States. On a more specific and immediate basis, they are grounds for questions about the ability of this vital part of the industrial base to meet future military needs.

After a discussion of defense procurement, this committee agreed that an assumption of its study was that a healthy machine tool industry is an important element of national defense. This is not to say that

national self-sufficiency in machine tools is necessarily desirable. Some of the new technology in the field is in foreign hands, and free trade in machine tools will tend to improve domestic technology. The Under Secretary of Defense for Policy notes that the United States has a commitment to international trade under the General Agreement on Trade and Tariffs. He states, however, that a Defense Department goal is to have a domestic production capability for all critical military items. Although DoD cannot exert enough leverage on the market to obtain all critical components from domestic firms, it should be able to have a domestic source for all such components if and when the need arises.⁶

The committee has focused on particular questions and issues concerning the machine tool industry's contributions to military production needs. Such a limited analysis may have broader implications; however, this study does not address the current state of the domestic industry, its problems, or its potentials as ends in themselves.

RECENT ASSESSMENTS OF THE MACHINE TOOL INDUSTRY

A number of recent studies of the nation's industrial base and its machine tool industry have reached strikingly similar conclusions.^{1,2,3,7} They paint a picture of an industry characterized by small, specialized firms, closely held (often family-owned) and conservatively managed. These firms, it is reported, are not highly capitalized and tend to make small investments in applied research and product and process development--a tendency exacerbated by the cyclical nature of the market in which they operate. They are also said to suffer from extreme shortages of skilled personnel; this also is attributed to the cyclicity of the market, which makes it difficult to attract or retain trained employees. The companies are not aggressive exporters. In sum, these tendencies result, say the reports, in declining productivity, long lead times, large order backlogs, and--as a consequence--heightened vulnerability to foreign competition. Such an industry fits the pattern of industries sometimes called "mature," displaying the familiar cycle of low productivity, low profits, low investment, and heightened competition from abroad, resulting in even lower profits, lower investment, and the loss of further ground to foreign competitors.⁸

The most comprehensive recent study of the machine tool industry and its technology is a 1980 report to the Manufacturing Technology Division of the Air Force Wright Aeronautical Laboratory by a Machine Tool Task Force organized at Lawrence Livermore Laboratory.² This report, like all the reports considered by the committee, suffers the defects of highly aggregated data and a narrow definition of the industry under study, treating only those companies traditionally included in the machine tool industry. Furthermore, these reports tend to emphasize the smaller firms, disregarding the large machine tool companies that do have major research and development programs, as well as greater access to capital.

- 3 -

The Machine Tool Task Force asserted that most change in machine tool technology over the past 40 years has been prompted by user demands and technical advances made by suppliers, rather than by the industry's own initiatives. Significant examples are the introduction of new cutting tools (the cutting tool industry is not considered part of the machine tool industry in most statistical schemes) and the Air-Force-subsidized introduction of numerical control techniques in the aerospace industry.

Among the more important stimuli of future technological change in machine tools, according to the Task Force, will be (1) the advance of computer technology and computer-integrated manufacturing systems and (2) the introduction of new materials and weight- and material-saving part designs with accompanying demands for higher accuracy in shaping. This pattern is an indication that the traditional boundaries of the machine tool industry, limited to producers of metal-removing equipment, may be too narrow for a coherent analysis of present conditions. The advance of sophisticated computer control technology, the rise of so-called near-net-shape forming technology, and the increasing importance of integrated manufacturing systems that include automated materials handling, forming, inspection, or assembly equipment all tend to stretch the boundaries of analysis. The increasing need for "systems engineering" in installing and maintaining computer control systems similarly expands the technological horizons.

Another indication that the industry may be too narrowly defined is given by recent ownership patterns in machine tool manufacture. A broadening of outlook might be expected from the increasing number of cases in which machine tool companies have merged with or been taken over by companies with unrelated product lines. In addition, companies in the automotive, aerospace, and computer industries are developing some of their own machine tools; such companies might take broader views of technological opportunities in forming, handling, and control technology than are typical of more specialized machine tool companies. For the purposes of this study, the committee has expanded its field of reference to include not only forming equipment in general, but also the associated cutters, gauging and measuring devices, control devices and software, and material handling equipment.

THE INDUSTRY IN THE WORLD MARKET

The U.S. machine tool industry has recently been losing ground in both domestic and world markets. From 1964 to 1979, the United States' share of world exports fell from approximately 22 percent to about 10 percent; over the same period the share of foreign machine tools in the U.S. market rose from less than 4 percent to 27 percent.⁵

The history of this phenomenon is not difficult to trace in outline. After a period of dominating world machine tool markets in the two decades or so following World War II (and thus exporting technology),

the U.S. machine tool industry in the 1960s entered a period in which rebuilt foreign industrial economies were reaching for export markets at a time when the dollar was becoming overvalued relative to other currencies. Domestic machine tool production was at high levels, and the U.S. market welcomed foreign tools, including many plain, sturdy Japanese tools at the low end of the price scale. Strong, service-oriented sales organizations were established by many foreign machine tool companies in important markets. During this period, with the domestic market expanding, U.S. manufacturers were distracted from the even more rapid growth of the international market, and from the spreading adoption of high-technology tools. Meanwhile, foreign manufacturers, aided in many cases by their governments in the forms of favorable financing and technological and management help, invested heavily in developing and marketing new products and installing efficient production processes.

By the 1970s foreign machine tool companies had built on their early successes with cheaper, simpler tools to penetrate deeply the higher ends of the U.S. market, selling high-quality, reliable, technically advanced machine tools and manufacturing systems. Their prices are competitive, and the associated service organizations have reputations for effectiveness. Lead times between ordering machines and putting them into production are in general markedly shorter than those characteristic of domestic machine tools and systems--in part because many foreign machines can be ordered off the shelf or easily customized, in part because of the shorter backlogs.

This pattern is in contrast to the domestic industry, if we are to believe the recent reports.^{1,2,3,9} They portray the domestic industry as being outstripped in adopting new technology by foreign competitors (though much if not most of the significant new technology was conceived and developed on these shores).² Some of its efforts to market abroad have fallen prey to bad luck and bad judgment. It suffers from numerous cost disadvantages, in labor, in debt financing, and in the nontariff import hurdles set up by some competitors.⁹ Its lead times can be quite long, since most domestic companies carry long backlogs when demand is rising. The result, as described in all reports, is an industry cut off from the world market and its competitive incentives: slow to innovate, prone to underinvest in both plant and R&D, and suffering its market's extreme cyclicity without the buffering effect that might be provided by sales to foreign markets with different cycles.

Chapter 2 DEFENSE NEEDS AND THE MACHINE TOOL INDUSTRY

In a national security emergency, the availability of production capacity to meet "surge" or "mobilization" requirements is critical; machine tools are an important component of that capacity. Several recent reviews have examined the Defense Department's machine tool reserve and found much of it to be obsolete.³ Similarly, they have considered the domestic machine tool industry's ability to expand capacity and output rapidly and judged it to be inadequate. In view of the long lead times characteristic of machine tool design, production, and delivery, a large increase in output would require a substantial investment and take several years to achieve. At a time of financial constraints on present weapons systems procurement programs, investment in creating and maintaining extra machine tool capacity to meet emergencies is highly unlikely. Therefore, it is particularly important that the Department of Defense carry out mobilization planning in consultation with machine tool manufacturers and users. Such planning should concentrate on maintaining existing machines in operation by ensuring the supply of spare parts, identifying critical equipment and its sources, and providing for the conversion of civilian machine tool production capacity to military applications. The issue of self-sufficiency versus reliance on foreign sources should also be confronted.

At the same time, in the interest of defense readiness and effective deterrence, the widely perceived and extensively documented deterioration in the defense industrial base, including machine tool industry production must be addressed. Among the indicators of this deterioration are the following:

- Productivity gains in the defense industries have fallen behind those of U.S. manufacturing generally, whose productivity growth rate is in turn trailing those of all other major industrialized countries.¹
- Failure to modernize plant and production equipment has contributed to lagging productivity. Again, investment in modernization by the defense sector has apparently fallen behind the performance of U.S. manufacturing as a whole. It is estimated, for example, that in the late 1970s 35 percent of all U.S. metal-cutting and metal-forming machine tools were more than 20 years old,¹⁰ while 60 percent of metalworking equipment in the defense sector was over 20 years old.¹

- Lagging productivity has been accompanied by a contraction of the defense industrial base, particularly among second- and third-tier contractors. Fewer suppliers are willing to invest in expansion for defense production. Many contractors have segregated and limited their defense procurement business and thereby placed it at a disadvantage in the competition for corporate resources. Others, especially smaller companies, have dropped out of defense procurement altogether or resort to it only at times of slack civilian demand.
- Lengthening lead times and chronic cost overruns on many weapons systems have forced procurement schedules to be extended. That, in turn, places a premium on getting the most production out of existing plant and equipment, further limiting investment in modernization.

Because of its important bearing on productivity, production rates, and cost containment, modernization of the DoD and contractor-owned machine tool inventory is a critical element of the defense industrial base revitalization strategy called for by the Defense Science Board,^{3,11} the House Armed Services Committee,¹ and others. Such a program would take several years to accomplish. During that period, presumably, the objective would not be to substitute 1970s state-of-the-art machine tools for outdated equipment but progressively to advance and incorporate in defense production new manufacturing technologies. From the point of view of defense needs as well as the competitiveness of the U.S. industry, therefore, two types of DoD policies assume major importance-- procurement policies and programs of technology development, innovation, and diffusion.

The Defense Department is a rather small purchaser of machine tools, accounting for only about 3.5 to 4 percent of domestic orders in 1978, compared to the automotive industry (28-30 percent) and the aerospace industry (10-12 percent).² These statistics, however, do not reflect purchases of machine tools by defense contractors; recent policy has favored divestiture of government-owned machine tools in favor of direct ownership by contractors. A 1972 estimate of the proportion of machine tool sales accounted for by defense contracts is 7.1 percent.¹² These figures, at the least outdated, may understate the magnitude of defense-related consumption and its leverage on the machine tool industry. They do not, for example, take account of the broader range of manufacturing equipment that should be considered along with metal-cutting and metal-forming machine tools.

In view of the shift in Defense Department procurement from "making" to "buying," it seems likely that contractor purchases considerably exceed rather than roughly equal DoD acquisitions. As the third largest machine tool market, after the automotive and civil aircraft markets, the defense procurement market represents a significant potential influence on the development of the domestic machine tool industry.

- 7 -

Previous reports on the defense industrial base have expressed various concerns about DoD procurement practices particularly relevant to the machine tool industry's response to the need for modernization. First, the policy of cost-plus reimbursement is said to discourage contractors' investment in more efficient plant and equipment. Second, Cost Accounting Standard (CAS) 409, requiring depreciation of contractors' tangible assets to be based on their historical or economical useful lives, may prevent full cost recovery in an inflationary period and thus impede replacement of outdated assets with efficient equipment. At the least, CAS 409 imposes a substantial recordkeeping burden on contractors; however, the recent elimination of the Cost Accounting Standards Board leaves no current mechanism for its revision. Third, various restrictions limit the use of multiyear contracting, which is widely believed to offer maximum economies and encourage participation in defense procurement, not least by producers in industries that, like the machine tool industry, are characterized by sharp fluctuations in civilian demand.

DoD manufacturing technology programs have been criticized, not as impediments to innovation, but as inadequate and in some circumstances ineffective. The success of the Air Force in developing and promoting the use of numerically controlled (NC) machine tools in the 1950s has not been repeated. Independent research and development (IR&D) funds are rarely available to second- and third-tier contractors. The Manufacturing Technology program has been funded at levels far below those recommended by the Defense Science Board, among others.³ Generally, manufacturing technology development and innovation must compete for a share of the procurement budget where the acquisition of finished products has far higher priority.

The Manufacturing Technology program sponsors generic technology in hopes that it will be widely transferred. The Technology Modernization program provides funding to address specific problems in particular plants. The panel-drilling robot at General Dynamics in Ft. Worth, where the Technology Modernization investment is expected to have a five-to-one payback, is often pointed to as an example of the program's success. At General Dynamics, however, most of the technology applied under the program was already available.

Chapter 3 DEFINING THE PROBLEM

This committee found it reasonable to assume that a healthy machine tool industry is important to the national defense. A healthy industry will be able to compete in domestic and world markets, as well as respond to defense needs.

So far as the Department of Defense is concerned, a healthy industry is one that is willing and able to provide a secure basis for defense production. As such it should produce products embodying the necessary levels of technology for efficient production of defense materiel, it should serve as a conduit for technology transfer both nationally and internationally, and it should offer competitive sources for vital products.

If, as stated in Chapter 2, the machine tool industry's capacity for "surge" or "mobilization" output is small, then planning for future mobilization is the only relevant aspect for this study.^{2,3} A more realistic strategic view of the industry is as a cornerstone of industrial production (and particularly military production) over the longer term. The strength of the nation's industrial base is the fundamental issue. Such a base, with efficient capital goods and the strength to rebuild if damaged, may be the most effective strategic deterrent. The nation's stock of machine tools, and its capacity to build new ones, are basic to this strength.

At present, Department of Defense needs for machining and forming capacity are apparently not being met adequately. Lead times are long and lengthening in the supply of many critical components for military systems; lack of machining and forging capacity for some large or complex parts is often blamed.⁴

Contemplated increases in military production will no doubt expand the domestic market for machine tools, other forming tools, and their associated control systems. New tax policy may have a similar effect. However, the ability of the U.S. industry to profit from these moves is in question. Domestic machine tool companies have tended to react to market expansion more by extending order backlogs than by adding new plant; foreign manufacturers have shown impressive abilities to take advantage of these backlogs by providing machines more quickly than domestic manufacturers, and by offering the necessary services to see that the machines go into production quickly and operate reliably.² If domestic manufacturers do not match or exceed this performance, the

- 9 -

expanding market may serve only to strengthen foreign producers in the U.S. market. This would further weaken the domestic industry as a strategic asset.

It is misleading to assume that the machine tool capability relevant to the Department of Defense rests entirely with the conventional machine tool industry. In point of fact, many defense contractors are highly capable of developing their own sophisticated tools. Although individual contractors have often developed sophisticated machines in-house, it has usually been machine tool companies that have built such machines, transforming prototypes into heavy-duty equipment suitable for high-volume production and making more standard models available for purchase. It is this role of technology transfer among defense contractors that may be the most important contribution of the domestic machine tool industry--and the one that would be most sorely missed if the domestic industry were to deteriorate further. It would be undesirable, too, to pass on this role to foreign suppliers, however competitive they might be.

Chapter 4 THE COMMITTEE'S ASSESSMENT OF THE DOMESTIC MACHINE TOOL INDUSTRY

This committee was not constituted to conduct an in-depth study of the machine tool industry. Its charge is much more specific: to identify the issues that must be raised in a more comprehensive study of the industry's potential contribution to the needs of the U.S. Department of Defense, and to plan such a study in outline. In carrying out this charge, however, the committee has made a set of tentative judgments, on the basis of its members' reading and discussion and their experience in management, business analysis, military procurement, and the machine tool industry. Such judgments are necessary for planning, but they must be understood to be preliminary.

The machine tool industry and its environment are changing rapidly, and the developing problems and opportunities are not yet well defined. In fact, the traditional industrial classifications themselves are increasingly found wanting as categories for analysis; it is important that a broader segment of U.S. industry be identified if the analysis is to reflect changing markets, technology, and defense needs.

CAPITAL INVESTMENT

Inadequate access to capital is commonly raised as the machine tool industry's fundamental problem.^{3,9} The extreme cyclicity of the domestic market is surely a factor in the tendency of investors to view U.S. machine tool companies as risky places to hazard capital. Changes in net sales have exceeded 25 percent in 13 of the 23 years from 1958 to 1980.^{5,7} However, both new orders and earnings have been high since 1978. The continued capital shortage may be due in part to fears that these financial successes will not continue, in light of the declining balance of trade in machine tools. Some sources cite the additional problem of overconservative managements reluctant to make needed investments in either plant or product development.^{2,3} It is also likely that the many small businesses in the machine tool industry have been hurt by high interest rates over the past few years.

This committee finds much of this description plausible. A domestic financial environment more favorable to capital investment would presumably raise sales of machine tools and other forming equipment. But should the domestic industry be unable to compete in technology, marketing, and service, such an environment might only increase the

- 11 -

market for foreign manufacturers. Effective management, with the capacity to grasp new technical and market opportunities, is also important.

LABOR

With its highly cyclical market, the machine tool industry in the United States understandably finds it difficult to attract and retain skilled craftsmen in the numbers necessary to meet business peaks.^{2,3,9} As a result, delivery on orders during such periods is slowed, intensifying the effects of the industry's common practice of carrying heavy order backlogs. When demand is high, therefore, many buyers turn to foreign machine tools, which can generally be delivered much more quickly. The immediate consequence is that even at peak demand domestic manufacturers must discount prices. In the long run, there is the danger that buyers will gain confidence in foreign producers, further eroding the market for domestic tools. Past reductions in order backlogs have been followed by increases in domestic orders, but there is no guarantee that this trend will continue.

According to the National Machine Tool Builders Association, by 1990 the industry can expect a shortage of 19,000 skilled personnel.² The National Tooling and Machinery Institute, in contrast, recently concluded that the shortage in the defense industry would reach 240,000 by 1985.³ There appears to be no certain basis for estimates of the shortage.

Capital investment is one solution to this potential shortage. The adoption of new, more efficient manufacturing technology may well diminish the requirement for machinists, tool-and-die makers, and members of other highly skilled occupations.

Higher wages would presumably go far toward attracting the necessary personnel. One government study⁹ in any case disputes the long-term impact of labor shortages, citing such indicators as average weekly overtime hours, quit rates, and relative wages.

Of more long-term significance is the industry's ability to attract the talented engineers, designers, and managers who will develop and manufacture the next generations of tools. Experts in cutting and forming technology, electronics, computerized control systems and their software, manufacturing systems design, and marketing, among other fields, will be needed. Some of these specialists are currently in very heavy demand in "growth" industries, and it may not be easy to attract them to an industry commonly perceived as heavily cyclical and technologically backward. Again, competitive salaries will have some effect, as will the challenge of working in an industry with technological and management challenges before it.

INDUSTRY STRUCTURE

The U.S. machine tool industry consists of a few large companies (with sales in the hundreds of millions of dollars) and a great number of small companies, often specializing in narrow ranges of products. The U.S. Department of Commerce's 1977 Census of Manufactures reports that 611 of the 917 machine tool companies (SIC 3541) in the United States had 20 employees or fewer and only an estimated 27 employed more than 500. The pattern is repeated in other parts of the industry (SIC 3542, 3544, 3545, 3546, 3547, and 3549). (These statistics ignore manufacturers of electronic controls, robots, programming services, or machine tool maintenance companies, all of which are becoming more closely associated with the machine tool industry.) The average annual value of shipments per establishment in SIC 3541 was slightly over \$3 million.¹²

With rapid technological change in both machine tool production and the end products that machine tools are used to produce, small firms may have difficulty keeping pace. Small firms rarely have international ties, and, as noted earlier, many do not have the funds for adequate capital investment. On the other hand, the history of manufacturing innovation shows that many small firms are highly innovative. Because of the high degree of specialization in the machine tool industry, some sophisticated equipment is available only from small firms.

If the United States is to retain a leadership position in the machine tool market, structural changes are likely to be necessary. Consolidation of the industry has already begun. This consolidation is in the form of mergers and takeovers by both U.S. and foreign firms. Recent examples include Bendix Corporation's acquisition of Warner and Swasey, the merger of the Cross Company with Kearney and Trecker, and the takeover of Motch and Merryweather by Oerlikon-Buehre-Holding AG of Switzerland.

Prior research has given little attention to the likelihood or the necessity of restructuring the domestic machine tool industry, or the potential role of the Department of Defense in such restructuring. It would be interesting, for example, to study the industry structure of foreign competitors, and to trace the effects on competitiveness.

MANAGEMENT

Some recent studies propose that the machine tool industry's slowness to innovate and unaggressiveness in marketing may be due largely to the "fragmented" nature of the industry and the specialized, narrow product lines offered by many of the companies.^{2,3} These factors, it is suggested, militate against adequate investment in innovation and in some way favor unsophisticated management. The Machine Tool Task Force,² for example, says, "Small businesses are typically owned and operated by people who were originally craftsmen

and they do not usually employ engineers or other university-trained people. As a result, they are, with some outstanding exceptions, nonparticipating members of the technology-exchanging community." Technological change in machine tools and forming technology, the report says, has over the past 40 years been prompted more by user demands (and government-subsidized development) and technical advances in the supplier industries (notably cutting tool manufacturers) than by independent initiatives in the machine tool industry.

As an explanation of the industry's performance, such an analysis is inviting. Overconservative and unsophisticated management is undoubtedly significant in the cases of many individual companies. In a field whose technological and market horizons are expanding as rapidly as are those of the forming industry, it is to be expected that small companies with narrow product lines and experience in producing standard products over long periods of time should miss important opportunities for innovation. However, it should not be forgotten that the industry's sales leaders are fully large enough to afford the technical and management resources necessary to take advantage of new technology and new markets.

While there are no intrinsic obstacles to effective management in the organization of the industry, taking advantage of the new technologies and markets available will require management of an extremely nimble kind, with the capacity and breadth of view necessary to grasp developments not merely in cutting and forming technology, but also in computer control, systems engineering, and marketing.

CAPACITY

The existence of large order backlogs and long lead times suggests that capacity is insufficient for peak peacetime needs. If the need for mobilization arises, the industry in its present condition will not have time to respond. Capacity concerns involve types of machines as well as quantity.

During mobilization, the easiest capacity to change to meet defense needs is capacity used for exports. Therefore, a machine tool industry that is competitive in world markets during peacetime should be able to meet mobilization demands. It should also be noted that foreign-owned machine tool plants in this country may be used during wartime to meet U.S. defense needs.

The recurrent backlogs of machine tool orders in the United States suggest that either capacity to supply peak demand is insufficient or it is not being used efficiently. In many cases, it appears that machine tool builders prefer backlogs to extra capacity, in order to smooth out the cyclical demand. The Defense Department can use the "defense priority" rating to have its orders filled first; however, the backlogs indicate that either capacity or technology may be inadequate for mobilization.

One might also question whether machine tool builders have the capacity to produce the types of machines that are or will be needed. Critical machines, such as five-axis machines, are in short supply. Large forgings that are the backbone of today's airplanes can be made at only three firms.⁴

The current emphasis among machine tool builders in the United States is still on simple machines rather than systems, although that may be due as much to low demand as to capacity. Japan has targeted flexible manufacturing systems as a specialty to mass market. As demand for these systems increases, as it surely will, Japan's early efforts will give it an advantage over U.S. machine tool builders.

The responsiveness of the machine tool industry to defense needs could be strengthened in several respects--types of machines, quantities, and response times. During mobilization, it will be too late to begin to address this issue; mobilization capacity should be addressed now.

TECHNOLOGY AND INTERNATIONAL COMPETITION

The U.S. machine tool industry's reputation for slowness in applying new technology, and for unreliability in the higher technology product lines, is no doubt a significant factor in its market performance against foreign competitors. The extent to which this reputation is deserved is unclear, but there is good evidence that it influences buyers.

On the basis of past performance, the industry's ability to develop and market competitive technologically advanced products can be gauged roughly against its competitors' performance in the recent remarkable penetration of the U.S. market by reliable foreign tools and systems embodying advanced technology.^{2,9} The most significant new technology in the field has to do with computer control of tools and integrated manufacturing systems. This technology was conceived and largely developed in this country beginning in the 1950s.² It has been commercialized and marketed most successfully by a number of foreign companies (though many U.S. tools are in the technological vanguard).¹³

Another measure of innovation in an industry is the age of those of its products that are still in use. In 1978, American Machinist reported that about 35 percent of the metal-cutting and metal-forming machine tools in the United States were over 20 years old.¹⁰ Only 31 percent were under ten years old; corresponding percentages for other countries are 60 percent in Japan, 47 percent in Canada, 42 percent in Italy, and 37 percent in the Federal Republic of Germany. These figures suggest that the domestic market, on which domestic producers largely rely, is itself rather slow to adopt new process technology, compared to those of other industrial nations. The U.S. machine tool industry's failure to market its products strongly overseas has thus, probably, cut it off from sources of more sophisticated demand than those available at home. If so, it has correspondingly reduced its incentives to innovate.

Nor has the U.S. industry benefited from national research and development organizations, such as those established for the machine tool industries of some other countries (notably Japan, West Germany, and France).⁹ Many believe that, especially in Japan, government guidance has been critical to the international success of foreign machine tool industries. In addition, the close working relationships between foreign industry and universities are absent in the United States.

It is hard to judge the domestic industry's technological position in relation to its foreign competitors because the parameters of technological leadership are not clearly defined. For example, new orders have been increasing in recent years, while the balance of trade has been decreasing. Many believe that the United States holds a technological edge in computerized numerical control techniques. For example, the U.S. machine tool industry's prototype computer-controlled flexible manufacturing systems have, since about 1970, continued to embody the most cost effective technology in the world. Nevertheless the industry's prime market, namely the U.S. manufacturing industry, has moved much more slowly than that in a number of other countries to acquire such systems. As a result, it is becoming increasingly difficult for the U.S. machine tool industry to maintain the technological preeminence that it has enjoyed. The machine tool industries of several foreign countries are challenging this position, and some are approaching rough parity with U.S. products on technological grounds.

Chapter 5
PRIOR RECOMMENDATIONS

Recent reports on the machine tool industry were, as we noted in Chapter 1, strikingly unanimous in their assessments of the problems facing the domestic machine tool industry. Many of these reports offered suggestions for improving the health or competitiveness of that industry. As might be expected, the recommendations as a whole overlapped to a large extent, and it would be impossible to implement all of them.

The chart below summarizes the recommendations of prior studies. Each recommendation is described in terms of the effect its authors intended. While this study emphasizes actions to be taken by the Department of Defense, its scope is broad enough to include actions that might be taken by other parties. Accordingly, the recommendations are listed under headings that indicate the party responsible for carrying them out. One final organization of the recommendations is by problem area, as identified in the preceding chapter of this report.

Presumed Effect	Responsibility		
	DoD	Other Government	Industry

Capital Investment

Incentives to modernize equipment	Accelerated depreciation rates; tax credits ^{1,2}
Smooth demand cycle; encourage export sale	Remove restrictions on multi-year procurements; adhere to planned production rates ^{1,14}
Smooth demand cycle	Discontinue practice of selling used machine tools during business slumps

Presumed Effect	Responsibility		
	DoD	Other Government	Industry

Encourage joint investment in non-proprietary projects (R&D, safety, etc.)		Clarify antitrust laws ²	
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Capacity

Reduce nonproductive costs and encourage more suppliers	Reduce paperwork and reporting requirements ^{6,13}		
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Reduce nonproductive costs and encourage more suppliers	Write performance specifications, but avoid specifications for tool construction ⁷		
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More predictable demand; incentives to work with DoD	Greater use of sole-source contracts ⁷		
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Modernize government-owned machine tool inventory	Phase out obsolete machine tool base; upgrade government-owned machine tool base by one-time 25% investment and selective modernization at 5% per year ³		
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Labor

Upgrade skills and increase supply of workforce	Tax incentives for training and education ²		
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Increase attractiveness of industry to workers		Shorten apprenticeship periods ²	
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Increase labor supply	National drive to induce young people to choose manufacturing as their vocations ²		
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Presumed Effect	Responsibility		
	DoD	Other Government	Industry
<u>Management</u>			
Coordinate industrial program		Establish focal point within Executive Office of the President to direct and coordinate efforts related to the defense industrial base ²	
Greater efficiency			Integrate military and civilian production ¹⁴
<u>Technology</u>			
Accelerate innovation to production application	Expand Manufacturing Technology to 1% of procurement budget ³		
Encourage private investment in R&D, innovation	Multiyear procurement ¹		
Widen R&D base	Direct more R&D to small firms ¹⁴		
Increase university-industry collaboration		Continue to fund research in universities ²	Sponsor professorships in machine tool technology at universities ²
Promote useful standards		More user participation in standardization efforts ²	
Reduce duplication; speed technological advance		Establish technical information service for the machine tool industry (might also be done by industry association) ²	

Chapter 6 PHASE II STUDY DESIGN

The most prominent aspects of the machine tool industry, so far as this committee's charge is concerned, are (a) the rapid expansion of its technological and market horizons over the past decade or so, and (b) its deteriorating position in the world market, as measured by market share at home and overseas. In outlining a plan for a more comprehensive study of the industry's potential contributions to defense needs, the committee has concentrated on these characteristics.

Such a comprehensive study must begin by setting boundaries on the field of investigation somewhat wider than the machine tool industry's traditional limitation to metal-removing equipment, taking into account new materials and the information technologies of control and systems integration. Then, with such a definition in hand, a further study can assess the health of the industry, and its ability to serve Defense Department needs. The following outline embodies this committee's recommendations as to how such a study should proceed.

I. Industry Analysis

As a first step, the industry and its markets should be identified and characterized:

- A. Define the machine tool industry. For purposes of this study, the definition should be broad enough to include not only firms traditionally considered part of the machine tool industry, but also manufacturers of manufacturing systems components (machine, holding device, cutting tool, gauging and measuring device, controls, and material handling equipment). Include information integration and such competing industrial shaping technologies as near-net-shape forming. Examine the current structure of the machine tool industry, the changes it is undergoing, and its expected evolution over the next 20 or so years.
- B. Assess the technological and economic trends to which the industry should respond. Most important among these trends is the integration of fabrication, assembly, material handling and storage, production control, and management information systems. New methods of metal-forming and metal-cutting as alternative shaping techniques, the importance of new technical disciplines such as computer control, the merger of electronic controls and

mechanical processes, changing cost factors in production, market trends, joint international ventures and exchanges of information, and financial considerations should all be assessed.

- C. Group the firms in the machine tool industry according to categories that will aid an analysis of the industry's responsiveness to military needs. Which sectors are most important to the Department of Defense? In which firms is research and development being done? Possible categories include high-volume suppliers, suppliers of high-technology equipment, suppliers of equipment particularly critical to military needs, and custom integrators of manufacturing systems. Consider also which classes of tools are important to the Department of Defense.
- D. Assess the reasons why some machine tool companies prefer not to seek Defense Department contracts.
- E. For industry sectors identified as important to the Department of Defense, conduct case studies of their monitoring of the defense environment and their decisionmaking processes, to test how each type of company is likely to respond to different DoD initiatives or policies.

II. International Competitiveness

The past performance of the U.S. machine tool industry suggests that the industry is losing some of its ability to compete. A more comprehensive study should investigate the facts of the case and assess and weight the various contributing factors that have been proposed.

A. Export decline analysis

1. To what extent has recent booming domestic demand favored imports? How have domestic manufacturers responded?
2. Is national export-import policy a significant factor?
3. Do intrinsic cost advantages play important roles in foreign manufacturers' success? If so, what are these advantages and how important are they?
4. To what extent do labor and management practices contribute to the success of foreign manufacturers?
5. Are claims of superior quality, higher reliability, faster service, and lower prices for foreign tools based on fact?
6. Which tools are the primary imports, and which the primary exports?

- B. Comparison with key competitors (e.g., Japan) from users' perspective: price, quality, delivery, and reliability.

III. Problem Synthesis

On the basis of items I and II, identify the newly defined industry's fundamental problems (if any), describe potential DoD strategies for assisting in correcting these problems, and identify obstacles to putting those strategies in effect. The following issues may provide lines for this analysis:

- A. The influences of government policies in the fields of taxation, antitrust restrictions, manpower training and education, research and development, and restrictions of sales to the "Eastern bloc."
- B. Direct funding of research and development relevant to machine tool technology, in both the machine tool industry and universities, by the Department of Defense.
- C. Alternative Department of Defense procurement strategies.
 - 1. Is it possible, and under what circumstances would it be desirable, for the Defense Department to modernize the government-owned portion of the defense industrial base on a continuing and sustained basis?
 - 2. Can and should procurement regulations be changed to foster the installation of capital equipment by defense contractors?
 - 3. Should research and development funding be augmented? If so, how should funds be allocated between product and process development? How should they be allocated between universities and industry?
 - 4. Would formation of a joint Defense Department-machine tool industry committee be an effective group to develop plans for surge and mobilization?

IV. Recommendations

The recommendations will follow from the analysis in part III of this Phase II study, as described above. Likely categories for recommendations include the following:

- A. Business strategies
- B. Procurement strategies

C. Technological strategies

1. Product research and development
2. Process research and development

Parts I and II should be undertaken simultaneously by committee staff and consultants. We suggest that four investigators divide the research as follows: (1) industry analysis [I.A-D], (2) case studies on decisionmaking [I.E], (3) export decline analysis [II.A], and (4) comparison with key competitors [II.B]. This group should closely coordinate its work. The description of the industry and its components is an obvious necessity for an investigation of that industry's markets.

We further propose that the committee meet after the staff and consultants have completed researching parts I and II. The purpose of the meeting will be to review and analyze the foregoing research and to synthesize the results for part III.

The committee's development of alternative actions for the Defense Department will require additional staff work to assess the effects of each alternative. In particular, the effect of increased or stabilized demand on the machine tool industry and of various forms of research and development funding will be investigated. At a second or third meeting, the committee would address part IV, the recommendations, to develop a range of coherent Defense Department strategies based on the evidence gathered during the study.

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