ADVANCED MANUFACTURING INDUSTRY STUDY REPORT 1996

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Places Visited (U.S.):
Ingersoll, Rockford, IL
Gore, Elkton, MD
Museum of American History, Washington, DC
Association of Manufacturing Technology, McLean, VA
Caterpillar, York, PA
General Dynamics, Lima, OH
Cincinnati Milacron, Cincinnati, OH
Mazak, Florence, KY
Honda of America, Marysville, OH
CTP Corporation, Indianapolis, IN
Air Force Materiel Command, Wright-Patterson Air Force Base, OH
Texas Instruments, Lewisville, TX

Places Visited (International):
Hong Kong Productivity Council
Hong Kong Industrial Technology Center
Motorola, Hong Kong
Guangdong Provincial Economic Commission, Guangzhou, China
Elec & Eltek, Guangzhou, China
Nortel, Guangzhou, China
Shunde Municipal Government, Shunde, China
Kellogg, Guangzhou, China
Kelon Electrical, Guangzhou, China
Toyota, Nagoya, Japan
Nippondenso, Nagoya, Japan

Yamazaki Mazak, Nagoya, Japan
Okuma, Nagoya, Japan
Mitsubishi Heavy Industries,
Nagoya, Japan
Brother Industries, Nagoya, Japan
NGK Insulators, Nagoya, Japan
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ABSTRACT

This study of advanced manufacturing validates two facts: (1) manufacturing is vital to U.S. economic prosperity and national security, and (2) manufacturing will inevitably migrate out of mature industrial nations. The United States can reconcile these two facts only through a clear vision and a concerted effort by industry, academia, the Department of Defense, and the U.S. government. The report explores the nature of this vision and recommends actions to support it.

INTRODUCTION

Advanced Manufacturing Technology: The FY 94 Federal Program in Manufacturing Science, Engineering and Technology, highlights the importance of U.S. manufacturing: "Manufacturing is a cornerstone of the U.S. economy. The U.S. manufacturing sector directly employs 18 million people, or 17 percent of U.S. workers, and accounts for 22 percent of the U.S. gross national product--more than $1 trillion. Because jobs in manufacturing typically require more skills, these workers command a 20 to 30 percent premium in wages as compared with the average nonsupervisory U.S. worker in the private service sector. The manufacturing sector also employs approximately 75 percent of U.S. scientists and engineers and conducts 90 percent of the Nation's nondefense research and development." (Committee on Industry and Technology, 1993)

A large sector of U.S. manufacturing, the automobile industry, was caught off-guard in the late 1970s and early 1980s by the Japanese revolution in automobile production techniques and the demand for smaller, more fuel efficient automobiles. The Japanese automakers were able to take advantage of a slow-reacting U.S. auto industry by providing high-quality, low-cost cars to U.S. consumers. This phenomenon, termed *lean production* in *The Machine That Changed the World* (Womack, Jones, and Roos, 1991), began a revolution in Western industry that is still taking place today.

The history of the automobile industry also provides an excellent chronology of the evolution of manufacturing throughout the industrialized world. The first automobile was produced in 1894 by

Panhard et Levassor in Paris. The early manufacturing, called *craft production,* was typically done in small shops by skilled craftsmen. Henry Ford started using the process that came to be known as *mass production* with the Model T in 1908. What made mass production successful was the introduction of the moving assembly line by Ford in 1913.

Despite a number of innovations, the mass production system Ford developed continued almost undisturbed in the U.S. auto industry well into the 1980s. "This situation of stagnant mass production in both the United States and Europe might have continued indefinitely if a new motor industry had not emerged in Japan. The true significance of this industry was that it was not simply another replication of the by now venerable American approach to mass production. The Japanese were developing an entirely new way of making things, which we call lean production." (Womack, Jones, and Roos, 1991, 47).

When the major Japanese automakers began building production plants in the United States in the early 1980s, the U.S. auto industry finally took notice. In the mid-1980s, when Ford became the first U.S. auto manufacturer to discover lean production, what would become a rapid evolution of advanced manufacturing systems in the U.S. began.

The Evolution of Lean Production

The Japanese auto industry was forced to rebuild from scratch after the end of World War II. "Eiji Toyoda and his production genius, Taiichi Ohno, soon concluded that mass production could never work in Japan because: 1) the domestic market was tiny and demanded a wide range of vehicles, 2) the native Japanese work force was no longer willing to be treated as a variable cost, 3) the war-ravaged Japanese economy was starved for capital and for foreign exchange, and 4) the outside world was full of huge motor-vehicle producers who were anxious to establish operations in Japan. From this tentative beginning was born what came to be called the Toyota Production System and, ultimately, lean production." (Womack, Jones, and Roos, 1991, 49).

Lean production is the employment of some simple tenets involved in making things efficiently. Many of the following principles of lean production were developed in Japan from the teachings of American W. Edwards Deming:

- Just-in-time (JIT), "small-lot" production.
- Minimal in-process inventories.
- Multiskilled workers.
- High levels of subcontracting.
- Selective use of automation.
- Continuous incremental process improvement.

The primary purpose of these principles is to improve the flow and continuity of production, use a pull versus a push inventory system, and eliminate waste. In fact, lean production is obsessed with quality and the elimination of waste; it depends on workers with the skills to solve problems, not pass them down the line. Lean production systems also allow a greater variety of products to be made and new models to go into production faster.

Lean is now evolving into *agile* and *hybrid* manufacturing. Agile manufacturing, the ability to thrive on constant change, adds additional flexibility to the lean system that forces it to change rapidly based on market conditions or customer requirements. In a truly agile system, a manufacturer can turn a profit on a production lot of one item! Hybrid manufacturing incorporates some of the innovations in advanced manufacturing techniques discussed below.

ADVANCED MANUFACTURING DEFINED

Advanced manufacturing is characterized by a flexible and responsive manufacturing system that can react rapidly to changing market conditions and customer requirements. Advanced manufacturing systems incorporate new technology and innovative business practices to rapidly deliver high-quality, customized products that customers want to buy. Advanced manufacturing processes require interrelated changes in product design, manufacturing operations, supplier management, information technology, and management systems. The team's research and visits to industry sites led to the identification of four major components of advanced manufacturing:

1. The effective and efficient use of machine tools and robotics in the manufacturing process.

2. The use of advanced engineering technologies (e.g., computer-aided design and manufacturing [CAD/CAM], rapid prototyping [RP], computer-integrated manufacturing [CIM], computer numeric-controlled [CNC] manufacturing equipment, flexible manufacturing systems [FMS], flexible machining centers) in the design and manufacture of products, as well as the effective use of both product and process research and development (R&D).

3. The effective use of information technology and systems to manage the design and production process, using techniques including cycle-time reduction, JIT production systems, material requirements planning (MRP), manufacturing resources planning (MRP II), manufacturing execution systems (MES), and quality systems such as International Standards Organization (ISO) 9000.

4. The effective management of organizational and human resources to provide a highly motivated, educated, trained, and empowered work force, including the effective use of concurrent engineering and integrated product teams (IPTs) in the development of new products and a team approach on the manufacturing floor.

Machine Tools and Robotics

Advanced manufacturing requires advanced machine tools and robotics. "It is not possible to have world-class manufacturing without world-class tools." (Dertouzos, Lester, and Solow, 1989, 20). Over the past 15 years the United States has lost much of the global machine-tool and robotics market to Japan, Germany and Italy even though demand for machine tools and robots is growing as the world economy recovers. The Robotics Industries Association reports that since 1991 robot orders have increased nearly 140 percent.

Advanced Engineering Technologies

Computer-aided design. CAD began as a simple, two-dimensional automated system to replace the manual production of engineering drawings. Today's more sophisticated three-dimensional CAD systems allow the paperless design of parts and whole systems and give producers the ability to program and control the CNC machine tools producing the part.

Rapid prototyping. RP technologies cut the development time for new products by quickly producing prototypes for design verification and preliminary testing without the initial time and money required by traditional tool and die assemblies. The RP process feeds a 3-D CAD representation into an RP machine that produces the physical model. There are six basic RP technologies: stereolithography, selective laser sintering, fused deposition modeling, laminated object manufacturing, solid ground curing, and ballistic particle manufacturing.

Flexible manufacturing systems. FMSs feature the use of high-variety production and design equipment such as robots, flexible machining centers, automatic insertion machines for electronic components, and CAD and engineering technology.

Computer-integrated manufacturing. CIM is an FMS plus automated and flexible control of the flow of materials and tools, the use of bar codes to identify all inventories and activities in the operation, and the automation of the knowledge work of production planning and control.

Information Technology and Systems

A number of techniques related to information technology and systems were developed to meet the goals of factory automation: higher quality, lower overhead, and faster response time.

Just-in-time. Lean production systems stress the importance of JIT throughout the production cycle. JIT systems, which can be as simple as a pencil-and-paper spreadsheet or as complex as a full MRP system, have the goal of reducing inventory requirements, increasing productivity, eliminating waste, and lowering costs.

Material requirements planning. The purpose of MRP is to determine when the workstation on the assembly line needs parts or when a machining center needs raw materials. One element is a tool that makes the parts-purchasing and inventory control systems more effective.

Manufacturing resources planning. MRP II takes MRP to the next level by organizing the flow of manufacturing resources to meet delivery schedules while minimizing production costs. Functions that an MRP II system organizes include sales order management, inventory control, accounts receivable/payable, purchasing, and payroll.

Manufacturing execution systems. MES components include planning and scheduling, tracking, monitoring and control, quality management, and CIM interface. An MES assists production people in scheduling precisely, provides an electronic network for performance improvement, manages resources and dispatches production units, collects data automatically, delivers instructions and drawings to the workstation, records production details, manages alarms, analyzes performance, and continually interacts with the MRP II system. An MES brings automation to the shop floor to a much greater extent than MRP or MRP II does.

ISO 9000 quality systems. Management of quality, which used to be a lofty goal and an added cost of production, is now an absolute given for any company that hopes to become an advanced manufacturer today. Improved quality not only provides better products for the consumer but also eliminates waste and lowers costs. International quality standards, such as the ISO 9000 series quality standards, serve to level the playing field for manufacturers and provide a uniform set of criteria for quality. Quality systems include the organizational structure, responsibilities, procedures, processes, and resources needed to implement quality management. ISO 9000, a three-tiered approach to quality management systems, consists of ISO 9001, the high-level quality system, incorporating design, development, production, installation, and service into a total quality system; ISO 9002, the midlevel quality system, appropriate for production and installation only when design and development are not players; and ISO 9003, the low-level quality system, applicable to products in the final inspection and testing phase.

Management

An empowered work force. People are the most important asset of the modern manufacturing enterprise. A competitive work force requires a competitive organization and management structure. The individual worker is an asset to be developed, not a cost to be controlled. A work force consisting of multifunctional workers, the problem solvers in any organization, is facilitated by a flat organizational structure with empowered workers. Because a happy worker is a productive worker, the organization must focus on job satisfaction, which by some accounts is now more important to the average worker than monetary compensation.

Concurrent engineering. To significantly reduce product development times, manufacturers need to reduce the time that each phase takes and overlap the phases as much as possible. Concurrent engineering frees the design and development team from the step-by-step process of product development.

Integrated product teams. In IPTs, many functions in business enterprise (e.g., product design, engineering, manufacturing, marketing) collaborate in their management practices over the life of a product--from idea to obsolescence--to ensure that it reflects customers' needs. An IPT is generally formed for the life of the product development cycle and includes representatives from all functions responsible for developing and manufacturing the product: design, manufacturing, purchasing, quality, and suppliers.

CURRENT CONDITIONS

During our research and field studies, we visited manufacturers in the automotive, aerospace, electronics, and machine-tool industries as well as suppliers to these industries throughout the United States and in Hong Kong, China, and Japan. Below we summarize our observations on the current condition of manufacturing in the machine-tool, robotics, automobile, and electronics industries and on R&D in those countries.

Machine-Tool Industry

Recent performance paints a pessimistic portrait of the global competitiveness of the U.S. machine-tool industry today. After reducing the trade deficit in machine tools from 1987 until 1992, the industry completed 1995 with a projected record-high trade deficit of $3.54 billion (Womack, Jones, and Roos, 1996, S-4). This growth in the trade deficit overshadows the fact that domestic machine-tool production is also growing, but not as fast as U.S. consumption of machine tools. Meanwhile, the machine-tool industries in Japan and Germany are emerging from a recession and are increasing production at a greater rate than the U.S. machine-tool industry is.

As the Massachusetts Institute of Technology's Commission on Industrial Productivity observed in 1989, "The U.S. machine-tool industry has historically been fragmented, with small, mostly family-owned firms clustered in regions where user industries are concentrated. Each firm tended to specialize in a narrow product line for a particular market." (Dertouzos, Lester, and Solow, 1989, 234). Although the industry continues to consolidate, its overall structure continues to be one of relatively few large companies and hundreds of small companies. Of the 639 machine-tool firms active in 1992, almost 75 percent have fewer than 50 employees (Association for Manufacturing Technology, 1995, D-9). The top four U.S. companies in sales account for approximately 40 percent of domestic production.

A large percentage of U.S. machine-tool production continues to be in the area of "specialty" machines, leaving a large market for "commodity" machines to foreign competition. The United States' two largest competitors, Japan and Germany, continue to dominate large segments of the industry. "German firms stress high precision and special capabilities, whereas the Japanese concentrate on offering fast delivery of reliable, standard machines at low prices." (Dertouzos, Lester, and Solow, 1989, 233).

Domestic production continues to grow at an impressive rate--30 percent in 1995, with production estimated at $4.91 billion. (Production peaked at $5.1 billion before the industry's collapse in the early 1980s; Womack, Jones, and Roos, 1996, S-3). However, domestic consumption in 1995 grew 34 percent, causing a decrease in U.S. exports and an increase in imports. The resurgence of the economies and of the machine-tool industries in Japan and Germany, which grew 36 percent and 43 percent, respectively, overshadowed U.S. growth in 1995 (Womack, Jones, and Roos, 1996, S-1). Based on 1994 sales, the 4 largest and 8 of the top 15 machine-tool companies in the world are Japanese whereas only 3 U.S. firms, Giddings & Lewis, Western Atlas, and Cincinnati Milacron, made the top 15 (Ashburn, 1995, 87). Although U.S. machine-tool exports measured in dollars remained level from 1994 to 1995, exports as a percentage of production fell to a six-year low of 26.9 percent. Imports, in contrast, held at about 50 percent of U.S. consumption but soared on a dollar basis to $3.5 billion, an increase of 23.5 percent over 1994 (Womack, Jones, and Roos, 1996, S-3).

U.S. companies. U.S. machine-tool companies are taking different approaches to expanding their markets. Ingersoll Milling Company is developing high-velocity milling machines, particularly for the aircraft industry, and is redefining the state of the art in five-axis machining with its Octahedral Hexapod machine. They lead the industry in the development of linear motors to replace ball screws on large machining centers. Ingersoll is using a number of advanced manufacturing techniques. One is a CIM system that links design, manufacturing, and process controls, allowing the company to produce single, specialized parts at a cost that approaches the unit cost of a long run of a single standard part.

Cincinnati Milacron is becoming "lean" through its Wolfpack project, which involves "making machines that people actually want rather than engineering and building machines that someone within the organization maintains people have a yen for . . . and design[ing] for manufacturability, which has had a number of effects, including a 40 to 60% reduction in the number of parts used to build a machine and a 40% reduction in the cost of manufacture." (Womack, Jones, and Roos, 1994, 31). Milacron is also moving into plastics; 1994 sales of plastics machinery exceeded those for metalworking machinery.

Japanese companies. A key distinguishing feature of the Japanese machine-tool producers we visited (Yamazaki Mazak facilities in Japan and the United States and Okuma facilities in Japan) is a higher level of automation than U.S. firms employ. Mazak and Okuma use FMSs in a fully automated mode, allowing both firms to man one shift and manage fluctuating production needs by operating a second shift, a third shift, or both without human intervention.

Robotics Industry

The Robotic Industries Association (RIA) reports that 10,198 robots valued at $898 million were shipped in 1995, a jump of 34 percent in units and 30 percent in dollars over 1994's record-setting pace. Robot shipments have increased more than 128 percent since 1991, when the robotics industry began surging forward. In 1995, spot-welding robots accounted for 36 percent of the new orders, followed by material-handling robots at 27 percent and arc-welding robots at percent. Although the RIA estimates that some 65,000 robots are now at work in U.S. factories, this figure represents only a fraction of the potential U.S. market. An RIA official estimates that fewer than 10 percent of the companies who could benefit from using robots have installed even one robot. Japan, on the other hand, had installed two-thirds of the robots in use worldwide by the late 1980s and still holds a commanding lead over the United States in the number of robots used in manufacturing.

Auto Industry

One focus of our study was the Japanese revolution in automobile production beginning in the late 1970s. Although Ford Motor Company and other U.S. manufacturers have introduced some "lean" innovations, the results do not resemble lean production in Japan.

As we saw during our visit, Honda of America has successfully brought Japanese-style production to the United States. U.S. workers there effectively use modified Japanese-style work and management techniques. Realizing the importance of job satisfaction, Honda takes care of its workers, and the U.S. workers at Honda of America feel as empowered as their counterparts in Japan do. The flat Honda organization empowers workers to solve problems on the line. The multiskilled work force at Honda allows jobs on the assembly line to change every two hours.

The production system at Toyota's Motomachi Assembly Plant in Japan more than fulfilled our high expectations. JIT delivery from suppliers is in full practice; trucks constantly pull up to the receiving docks. The plant contained no more than a two-hour supply of most parts, and the assembly line was restocked like clockwork every 20 minutes.

Parts of the Motomachi plant are highly automated. For example, the entire body-welding shop, which fabricates 12,000 bodies for Toyota and Lexus automobiles per month, ran with only 300 employees on two shifts. Four hundred thirty robot spot welders employed throughout the facility perform more than 96 percent of all spot welds (4,300). Production at the Motomachi plant is the best in the world, as evidenced by the fact that the 1996 J. D. Power and Associates *Annual Report on Auto Quality* rated the Lexus SC 300 and SC 400 coupes, built at Motomachi, at the top of the premium luxury section with the fewest problems reported by new owners. (*The Japan Times*, May 10, 1996)

Toyota realizes the value of its work force and has thus far lived up to its lifetime employment philosophy. A sign at the entrance to the Motomachi plant sums up Toyota's commitment to its work force:

- Increase worker motivation.
- Design processes that anyone can perform.
- Employ automation that people want to work with.
- Make a comfortable work environment.

Electronics Industry

At Texas Instruments, we saw the stereolithography rapid prototyping process, which converts a 3-D image into slices as thin as .0025 inch on a machine that can be operated without supervision. A low-power ultraviolet laser traces across the surface of a vat of photocurable liquid polymer, turning it into a hardened resin wherever the laser contacts the polymer. The hardened layer is then lowered incrementally to allow the next layer to form. Completed parts, which can be as large as 20 inches by 20 inches by 24 inches, have high resolution and good surface finishes. Texas Instruments uses stereolithography to produce models of a diverse range of products from castings to electronic components. The quality of the models produced is so good that they can be used to make the molds for the castings.

Texas Instruments developed RP technology to reduce product development time and cost and to get products to market more quickly. The company estimates that it has saved $4.5 million over the past four years by using stereolithography prototyping.

The Nippondenso printed circuit board (PCB) production plant in Japan was the most automated of any facility we visited. The production line could handle up to seven different sizes of PCBs with only two or three human operators.

PCB manufacturing in Hong Kong was almost as automated and efficient as in Japan. In China, however, developing a work force in PCB manufacturing is a challenge, even though the United States, Japan, and Hong Kong are establishing advanced facilities there. Most firms responded to the work force problem by bringing in managers and engineers from the home country or from Hong Kong.

Research and Development

The Japanese commitment to R&D is legendary. "Despite the worst recessionary period in its post-war history, the Japanese economy continues to support massive expenditures for R&D. Outlays for 1994 are down from previous years, but still 40% above the amount spent 10 years earlier. Surprisingly, R&D expenditures in Japan have weathered the recession quite well, continuing to increase even after the growth of Japan's real GDP plunged from a high of 7.5% in 1990 to 1% in 1994. In fact, although economic growth has been almost nonexistent for the past three years, R&D expenditures have decreased by only 1%. In the U.S., on the other hand, R&D expenditures as a percentage of the GDP have declined by an average of 0.93% annually, even though the economy has been expanding for the past three years." (Henry, 1996, 2-3).

NGK Insulators illustrates the Japanese commitment to R&D. The company, which is recovering from a recession that has reduced its sales over the past five years, continues to pour 5-6% of revenues into R&D.

NGK's management sees this as the only way to maintain its competitiveness when the economy fully recovers.

CHALLENGES

Human Resources

A major challenge for the United States as it moves toward advanced manufacturing is human resources and corporate culture. U.S. industry traditionally has not taken a long-term view of growth, seeing U.S. workers as a variable cost that can be cut by downsizing, layoffs, and other methods. Companies tend to make capital expenditures based on a quick payback, sometimes within the next financial reporting period.

In contrast, Japanese companies continue to invest in technologies and in capital equipment that may not yield a payback for 10 or 20 years. A U.S. exception is Kellogg, the breakfast food manufacturer, which recently established a plant in China but does not expect it to be profitable for many years. The company has taken a long-term view of its venture in China not only because of the potential of the Chinese market but, as a Kellogg executive told us, for the long-term survival of the Kellogg company.

Since U.S. industry sees workers as expendable, training, particularly in how to work as a team, is lacking. "A company may decide to use teams, but only after it has cultivated the capabilities that will allow teams to be effective: credibility and trust between functional groups and a cadre of effective team leaders." (Hayes and Pisano, 1994, 86). Building successful teams violates the sanctity of two traditions of U.S. industry: the organizational hierarchy and the expendability of workers. The team concept is more natural to Japanese companies, which have a cultural heritage of concern for the group.

Productivity

Another challenge to U.S. industry is in the area of productivity and process improvements. "Many Japanese factories practicing lean manufacturing appeared to surpass their U.S. counterparts on several dimensions; they achieved lower cost, higher quality, faster product introductions, and greater flexibility, all at the same time." (Hayes and Pisano, 1994, 80). U.S. companies are beginning to make progress in this area, as shown by the increased U.S. investment in advanced machine tools and robotics mentioned above. Investment in advanced CNC machine tools and in such areas as flexible machining centers, flexible design and manufacturing teams, factory simulation, and cycle-time reduction would improve productivity in U.S. factories.

Another area for improvement in productivity is manufacturers' relationships with suppliers. Suppliers play a much more central role today in product design and delivery. When companies use an electronic data interchange system, suppliers can have instant access to production data on orders, deliveries, defective items, etc. Today, instead of "arms-length" relationships with suppliers, manufacturers must maintain "arms-around" relationships. JIT inventory, involvement in the design process, and loyalty are all areas where manufacturers and suppliers must work together to improve productivity and process.

Investment in R&D

The United States continues to be the world leader in developing advanced manufacturing technologies. Decreasing expenditures on defense R&D without increasing those for commercial R&D will cause U.S. industry to lose the technological lead to industry in other countries.

The loss of U.S. industries to the emerging markets in Asia and Mexico is a sign not of the defeat of U.S. industry but of a natural progression toward locating more high-volume, low-complexity manufacturing in countries that are just mastering the concepts of mass production. The challenge for U.S. industry is to retain and advance its ability to design and develop complex, high-value-added manufacturing in the United States.

OUTLOOK

The long-term outlook for U.S. manufacturing is conditioned on much of what has already been discussed.

U.S. manufacturers can remain globally competitive only if they are willing to make the investments required. "Capabilities that provide enduring sources of competitive advantage are usually built over time through a series of investments in facilities, human capital, and knowledge." (Hayes and Pisano, 80). Two of the United States' biggest global competitors, Japan and Germany, are coming out of long recessions. As mentioned, Japanese companies continued to invest in research and product development even when sales were down. As they now begin an economic upswing, the high cost of continuing R&D will make Japanese companies even more competitive globally. Whether industry takes a long-term view of capital investment and investment in human resources, supported by the active influence of the government, will determine whether the United States remains competitive in the global marketplace or continues to lose out to the manufacturers of Japan, Germany, and the emerging global players.

High-Value Production

The future for manufacturing in the United States does not lie in returning to the status quo of the 1970s. "The key to future national wealth is not standardized mass production, but high value production--the creation of goods and services than command a premium market price because customers place high relative value on those products." (Reich, 1991, 81). The United States must continue to concentrate on complex, high-value-added manufacturing while taking advantage of opportunities in less developed countries for high-volume, low-complexity manufacturing. To maintain its technological lead, the United States must invest in areas like CAD/CAM, rapid and virtual prototyping, factory simulation, factory automation, and the design of the factories of the future. Developing the human resources required to accomplish these tasks, through education, training, worker involvement and empowerment, and the use of teams in the design, development, and manufacturing processes, is the key to future competitiveness.

Machine-Tool Industry

Advanced machine tools are critical to U.S. manufacturing. Although the U.S. machine-tool industry is proud of its 30 percent growth during 1995, without increased productivity and increased plant capacity further growth will be slow. The world machine-tool market continues to grow at a rapid pace, but the U.S. industry continues to trail those of Japan and Germany in total sales. Continued R&D by major U.S. machine-tool builders can help maintain the U.S. position as the world leader in high-technology, specialized machine tools.

Support for National Security

Can U.S. manufacturing support national security resource requirements? The answer undoubtedly is yes, but the nature of that support will change. Off-shore production is now a fact of life for the United States and the rest of the industrialized world. The key for the advanced-manufacturing nations is to keep product and process expertise in the home country to maintain capabilities.

The future holds a number of challenges to meeting full surge and mobilization requirements. One of the most serious of those challenges concerns the implications of a JIT environment for surge and mobilization. A diminished but ever-changing threat means that the definition of mobilization formulated during the 1940s and envisioned during the Cold Car is probably obsolete. During the Cold War, a massive defense-related industrial base planned and executed surge and mobilization. Now that the defense-related industrial base is a smaller part of the national industrial base, flexible commercial manufacturers are the key to surge and mobilization. Because advanced manufacturers can adjust to changing requirements rapidly, future efforts to maintain surge and mobilization capabilities need to focus on second- and third-tier producers and suppliers who provide the parts and subassemblies to the end-item manufacturers.

An example of what one leading consumer goods producer, Levi Strauss, is doing to remain competitive illustrates what the future holds for mass production--in lots of one:

> One of the most dramatic benefits of the new technology may be the way it is changing the production of goods. Collecting customer data allows companies to deviate from the mass-production model, where a standard, assembly-line item is supposed to satisfy all consumers.

> With the new "mass customization," products can be efficiently made for a single person. At 19 Levi Strauss stores, for example, shoppers don't have to pick blue jeans off the shelf. Instead, customers can be measured for an exact fit and choose options, such as the color of the jeans. The data are then sent via modem to the Levi's factory in Tennessee, where the custom jeans are stitched. Approximately three weeks later, the perfect-fitting jeans are mailed to the consumer. The measurements are also kept on computer for future orders. Analysts believe that many goods will soon be delivered in a similar fashion because customized production cuts overhead. There is little waste, for instance, and inventory and transportation costs decline dramatically. (Cohen, 1996, 54)

GOVERNMENT GOALS AND ROLE

The large decrease in defense spending has caused the government's role in the U.S. manufacturing sector to shrink along with the defense industrial base. However, there is a continuing role for the government to play in shaping U.S. manufacturing for the 21st century.

Government-funded R&D since the end of World War II has provided the impetus for U.S. economic and manufacturing growth. With defense R&D spending on the decline, U.S. industry must now pick up much of the slack. In government-supported R&D programs, cooperative efforts with businesses, such as those used by SEMATECH and the Advanced Research Projects Agency, will ensure that the technologies developed match industrywide priorities.

Another role the government can play in improving the U.S. future in manufacturing is to support a U.S. export focus that will help maintain a positive balance of trade. Two means to achieve this are a more effective use of "technology attaches" in U.S. embassies abroad and support for U.S. Expo Centers in major markets abroad. These two steps will facilitate continued access to emerging technologies in the world and help market U.S. products and technologies in the global marketplace.

Tax, regulatory, trade, and program policies are another area in which the government can provide incentives to U.S. manufacturing. Favorable investment tax policies would encourage private sector capital investment in maintaining R&D capabilities in the United States and would foster increased U.S. investment in the flexible manufacturing advances that are so critical to maintaining a viable advanced manufacturing capability.

Another way for the U.S. government to support manufacturing is to do no harm to U.S. industry by unnecessary government intervention. One example is trade sanctions in U.S. foreign policy and their impact on U.S. manufacturers.

A major segment of U.S. industry that has largely failed to take advantage of the "lean" revolution is the defense industrial base. The primary reason for this failure is the way the Department of Defense (DoD) buys major weapons systems. Some of the laws, rules, and regulations that government agencies must follow when expending public funds do not facilitate efficient production. The DoD has an important role to play in the U.S. manufacturing sector. As the defense industrial base continues to shrink, the DoD should reduce the number of government-owned and -operated manufacturing and repair facilities to only those fulfilling needs unique to defense that the commercial marketplace cannot supply. Examples include the production of submarines, tanks, combat vehicles, and certain fighter aircraft. Beyond these defense-unique requirements, the DoD should rely on an agile and flexible commercial manufacturing sector to meet defense needs.

The DoD should also continue to focus on basic research in defense laboratories and universities to ensure that the United States maintains the leading edge in advanced technologies for national security. In addition, funding to develop manufacturing flexibility in both the defense industrial base and the commercial manufacturing sector will help fulfill future needs for surge and mobilization capability.

Just as industry should be taking the long view, so should the DoD. Long-term relationships with valued suppliers are important to long-term national security. Government/private sector cooperation through multiyear budgets and contracts allows both parties to look beyond the next budget cycle. Long-term R&D in both product and flexible manufacturing processes will help the United States remain competitive in the global marketplace.

CONCLUSIONS

Paul Kennedy, in *Preparing for the Twenty-First Century,* offers the following recipe for improving U.S. competitiveness in the global marketplace:

> Increase national savings rates and slash budgetary deficits which drain funds from productive investment; enhance the levels of commercial R&D; avoid the diversion of too many resources to the military; escape (but how?) from a business culture that has become too dependent upon Wall Street's expectation of short-term profits; focus upon making well-designed, reliable products for the world's most demanding markets; vastly improve the levels of skill and training among the work force at large and provide opportunities for thorough retraining; and raise the educational standards, especially for those not going to college. (Kennedy, 1993, 337)

A commitment to advanced manufacturing requires the United States to do all that Kennedy suggests and more. The current U.S. technological advantage over global competitors will fall short in the future if the nation does not exploit that advantage for increased global competitiveness. The United States needs to develop a vision of manufacturing for the future. For industry to do what it has done for the past 100 years will only speed the inevitable shift of manufacturing from U.S. shores. Future U.S. national and economic security requires a commitment to keep a globally competitive advanced manufacturing capability in the United States.

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