New Directions in Manufacturing: Report of a Workshop

Committee on New Directions in Manufacturing, National Research Council

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NEW DIRECTIONS IN MANUFACTURING

Report of a Workshop

Committee on New Directions in Manufacturing
Board on Manufacturing and Engineering Design
Division on Engineering and Physical Sciences

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Preface

Since the Industrial Revolution, when we exchanged handmade manufactured goods for machine-made, the changing nature of manufacturing has been apparent, and its evolution continues today. Such new developments as micro- and nanomanufacturing, computer-aided manufacturing, and innovative supply chain management are only a few of the current advances in a long history of manufacturing innovations.

To highlight synergies, emphasize partnerships, facilitate discussion, and raise awareness of the far-reaching impacts that these changes in manufacturing will have on other spheres, the Board on Manufacturing and Engineering Design (BMED) of the National Research Council (NRC) established the Committee on New Directions in Manufacturing to organize a workshop and prepare a report of the results. The committee was asked to design a workshop program that would address issues central to the evolving world of manufacturing, such as robust manufacturing; micro- and nanomanufacturing; workforce and education; lean manufacturing; contract manufacturing; surge manufacturing; new strategies for product design and realization; globalization; and regulatory considerations.

"New Directions in Manufacturing," a workshop held March 27 and 28, 2003, at the National Academies headquarters in Washington, D.C., brought together government policy makers, visionary leaders in the manufacturing industry, members of the manufacturing research community, developers of manufacturing systems, manufacturing workforce representatives and advocates, and end users of manufactured products to give presentations and participate in discussions on the current state of the manufacturing enterprise in the United States and the challenges to be faced in the coming years.

To focus discussion, sessions were convened that addressed the following major drivers for manufacturing: the human element, globalization, challenges and opportunities arising from new technologies, energy and the environment, and national security. Each session consisted of brief presentations by invited speakers, followed by extended panel discussions. The workshop began with a session on the importance of manufacturing and its economic value and ended with a session highlighting the dilemmas faced by manufacturers today.

Part I of this report summarizes the workshop discussion and draws on some of the material in the written presentations to develop a basis for the committee's deliberations. Parts II through VII contain the individual papers authored by those making presentations. Biographies of the committee members and the workshop agenda are given in the appendixes. While the committee is responsible for the overall quality and accuracy of the report as a record of what transpired at the workshop, the views contained in Part I of the workshop report are not necessarily those of the committee.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity,

evidence, and responsiveness to the study charge. The contents of the review comments and the draft manuscript remain confidential to protect the integrity of the deliberative process. The committee wishes to thank the following individuals for their participation in the review of this report: Thomas C. Mahoney, West Virginia-Manufacturing Extension Partnership; Rito A. Martinez, Intel Workforce Development; Deborah Seifert Nightingale, Massachusetts Institute of Technology; and Philip P. Shapira, Georgia Institute of Technology.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the report, nor did they see the final draft of the report before its release. The review of this report was overseen by R. Stephen Berry, University of Chicago. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

The committee also thanks the speakers, session chairs, panelists, and others who helped to make the workshop a success, and it acknowledges the work of the NRC staff, including Emily Ann Meyer, Teri Thorowgood, Laura Tóth, and Toni Maréchaux. Workshop participants made uniformly positive comments on the selection of topics and the quality of the talks and discussion sessions. They were particularly pleased that the NRC brought together the diverse segments of the manufacturing community in a single, unifying event.

Robert J. Hermann, *Chair*
Committee on New Directions in Manufacturing

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Executive Summary

The United States is a prosperous nation. Many of the assets that signal this prosperity are a result of the nation's manufacturing proficiency. Manufacturing is a principal driver of growth in productivity, with a revolution in manufacturing having occurred over the last 50 years. In addition, between 1992 and 2000, the manufacturing sector contributed 22 percent to the U.S. gross domestic product and at its peak, in 2000, it employed more than 17 million people.[1]

Manufacturing has historically been the engine for greater economic growth, including in the service sector. But the 2001 recession hit manufacturing significantly harder than the rest of the economy, in terms of both depth and duration. According to the Bureau of Labor Statistics, the manufacturing sector lost 3 million jobs between July 2000 and January 2004. This has led to a sharp and sustained decline in the nation's overall employment levels and a drop in capacity utilization.

Potential reasons for these declines include the nature of increasing productivity; decreased business spending; changing strength of the dollar; and an increased trade deficit. There is disagreement over whether the movement of production jobs overseas is a net positive or net negative trend—that is, whether production capacity today is a commodity or a strategic asset.

CHALLENGES FACING U.S. MANUFACTURING

The U.S. manufacturing sector faces seven central challenges in rebuilding the nation's manufacturing capacity and jobs.

Understanding Manufacturing Trends

Manufacturing is a means of satisfying higher societal objectives, and the current state of “making things” therefore deserves to be placed in a larger societal context. The current national debate on manufacturing is often narrowly focused on “little m” manufacturing, or the actual physical fabrication of goods. Manufacturing also involves "big M" concerns, meaning the business practices that surround the physical plant. Because all manufacturing organizations must attend to both little m and big M concerns, any government actions intended to help the manufacturing sector must take both concerns into account.

It is increasingly important that the discussion of manufacturing issues, which forms the basis for decisions and policy at the federal, state, and local levels, take place using appropriate metrics in the correct context. For example, measuring manufacturing in terms of the wealth it generates among both investors and workers, leading to the stimulation of the economy as a whole, could help policy makers understand the true impact of changes in the manufacturing sector.

[1] National Association of Manufacturers. "Quickfacts" summarized from data from the Bureau of Labor Statistics and the Bureau of Economic Analysis. Available at http://www.nam.org/secondary.asp?TrackID=&CategoryID=1155. Accessed November 2003.

Manufacturing Globalization

Globalization—an overwhelming trend that is affecting almost every facet of manufacturing—is a reality for U.S. manufacturing, in both the civilian and defense sectors. In this new reality, manufacturers must find ways to exploit the advantages of globalization of production and expansion of world markets to the benefit of everyone, including employees, companies, consumers, and the nation as a whole. In addition, maintaining defense capacity must be taken into consideration.

A combination of factors is responsible for the movement of production overseas. Although labor costs in developing countries have traditionally been lower than those in the United States, only in recent years has the infrastructure of these countries improved enough to allow them to manufacture with reliable quality. Their transportation and communication systems are much more robust than in the past, and because these systems are often built on new technologies, they have not required the same investment as older systems. The infrastructure for education and training of workers is also much improved in many countries around the world.

Labor organizations and businesses have serious concerns about the loss of U.S. manufacturing jobs resulting from this movement of capacity overseas. While this is a clear trend, some corporate representatives at the workshop claimed that moving certain jobs overseas resulted in overall job retention in the United States. Because globalized production can enable the efficient distribution of engineering and manufacturing responsibilities, it can result in decreased overall costs and the creation of better jobs in the United States. Additionally, the globalization of production has created opportunities for many companies to capture new market growth in developing regions around the world.

Such influences as trade policies, dollar valuation, and tax policies are arguably crucial in the competition with the low labor rates and varying regulatory environments abroad. If manufacturing cannot provide a distinctive competitive advantage in new or existing markets, companies stand to gain by channeling their resources into functions and activities that will result in a competitive advantage to them. This may lead to a further reduction in investment in domestic capacity.

Information Technology Opportunities

New information technologies present a continuing and growing number of opportunities to manufacturers. Information, data communication, and data processing technologies are powerful tools that can be used in every element of the manufacturing enterprise, including just-in-time delivery of raw materials, activities on the factory floor, shipping, marketing, and strategic planning. The power of information technology has contributed to globalization and the ability to outsource manufacturing activities both inside and outside the United States. These trends could result in reduced domestic content in the products of U.S. manufacturing firms, with significant implications for national and regional manufacturing jobs and labor markets. At the same time, the growing reliance of manufacturing and other economic sectors on information and communications technology has spawned completely new industrial sectors—and occupations—devoted to the production and implementation of these systems.

Maintaining Innovation

Technological innovation and engineering design capabilities are critical for the creation of new industries and jobs. The growing demand for products with improved quality, functionality, and reduced time to market can strain established production processes, making

innovation necessary for sustained competitiveness. Advances in technology can also provide ideas for new products.

Innovation, in this case the successful exploitation of new ideas, has many prerequisites. The most important is the new idea itself, which in turn relies on research. The federal government can facilitate innovation in the manufacturing sector by establishing policies that encourage basic science and, at the same time, implement programs that share the risk of development with the private sector. This type of public-private partnership can be very effective in accelerating the transition of new technology concepts. For all the partners to interact effectively, it is important to establish responsibilities for the intellectual property and standards for research, product development, and product realization.

Strengthening Small and Medium-Sized Enterprises

Manufacturing employment is becoming increasingly concentrated in small and medium-sized enterprises, which are the primary suppliers for large domestic companies. As large companies outsource more of their manufacturing and services, they choose where their business goes based on competitiveness. It is therefore important to modernize and strengthen these small and medium-sized companies in the United States. Improved integration of the supply chain is needed, as is easier access to technology and to capital for small manufacturers. A holistic approach that includes all stakeholders—employers, educators, students, and government leaders—is needed.

Workforce Education

The educational and training systems that support the manufacturing sector are key to its success. These systems will ensure that an adequate talent pool exists for manufacturing jobs and that workers already on the job continue to be trained. To implement technological innovations and promote sustained improvement, the manufacturing workforce must possess continually updated technical knowledge. It is important that accessible and broadly distributed workforce development programs be supported and integrated into economic and technology development programs. Increased accessibility and dissemination of information on these programs to incumbent workers, for example, may provide opportunities for promotion and free up manufacturing jobs that can then be filled by displaced workers.

Rising Infrastructure Costs

The costs of infrastructure, including those for health care, legal protection, and regulatory enforcement, are often the difference between competitiveness and closed doors. Health care costs are a serious concern for both large and small manufacturers. The rapid rate of increase in these costs has caused some firms to reduce hiring or limit spending on capital improvements. At the same time, many U.S. concerns feel that the cost of compliance with current regulatory and legal requirements undercuts their global business competitiveness. Small manufacturers may be especially hard hit by the cost of legal and regulatory compliance because of the variety of raw materials they handle and the many industrial processes they use.

NEW DIRECTIONS

This summary of the ideas raised at the workshop points to the national need for a strategic conceptual framework for the support of domestic manufacturing. Such a framework can allow constructive debate of policies and legislation and can foster new attitudes and practices. Some workshop participants felt that the federal government, specifically the

Department of Commerce, is the logical home for the development of such a strategy.

The workshop participants discussed a number of issues. Foremost among them was the observation that the United States has long had a number of advantages for attracting manufacturing businesses, including personal freedom, political stability, an entrepreneurial business environment, a skilled and educated workforce, and access to large consumer markets. However, to ensure that the United States remains an attractive place to locate manufacturing businesses, the country must consider the supporting infrastructure for manufacturing. In many cases, this infrastructure is aging and may become unreliable or outdated. This has already happened for the power grid and is expected to happen for our crumbling bridges. An important question is how manufacturers can reduce the risks associated with operating in the United States.

Actions by federal, state, and local governments could contribute to the attractiveness of the United States as a location for production activities. Suggestions for such actions raised during the course of the workshop include:

- Available and reasonably priced health care for all;
- Sustained and increased support for small and medium-sized enterprises;
- Continued attention to the costs of compliance with regulations;
- Support for standards such as those for data exchange and production quality;
- Tax incentives for investment in production activities;
- Strengthened public-private partnerships; and
- A heavy commitment to improved education and training at all levels, including the critical K-12 years and the continued training of incumbent workers.

Because these ideas have implications beyond the manufacturing sector, their implementation would need further investigation of alternatives and consequences. As a first step, improved understanding of the underlying issues and the challenges facing U.S. manufacturers could encourage government responses that are more prudent, more targeted, and more likely to succeed. In this respect, a number of metrics are routinely used as the basis for federal policies and legislation, and it is very important that these measures be well understood. Such indicators as the percentage of the manufacturing sector's contribution to the gross domestic product; the level of manufacturing orders; industrial production and capacity utilization; labor productivity; income and compensation; and energy production and prices may not be adequate for understanding the underlying issues. Both the measurement strategy and the measured information, and the ways they have changed over time, complicate the interpretation and understanding of the information. Whereas some trends are easily seen in retrospect, it is unclear whether or not the measures currently in use accurately reflect the state and trends in the economy as a whole or the manufacturing sector.

It is also important for a healthy manufacturing sector that the supporting infrastructure for manufacturing is maintained and improved. The United States currently maintains superior service in such areas as transportation, including land, sea, and air; information systems, including telephone and broadband; and power systems, including electricity and natural gas. As these provide the foundation for the manufacturing enterprise, workshop participants observed that they need to be upgraded and protected against terrorist attacks.

Part I

Summary of the Workshop Sessions

1

Manufacturing in the United States

The United States is a prosperous nation. Many of the assets that signal this prosperity are a result of the nation's manufacturing proficiency. Further, companies in the United States have invented and produced goods used to build this nation and have also provided these goods to the rest of the world. Over the past two centuries, manufacturing in the United States has contributed substantially to a steadily increasing standard of living—including improved education, health, economic security, and more leisure—within the United States as well as abroad. In addition, a strong domestic manufacturing base is essential for maintaining national security, to produce both modern defensive weapons and the equipment needed for homeland security and public health. Manufacturing is crucial to U.S. government operations and has been central to the country's vision of a high-wage, high-value, and high-skills-based economy.

A DRIVER OF U.S. ECONOMIC GROWTH

Manufacturing has been a principal driver of productivity growth in the United States. From 1950 to 2000, federal government data show that the average growth of productivity in U.S. manufacturing was 2.8 percent per year. During the past two decades, the growth rate accelerated, with the growth in average manufacturing productivity exceeding that in other sectors by more than 1 percent per year.[1,2] In durable goods, productivity surged 39 percent from 1994 to 2001, more than twice the 16 percent growth of the economy overall.[3] The high-tech manufacturing sector experienced rapid growth in output per hour throughout the 1990s, accelerating from 9 to 13 percent per year.[4]

The major improvements and innovations that have occurred in manufacturing processes and that helped power a U.S. economic boom in the 50 years since World War II can be compared in terms of significance with those that took place during the Industrial Revolution. From 1992 to 2000, manufacturing gross domestic product (GDP) grew at 4.6 percent annually, significantly faster than the overall U.S. economy, which grew at 3.6 percent annually. Manufacturing also represented a significant and growing portion of the GDP in the United States, contributing a full 22 percent during this same period. By comparison, the service sector contributed 14 percent to economic growth, while transportation and utilities each supplied 10 percent.[5]

The contribution of manufacturing to the U.S. economy is also important because of its multiplier effect on economic output. For every $1.00 of manufacturing product sold to a final user, an additional $1.26 of intermediate economic output is generated. The manufacturing

[1] Department of Labor, Bureau of Labor Statistics. 2003. Major Sector Multifactor Productivity Index. Available at http://www.bls.gov/data. Accessed November 2003.
[2] Chemical and Engineering News. 1996. Chemical Industry Productivity Rose Again. Available at http://pubs.acs.org/hotartcl/cenear/960624/rose.html. Accessed November 2003.
[3] Department of Commerce, Bureau of Economic Analysis. 2003. Analysis of gross domestic product. Available at http://www.bea.doc.gov/. Accessed November 2003.
[4] Department of Labor, Bureau of Labor Statistics. 2002. High-tech productivity gains in 1990s. Available at http://www.bls.gov/opub/ted/2002/may/wk2/art02.htm. Accessed November 2003.
[5] Department of Labor, Bureau of Labor Statistics. 2003. Employment and unemployment statistics. Available at http://www.bls.gov/data/. Accessed November 2003.

sector's multiplier effect is greater than the general multiplier effect of 98 cents for all industries and far greater than that of the service sector, which generates only 74 cents of intermediate activity per $1.00 of final sales.[6]

The 300,000 businesses that constitute the manufacturing sector directly employ more than 15 million people in the United States.[7] According to the 1997 U.S. Census, the payroll of the U.S. manufacturing sector was 14 percent larger than that of the next two largest sectors combined (finance and insurance, and retail trade) despite the sector's 15 percent fewer employees.[8] The multiplier effect of manufacturing jobs is also important: It is estimated that each direct manufacturing job creates or supports between three and nine additional nonmanufacturing jobs. For example, a recent study concluded that more than 8.5 spin-off jobs (trade, service, and indirect manufacturing) were created for every direct automotive manufacturing job.[9]

The productivity gains in manufacturing over the past 50 years can be attributed to a combination of competitive pressures, the advent of new technologies, and a series of product and process innovations. The U.S. manufacturing sector invested heavily in research and development (R&D) during that period and currently accounts for 62 percent of all research and development performed in the United States.[10] In addition, more than 90 percent of all patent approvals originate in the manufacturing sector.[11] This is important, as research and development is the single most important source of the technological advances that lead to higher productivity. All of the activities associated with manufacturing—products, processes, and practices—must advance continually for any country's economy to keep pace in a rapidly changing global economy.

MANUFACTURING AT A CROSSROADS

The recession occurring between 2000 and 2003 has been fairly short and shallow for the economy as a whole. However, it has hit manufacturing much harder than other sectors, in terms of both depth and duration. Manufacturers began slipping into recession in the third quarter of 2000, well ahead of the rest of the economy. By the time manufacturing output began to increase again in the beginning of 2002, it had fallen by 8 percent over the previous 18 months. While the overall economy grew a modest 3 percent in 2002, the increase for manufacturing output was only 1.7 percent. Finally, the recovery in the manufacturing sector in 2003 was slower than the first year of any recovery over the past 40 years.[12]

During the recession, the manufacturing sector also faced a more severe job loss than the rest of the economy. Between July 2001 and July 2002, manufacturing accounted for more than 70 percent of the total job losses in all sectors. Between July 2000 and June 2003,

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[6] Department of Commerce, Bureau of Economic Analysis. Input-output tables. Available at http://www.bea.doc.gov/bea/dn2/home/i-o.htm. Accessed November 2003.

[7] Department of Labor, Bureau of Labor Statistics. 2003. Employment and unemployment statistics. Available at http://www.bls.gov/data/. Accessed November 2003.

[8] Census Bureau, Department of Commerce. 1997. Company summary. Available at http://www.census.gov/prod/ec97/e97cs-1.pdf. Accessed November 2003.

[9] Sean P. McAlinden, Kim Hill, and Bernard Swiecki. 2003. Economic contribution of the automotive industry to the U.S. economy—An update. Ann Arbor, Mich.: Center for Automotive Research. Available at http://www.cargroup.org/pdfs/Alliance-Final.pdf. Accessed November 2003.

[10] National Science Foundation, Division of Science Resources Statistics. 2003. Research and Development in Industry: 2000. NSF 03-318. Arlington, Va.: National Science Foundation.

[11] B.H. Hall, A.B. Jaffe, and M. Tratjenberg. 2001. The NBER patent citation data file: Lessons, insights and methodological tools. NBER Working Paper 8498.

[12] Department of Labor, Bureau of Labor Statistics. 2003. Major Sector Multifactor Productivity Index. Available at http://www.bls.gov/data. Accessed November 2003.

manufacturing employment fell by 2 million. By contrast, employment in the rest of the economy grew by 954,000, with a brief, but sharp, drop in employment immediately following the events of September 11, 2001, sandwiched between months of modest employment growth. In August 2003, manufacturing shed an additional 44,000 jobs, the 37th consecutive month of falling employment in this sector.[13]

The largest employment declines have taken place in the electronics and industrial equipment industries. Each of these sectors has lost more than 350,000 jobs. These high-technology sectors include the manufacture of computers and office equipment, electronic components and accessories, and communications equipment. Services that are linked to manufacturing, such as computer, data processing, and engineering services, have also experienced significant employment losses during this period.

The loss of manufacturing jobs has also had a more severe impact on manufacturing than that of previous recessions. During the manufacturing downturn that began in June 2000 and ended in December 2001, 1.4 million manufacturing jobs were lost. This 8 percent decline in the manufacturing employment rolls matches the average decline during the past six recessions. However, for 2002 overall, another 592,000 manufacturing jobs were lost. This stands in stark contrast to the average increase of 352,000 in manufacturing employment that has typically taken place during the first year of previous expansions.[14]

Manufacturing employment had been in decline even before the recent recession, according to several measures. Manufacturing jobs had decreased as a percentage of total employment in the United States. For example, manufacturing's share of nonfarm employment decreased from 35 percent in 1947 to 14 percent today. In addition, the absolute number of manufacturing production workers has decreased to the lowest levels since 1947.[15]

ROOT CAUSES

There is substantial agreement that U.S. manufacturing capacity is experiencing a serious contraction that cannot be attributed solely to an economic recession. The U.S. manufacturing sector has experienced tremendous job losses both prior to and during the 2001 recession. However, the reasons for this decline are generally understood to be the result not of a single factor but of a combination of factors. Because the root causes are not understood, it is difficult to predict the timing or extent of a recovery of these jobs. If such a recovery occurs, it will also be impossible to know how to sustain that trend.

Certainly, some of the factors responsible for declining employment in the manufacturing sector may be part of the usual process of economic development. First, as the U.S. economy has expanded, the amount consumers spend on service items such as health care and recreation has increased, so the percentage spent on hard goods may also change.

Second, there may be a shift in capacity for some goods out of the United States as companies cut their workforce and move commodity industries overseas. This may occur as a result of competitive pressures, a desire to reduce risk or cut costs, or other drives toward optimization. Should such practices become widespread, they are expected to have the net result of job losses in the United States.

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[13] Department of Labor, Bureau of Labor Statistics. 2003. Labor force statistics. Available at http://www.bls.gov/data. Accessed November 2003.

[14] Department of Labor, Bureau of Labor Statistics. 2003. Production labor force statistics. Available at http://www.bls.gov/data. Accessed November 2003.

[15] Department of Labor, Bureau of Labor Statistics. 2003. Labor force statistics. Available at http://www.bls.gov/data. Accessed November 2003.

Third, because industries become more productive as they mature, over time, fewer people are needed to produce the same amount of goods. Large gains in productivity result in additional capacity that almost always exceeds increased consumption. In a growing economy, excess capacity can be used to produce additional goods for export or it can be phased out and replaced by new processes or products. Increased productivity can enable decreased spending per capita while the functionality of manufactured products is maintained or improved.

The fundamental question at the root of each of these observed trends is the quality of the data used to measure them. Much of the data collected today by various government agencies is based on old business paradigms and does not take into account a number of factors. For example, many companies today outsource such services as accounting or security, jobs that were once counted in the manufacturing sector. Another example is extended supply chain integration, where a single end product will have components manufactured in a number of worldwide locations, with the combination of locations varying from lot to lot. This increased flexibility in manufacturing processes makes it very difficult to answer a seemingly simple question on a government survey.

Given the lack of robust supporting data, it is not surprising that opinions vary on why manufacturing appears to be hit harder than the rest of the economy. The recession may have its root causes in a collapse of business investment and exports. The decrease in business spending, especially in manufacturing, might be attributed to overinvestment in manufacturing during the 1990s. Weak business investment and weak export growth may have also constrained the recovery for the manufacturing sector, compared with both the rest of the economy and to previous recoveries. Certainly, business confidence has been undermined by a number of events, including the attacks of September 11, 2001; the emergence of several major financial scandals in 2002; and the cost of war in the Middle East.

Currency valuation is another influencing factor. The U.S. share of manufactured exports has fallen from 13 to 11 percent since 1997, and part of this can be attributed to the overvaluation of the dollar.[16] A strong dollar adversely affects the competitiveness of domestic manufacturers in the international market. Currency movements can have a significant impact on the financial performance of U.S. manufacturers, influencing decisions about where to locate production facilities. The strong dollar makes it more appealing to relocate production overseas, pay for labor with undervalued local currency, and still earn highly valued dollars by re-exports to the United States. The result can be additional losses of domestic jobs and manufacturing capacity. It is possible that adjustment and stabilization of the dollar, as well as more accurate valuation of currencies around the world, is part of a solution to the manufacturing downturn.

Finally, the increasing trade deficit adversely affects economic growth. In 2002, the increase in the trade deficit neared 5 percent of the GDP.[17] This deficit is a measure of the balance of trade in manufactured goods, or the difference between the amount of goods that are imported and exported. As such, it can be tied directly to the steady decline in U.S. manufacturing as a percent of worldwide capacity. As a nation, the United States borrows $1.3 billion each day to pay for manufactured goods that are consumed but not produced here. Interest must be paid on this borrowed money. In 2001, the United States owed $2.3 trillion, or close to 23 percent of the GDP, as a result of this incurred interest. This figure could grow to 40 percent by 2006 if current trends persist.[18] Some economists consider this a serious structural

[16] Department of Commerce, International Trade Administration. 2003. Trade and industry data. Available at http://www.ita.doc.gov/td/industry/otea. Accessed November 2003.
[17] Department of the Treasury, Bureau of the Public Debt. 2003. Annual historical debt. Available at http://www.publicdebt.treas.gov. Accessed November 2003.
[18] OMBWatch. 2003. Half of 2004 deficit deterioration due to revenue-reduction legislation. Available at http://www.ombwatch.org/budget/pdf/cbo_percentages.pdf. Accessed November 2003.

problem in the U.S. economy.

Although there is some agreement that the 2001 recession was caused by a decrease in business investment, there is little agreement about what kind of economic policy would speed up a recovery. There is speculation that the long-term manufacturing downturn was related to increases in productivity (and the subsequent reduction in labor needs) and to competitive pressures (and the subsequent increase in global outsourcing). Both of these trends have resulted in a loss of capacity utilization and jobs in the United States. However, there is disagreement over whether the movement of production overseas has, on balance, a positive or negative effect on U.S. manufacturing.

It remains a matter of debate whether manufacturing production capacity is a vulnerable commodity or a strategic asset.

2

Challenges Facing U.S. Manufacturing Today

The U.S. economy faces major challenges to rebuild and retain the nation's manufacturing capacity, jobs, and innovative edge in a global, virtual market economy. Several central questions arose during the course of workshop discussions on these challenges:

- How can we ensure that the discussion of manufacturing issues takes place using accurate and useful metrics in the correct context?
- How do we effectively exploit manufacturing globalization for the mutual benefit of employees, companies, consumers, and society, both here and abroad?
- How can the manufacturing enterprise effectively exploit the opportunities presented by new technologies, especially information technology?
- How can we maintain the pace of innovation, to create new jobs for those displaced by changes in the manufacturing enterprise?
- How can we ensure that small and medium-sized manufacturers remain strong and competitive?
- How can we maintain a sufficient talent pool and adequately skilled manufacturing workers?
- How can manufacturing enterprises tackle the rising costs of health care, regulation, and litigation?

In short, the workshop addressed these indicators of how manufacturers can reduce the risks associated with operating in the United States.

UNDERSTANDING THE ROLE OF MANUFACTURING

Manufacturing is a word that means many things to many people. To ensure that the discussion of manufacturing issues, and the basis it sets for decisions and policies at the federal, state, and local levels, is meaningful, it is critical to understand and use the appropriate metrics in the correct context.

Metrics

Manufacturing is measured in a number of ways and can be described with a large array of statistics and analyses. These metrics range from the amount and type of goods produced, to a detailed breakdown of the people who contribute to this production, to the economic impact of both. Many workshop participants came away from the workshop distrusting the metrics currently being used in the national debate on the status of the U.S. manufacturing sector.

Over the past 65 years, various federal agencies have been gathering data on industrial sectors to calculate such indicators as manufacturing's percentage of the gross domestic product (GDP); the level of manufacturing orders; industrial production and capacity utilization; labor productivity; income and compensation; and energy production and prices. However, both

the measurement strategy and the information being measured have changed over time, and this complicates the interpretation and understanding of the information. Whereas some trends are easily seen in retrospect, it is unclear whether or not the measures currently in use accurately reflect the state of the overall economy or the manufacturing sector and the trends that are developing.

Because such metrics are routinely used as the basis for federal policies and legislation, it is very important that the measures be well understood in order for them to be useful. For example, measuring direct employment in the manufacturing sector may be misleading. A decrease in employment might indicate a loss of manufacturing production capacity in the United States; however, it might also reflect an increase in productivity, and production might actually be increasing. Such a decrease in employment numbers may also indicate that some jobs once counted as manufacturing (security guards or payroll clerks, for example) may today be outsourced by the manufacturing company and are now counted in the service sector. Many conclude that all three trends are at work, but today's data are viewed as inadequate to determine their relative importance. In addition, no metrics today look at such factors as wealth generation from manufacturing, for example, which could help policy makers understand the true impact of changes in the manufacturing sector.

Further, the changing operating models in the manufacturing sector make it an interesting challenge to find accurate and useful metrics. Goods are produced in a variety of ways: some are used as raw materials, others with added value from processing techniques, and some as finished products sold to an end user. These different types of products are all tracked by federal agencies, and their levels of production are quantified in systems that are sometimes similar and sometimes orthogonal. In addition, tracking of products is complicated by the fact that the components of a single product may come from a variety of sources and may be processed several times. Each processing step may happen at a different company and/or location, either in the United States or abroad.

As productivity increases, our standard of living could increase even as direct manufacturing employment decreases. As manufacturing grows in the developing world, markets are growing as well. Although it is easy to speculate that these changes will be reflected in the measures the U.S. government gathers and uses, it is difficult to ascertain the extent or dimension of the changes. An additional complication arises because of the growing interdependence between manufacturing and service jobs: The continued loss of manufacturing jobs could have a direct relationship to a corresponding loss of service sector jobs.

Context

Historically, much of the discussion and measurement of manufacturing elements have been in the context of factory floor activities. Also referred to as “little m” manufacturing, this facet is concerned with direct production, or the cutting, grinding, fabrication, and assembling of materials. In a larger context, “big M” manufacturing expands this scope to include many of the decisions, processes, and activities that occur both upstream and downstream of factory floor activities. "Big M" manufacturing includes areas such as e-business, product design, process development, supply chain management, plant design, capacity management, product distribution, product costing, performance measurement, plant scheduling, quality management, workforce organization, equipment maintenance, strategic planning, and interplant coordination, as well as direct production.

The current national debate on manufacturing is sometimes narrowly focused on little m manufacturing. However, all manufacturing organizations must attend not only to little m

concerns, such as direct production, but also to big M concerns. Commercial viability and profitability are the main drivers for manufacturing, most of which is managed by for-profit business organizations. Any government actions intended to help the manufacturing sector must also clearly pay attention to both the broad and narrow contexts.

Because of the importance of manufactured goods to all aspects of American life, a broader view of manufacturing must be considered in any policy decisions. Manufacturing is a means of satisfying higher societal objectives, and the current state of "making things" should therefore be placed in a larger societal context and should form the basis for effective government action. Many workshop participants felt that a discussion at the national level that included such a broad view was needed.

DRIVERS FOR MANUFACTURERS

Globalization

Globalization is evident in almost every aspect of manufacturing everywhere. In the past, a company may have bought supplies and sold its products only locally or regionally; today, global supply chains and global markets are a reality for most U.S. manufacturers. To be successful in this evolving climate, manufacturers must find ways to exploit the advantages of globalization of production and expansion of world markets in such a way as to benefit everyone, including employees, companies, consumers, and society as a whole.

A portion of the perceived decline in manufacturing in the United States can be attributed to the decisions of firms to move some production operations overseas. Many factors contribute to such a decision. First, wages and employee benefits are much lower in a number of other countries. These places may also have lower costs for insurance and taxes. It is possible as well that they may also have lower costs for energy, for compliance with environmental or efficiency regulations, or for legal liability.

In addition to these cost considerations, the quality of goods produced in the developing world is increasing rapidly. In many cases, plants being built in developing countries utilize the newest technologies, whereas existing plants in the United States do not. Older and established facilities must recover capital costs incurred years or sometimes decades in the past and so cannot always be as up to date as a new factory. Personnel around the world now have access to the education and training needed to work with these new technologies. Finally, the transportation and communication infrastructure needed to support manufacturing may also be brand-new and utilize more modern technology than that in much of the United States.

A common perception has been that transportation costs will limit globalization. For high-tech manufacturing products, however, transportation costs can be a small percentage of the total cost of product realization and delivery. Moreover, business models demonstrate that global production and transportation can be cost-effective even for such commodities as gravel or coal, with very low prices per ton. Corporations may also find that globalized production can enable the efficient distribution of engineering and manufacturing responsibilities, with the retention of intellectual property.

The world economy in the second half of the last century has become increasingly global, with a vast expansion of trade in goods and assets and increased interdependence among trading nations. The United States has been much involved in this process, both as a leader in securing successive rounds of trade liberalization and as an active participant in world trade.

Information Technology

The proliferation of information systems, modern management practices, virtual enterprises, and outsourced activities all add to the complexity of modern manufacturing systems. For a manufacturing enterprise to be successful, it is important to understand and control data, information, and knowledge. Manufacturers must find ways to exploit the continuing opportunities presented by new information technologies.

Information, data communication, and data processing technologies are powerful tools that can be used in every element of the manufacturing enterprise, including just-in-time delivery of raw materials; activities on the factory floor; shipping; marketing; and strategic planning. These tools can manipulate, organize, transmit, and store different types of information in digital form. The impact of these technologies has been compared to that of the technological advances that spurred the Industrial Revolution.

The importance of information technology in little m manufacturing is largely the result of the digitization of automation and feedback control systems that was introduced as early as the 1930s. Digitization of manufacturing operations on a scale sufficiently large to make a difference was made possible by the advent of miniaturized semiconductor electronic components. In particular, it was made possible by the ability to package large numbers of electronic circuits into tiny semiconductor devices (microprocessors) at low cost. These advances played a critical role in the productivity gains in manufacturing, especially during the 1990s. Today, almost all process and metal-forming manufacturing industries are highly dependent on control devices and machinery and utilize advanced digital networking to link operations internally and with suppliers and customers.

The Internet has amplified, extended, and added its own characteristics to the transformation in both little m and big M manufacturing. Internet-based technologies offer a ubiquitous and economical way of transferring information, and the benefits of networked production now clearly outweigh the cost of the technology investment, even for most small and medium enterprises.

Key technologies for the future of manufacturing include interoperability/interoperability standards; pervasive and adaptive process control; advanced learning technology; global collaborative capabilities; enterprise-wide supply network management; knowledge management and navigation tools; security and other protection systems; modeling and simulation technology; wireless and remote communication; software to enhance moving from ideas to products; and the incorporation of intelligence into processes and products.

The combination of information technology and increasing globalization has the potential to foster widespread outsourcing of manufacturing activities. In some cases, this trend has reduced the domestic content of U.S. manufacturing, and has had significant implications for manufacturing jobs and labor markets. This growing reliance of manufacturing and other economic sectors on information and communications technology has also spawned completely new industrial sectors—and occupations—devoted to the production and implementation of these systems in many industrial sectors.

Products and Productivity

Advances in technology have been a boon to our nation by enabling new manufactured products and new manufacturing processes. New products have improved our quality of life and the health of our bodies and our environment and have contributed to our national security. Improved productivity in manufacturing as well as in design and other supporting activities can open up new markets by making products more affordable.

Increases in productivity can also mean that fewer jobs are needed to produce what can be consumed by the U.S. economy. Companies can deal with this in a number of ways. One manufacturer might choose to expand operations to new products that allow it to maintain historic levels of employment; another might open a new plant to take advantage of available workers. An obvious solution that many U.S. manufacturers have relied on is to export their products to new and larger world markets.

In doing so, many U.S. companies have discovered market growth opportunities in the same regions that supply low-cost labor. For example, some companies moved their manufacturing operations to China because they were concentrating on low cost. But China is one of the largest markets in the world, with over 1 billion potential consumers. Producing a product in China can increase the probability of successfully selling it to the consumers and industries in that area.

Adding to the complexity is the emergence of a new class of companies that provide third-party manufacturing capability. These contract manufacturers have been joined by firms that engage in product design, engineering, shipping, and repairs on a contract basis in addition to manufacturing. As the trend toward outsourcing continues, it becomes much harder to identify where manufacturing is performed and who is performing it. Companies often are not consciously deciding where to manufacture but leave this up to the contract manufacturing service company. If manufacturing cannot provide a distinctive competitive advantage to an enterprise, that enterprise may choose to channel its resources into those functions and activities that give it a competitive advantage.

DILEMMAS FOR MANUFACTURERS

The complex interplay of productivity increases, domestic market limitations, technological change, and trade policies appears to be fostering overseas outsourcing of U.S. manufacturing capacity and jobs. A number of workshop participants expressed concern about the current extent of international outsourcing, its growth over the past two decades, and the economic and employment implications. The committee observed growing concern about how globalization is affecting the industrial base for national defense and homeland security.

Workshop participants identified the desire to retain and create new high-skill, high-wage U.S. jobs in manufacturing and in the services that support manufacturing. This will clearly be difficult in the face of global market pressures on U.S. companies to outsource and move manufacturing facilities to low-cost, low-wage locations. In addition, they identified the challenge of balancing (1) the need to preserve strategic manufacturing and technological capacity domestically, for materials, components, and products critical to homeland security and national defense, with (2) the perceived cost advantages associated with globalization and the increasingly virtual nature of manufacturing supply chains.

The Jobs Factor

Many labor organizations associate movement of production overseas with the loss of manufacturing jobs in the United States. This aspect of globalization is the bane of workers and communities who see their jobs migrating to foreign locations where lower standards of living and poor working conditions undercut U.S. workers' jobs. A counterargument is that by manufacturing products cost effectively, these corporations retain their market share and thereby retain the ability to employ workers in the United States. However, these trends in employment are becoming more difficult to observe and measure because of changing business models.

Demands for Innovation

The sustainability of growth in the U.S. manufacturing sector has been based on the ability of the United States to innovate, and this trend will likely continue. In order to create new industries and jobs, manufacturers in the United States must preserve and strengthen technological innovation and engineering design capabilities.

When the production in one plant or one industry moves out of the United States, displaced workers must be able to shift to new occupations requiring new skills and abilities. History has shown that this shift can be either detrimental or beneficial to workers, with the most important determinant of benefit being the presence of innovative new industries that create high value for their markets. Transitional resources must also be available from the government and private sector to help communities rebound from economic dislocation.

In addition, the growing demand for products with improved quality, functionality, and time to market puts an enormous strain on established production processes. Advances in technology can provide ideas for new products. For example, moving to precision manufacturing of components using revolutionary nanomanufacturing processes could stimulate the invention of new products. Biotechnology and nanotechnology are emerging fields that may be able to boost the U.S. economy as other industries have done in the past.

Research and Development

To thrive in competitive markets, manufacturers must innovate, and innovation often relies on research and new technologies. The increases in productivity over the past 50 years have been the result of heavy investment in research and development by the manufacturing sector. Between 1983 and 1997, the ratio of industry-funded research and development to sales for all manufacturing increased from 2.6 to 3.3 percent.[1] Reduced profits, however, often because of the recession, have led most companies to decrease their investments in research and development.

The federal government's support of the research and development infrastructure, through investment in long-term, high-risk research, is critical to the health and vitality of the U.S. economy's technology engine. The committee noted broad support among the workshop participants for collaborative manufacturing programs such as the Advanced Technology Program (ATP)[2] and the Intelligent Manufacturing Systems (IMS)[3] program. Unfortunately, the federal commitment to the research infrastructure has been slowly eroding[4]

To encourage innovation in the U.S. manufacturing sector, greater emphasis can be placed on development, which may occur at the expense of basic research. Few organizations are willing to bear the risk of development, and even fewer mechanisms are designed to encourage it. Investment in basic research is squandered, however, without sufficient development funding to balance the research portfolio.

The federal government can help create innovation in the manufacturing sector by establishing policies that encourage basic science and, at the same time, implement programs that share the risk of development with the private sector. The Department of Defense has had

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[1] National Science Foundation, National Science Board. 1998. Science and technology indicators. Available at http://www.nsf.gov/sbe/srs/seind98/frames.htm. Accessed November 2003.

[2] Department of Commerce, Advanced Technology Program. Available at http://www.atp.nist.gov. Accessed November 2003.

[3] Intelligent Manufacturing Systems. Available at http://www.ims.org. Accessed November 2003.

[4] National Science Foundation, National Science Board. 1998. Science and technology indicators. Available at http://www.nsf.gov/sbe/srs/seind98/frames.htm. Accessed November 2003.

an admirable track record of technology development, with a roughly equal ratio of research to exploratory development. The federal government may be able to improve innovation by encouraging all agencies that fund research to achieve the same 50:50 research to development funding ratio.

Implementing Standards

Standards are part of the technical infrastructure that underpins all aspects of manufacturing, including innovation. Effective standards for research, production, and product development can enable a vigorous and sustainable future for manufacturing. In specifying characteristics or performance levels, standards promote efficiency in domestic and international markets. Although the implementation of new standards always incurs cost, by adhering to agreed-upon standards, businesses can negotiate according to widely accepted criteria for products or services.

Every aspect of manufacturing depends on standards. Measurement standards establish criteria for accuracy, precision, and efficiency in documenting and specifying, for example, the dimensions of screw threads, the diameter of optical fibers, the content of steel alloys, information technology interfaces, electromagnetic compatibility requirements, and the performance of machine tools or robots. New transaction standards, including those for configuration documentation, quality processes, and now identification cards, are becoming more pervasive and better integrated. And finally, international standards of practice encompass a wide variety of processes from labor relations to health and safety, from anti-tampering warranties to cost accounting, and from energy efficiency to environmental stewardship.

Participation by the United States in the development of international standards is essential for the continued success of the U.S. manufacturing sector. The better the underlying foundation is and the more effectively it is used in research, production, and the marketplace, the brighter are the nation's prospects for maintaining a vigorous manufacturing sector and for sustaining U.S. leadership in high technology.

Rising Infrastructure Costs

Finally, rising health-care, legal, and regulatory costs are affecting all sectors of the economy. Rising insurance costs could force many small manufacturers to cut back on technology investment.[5] No other single issue was given as much attention at the workshop by both employee and employer representatives as the subject of health-care costs, which rose an average of 10 percent in 2003.[6] Many manufacturers, large and small, are having an increasingly difficult time affording coverage of employee health-care benefits. In many instances employers are passing on these higher costs to their employees—and in some cases, eliminating such coverage altogether. Absorbing these costs can impact a company's ability to compete with overseas firms that aren't required to provide the same level of health care. While a company may pay indirectly for health-care costs under other social welfare systems, removing this charge from direct billing represents a lower risk for an employer. For example, an employer would not have to negotiate rates, nor would it be susceptible to radical changes in rates from year to year.

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[5] C. Wilkerson. 2001. Trends in Rural Manufacturing. Available at http://www.kc.frb.org/RuralCenter/mainstreet/MSE_1201.pdf. Accessed November 2003.

[6] J. Appleby. 2003. Workers bear brunt of rising health care in '03. Available at http://www.usatoday.com/money/industries/health/2003-12-07-healthcosts_x.htm. Accessed November 2003.

Although every manufacturer wants to be environmentally responsible, without careful attention to synergies, economic development can occur to the detriment of environmental health. On the other hand, poorly planned environmental regulations can also adversely impact development. At the same time, the high cost of compliance with regulations and protection against litigation are undercutting business competitiveness. In 2002, the combined regulatory and legal burden cost U.S. firms $697 billion, or 6.7 percent of the GDP. Manufacturers are especially hard hit by these burdens. The cost of regulatory compliance alone adds up to $8,000 per manufacturing employee, 67 percent higher than the average cost per employee of businesses overall.[7] The costs of regulatory compliance are tremendously important, and the differentials in regulatory standards, enforcement, and compliance around the world are a matter of much debate.

THE CHANGING NATURE OF MANUFACTURING JOBS

Flexible and pervasive educational and training systems are necessary to ensure that an adequate talent pool exists for manufacturing jobs, as well as to ensure that workers already on the job continue to be educated. By offering continuing education for manufacturing workers, direct product and process innovation is improved and workers are prepared for future industries.

Shortages of Skilled Worker

The need for highly skilled workers in the manufacturing sector persists despite the loss of U.S. manufacturing jobs, and a shortage is predicted as early as 2010. This projected shortfall in the skilled-labor force can be attributed to the retirement of skilled workers, the interaction of demographics and technology, and the failure of the educational system to keep up with the needs of manufacturing.

In a recent survey of manufacturers, more than 80 percent of respondents reported a moderate to serious shortage of qualified job applicants.[8] Two-thirds of the firms surveyed reported that their most serious workforce shortages were in production areas, ranging from entry-level workers, operators, machinists, and craft workers to technicians and engineers. The major areas of concern have shifted from specific technology skills back to the fundamentals, with basic employability skills cited as the number one deficiency for both current hourly workers and applicants for hourly positions. These skill deficiencies have impaired manufacturers' ability to maintain production levels, implement new productivity improvements, or deploy quality initiatives. In fact, some manufacturers stated at the workshop that they could not accept new orders because they lacked the workers to produce their products.

Today's manufacturing jobs require more and more technological literacy, and employees at all levels must have the wide range of skills required to respond to the demands of an increasingly complex work environment.[9] Manufacturing is perceived by many to be "dangerous, dark, dirty, and dead-end."[10] On the contrary, most modern manufacturing facilities are light, clean, airy, pleasant, and safe places to work. In addition, since the 1970s, workplace

[7] Thomas Hopkins and Mark Crain. 2001. The impact of regulatory costs on small firms. NTIS #PB2001 107067, U.S. Washington, D.C.: Small Business Administration. Available at http://www.sba.gov/ADVO/research/. Accessed November 2003.

[8] National Association of Manufacturers. 2001. The skills gap 2001. Available at http://www.nam.org/tertiary.asp?TrackID=&CategoryID=958&DocumentID=24443. Accessed November 2003.

[9] National Research Council. 2002. Technically Speaking: Why All Americans Need to Know More About Technology. Washington, D.C.: National Academies Press.

[10] Stated at a roundtable of the Small Business Committee of the U.S. House of Representatives. October 28, 2003.

fatalities have been cut by 62 percent and occupational injury and illness rates have declined 40 percent; and at the same time, U.S. employment has doubled and now includes nearly 100 million workers at 7 million sites.[11]

Manufacturing companies employ professionals and skilled and semi-skilled workers from many different fields: graphic designers, sales executives, physicians, scientists, lawyers, and marketing managers. These employees are well compensated, with the average manufacturing worker earning $46,000 per year in wages and an average total compensation package of $54,000 in 2000. Both of these figures are more than 20 percent higher than comparative averages for all U.S. workers. In addition, more than 80 percent of manufacturing workers received direct health-care coverage through their employers in 2001.[12]

Education Essential for Innovation

Most of the innovation that results in new industries is based on the combination of new technology and market needs. Technology can be defined as the practical embodiment of knowledge—the useful application of basic science. Thus, in order to create new technological innovations, the manufacturing workforce must understand existing technology. Education is a lifelong process, and employees without adequate technical knowledge are unable to achieve continuous improvement.

Workforce Development Programs

The committee found substantial support among the workshop participants for various workforce development programs, including training partnerships (many involving labor-management collaboration), and for more federal and state resources for such programs. Making services accessible to employers is important. One federal program that provides funds for training is the Workforce Investment Act, administered by the U.S. Department of Labor. Communities can pool resources from multiple organizations to holistically address the needs of manufacturers. Participants at the local and regional levels include workforce and economic development agencies and organizations, local Chambers of Commerce, community colleges and private education providers, literacy councils, state and local chapters of business and industry associations, local manufacturing extension centers, small business development centers, and organizations promoting entrepreneurship.

Small and Medium-Sized Manufacturers

Small and medium-sized manufacturers, generally firms with fewer than 500 employees, are an important sector of the U.S. economy. Small firms are important for a variety of reasons; for example, they produce more frequently cited patents than large firms, on average. Although their share of patents is similar to their share of manufacturing employment, the patents of smaller firms are twice as likely as large-firm patents to be among the 1 percent most cited. This suggests that small-firm patents are, on average, more technically important than large-firm patents.[13]

Small and medium-sized manufacturers provide the primary supplier base for large

[11] Department of Labor. Occupational Safety and Health Administration. All About OSHA. Available at http://www.osha.gov/Publications/osha2056.pdf. Accessed November 2003.
[12] Department of Labor, Bureau of Labor Statistics. 2003. Current employment statistics. Available at http://www.bls.gov/data. Accessed November 2003.
[13] CHI Research, Inc. 2003. Small serial innovators: The small firm contribution to technical change. Available at http://www.sba.gov/advo/research/rs225tot.pdf. Accessed November 2003.

domestic manufacturers. This has been the result of a 30-year trend of outsourcing by large automotive, aerospace, and heavy equipment manufacturers. Since the early 1980s, manufacturing employment has become increasingly concentrated in smaller plants and decreasingly concentrated in larger companies. The number of manufacturing plants with fewer than 500 employees in the United States fell in 2000 and 2001 for the first time since 1978.[14] The influence of this small-manufacturer segment is exemplified by the fact that in large manufacturing plants that have experimented with a variety of ways to empower employees, it is routine today for small work units to operate independently within a larger plant. In other words, large firms are trying to emulate the productivity factors of small firms, which are perceived as being better.

Small and medium-sized manufacturers face specific issues, including a small client base and a greater dependence on revenue from each client; small management teams; limited access to capital for improvements; and difficulties in providing service overseas. In order for these enterprises to prosper, increased integration of their supply chain is important, as is easier access to technology and capital. The manufacturing sector needs to find a way to modernize and strengthen small and medium-sized manufacturing enterprises. Support from federal and state governments can be very effective, and the committee noted broad support for the Manufacturing Extension Partnership program. It is key that this type of support be sustained and that it be coordinated among the stakeholders: employers, educators, students, and government leaders.

RISK

The bottom line for many manufacturers today is risk. Decisions on manufacturing domestically or overseas, to adopt innovations or evolutionary improvements, or to hire and train new workers or to invest in more productive technology are all based on the perception or measurement of risk. In many cases, the United States does not offer a least-risk environment to start or expand a manufacturing enterprise.

[14] Daniel Luria. 2003. U.S. component manufacturing at a crossroads: Region-loyal production and global manufacturing deflation. Available at http://www.cows.org/supplychain/pdf/present/luria.pdf. Accessed November 2003.

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NEW DIRECTIONS

A theme that emerged from the workshop is that manufacturing has traditionally been and will remain an important element of the U.S. economy and society. Additionally, it is clear that the United States has a number of attributes that provide advantages to manufacturing companies working and pursuing business within its borders, including:

- Unparalleled individual freedom and political stability;
- An environment of safety and security;
- An entrepreneurial business environment with relatively easy access to large and liquid capital markets, which promotes small business start up and creates an environment of innovation not found elsewhere;
- A skilled workforce with a work ethic that favors high-salaried jobs;
- Easy access to a large consumer market; and
- A superior system of higher education at colleges and universities.

Whether or not there is a crisis in manufacturing remains a question for debate. Regardless of the answer, the federal government, specifically the Department of Commerce, holds the responsibility to develop a conceptual and comprehensive framework for support of domestic manufacturing. Such a framework can allow constructive debate of policies and legislation and can foster new attitudes and practices.

One of the important actions that the nation can take to achieve its objectives is to ensure that the United States remains an attractive place to locate businesses that create quality jobs and an attractive place for skilled employees to choose to live. The people of the United States and their government have a long-standing commitment to free and fair trade. Successful national economic policy has historically influenced in a variety of ways the choices companies and individuals make. Thus, many separate policies and practices may contribute to the creation of an attractive environment for manufacturing.

The following comments are offered by the committee for consideration:

1. **Actions by federal, state, and local governments could maintain and improve the attractiveness of the United States as a location for production activities.** The following general factors are of primary importance to the health of the manufacturing enterprise in the United States:

- Available and reasonably priced health care for all;
- Sustained and increased support for small and medium-sized enterprises;
- Continued attention to the costs of compliance with regulation;

- Support for standards such as those for data exchange and production quality;
- Tax incentives for investment in production activities;
- Strengthened public-private partnerships; and
- A heavy commitment to improved education and training at all levels, including the critical K-12 years and the continued training of incumbent workers.

2. Because these ideas have implications beyond the manufacturing sector, their implementation would need further investigation of alternatives and consequences. As a first step, **improved understanding of the underlying issues and the challenges facing U.S. manufacturers could encourage government responses that are more prudent, more targeted, and more likely to succeed.** A number of metrics are routinely used as the basis for federal policies and legislation, and it is very important that these measures be well understood in order for them to be useful. Such indicators as the percentage of the manufacturing sector's contribution to the gross domestic product; the level of manufacturing orders; industrial production and capacity utilization; labor productivity; income and compensation; and energy production and prices may not be adequate for understanding the underlying issues. Both the measurement strategy and the measured information, and the ways they have changed over time, complicate the interpretation and understanding of the information. Whereas some trends are easily seen in retrospect, it is unclear whether or not the measures currently in use accurately reflect the state of and trends in the economy as a whole or the manufacturing sector in particular.

3. The United States currently maintains superior service in several supporting infrastructure systems that are susceptible to environmental degradation or terrorist attacks and must be protected to maintain their uninterrupted function. **Maintaining and improving the supporting infrastructure for manufacturing is important for a healthy manufacturing sector.** These critical services encompass transportation, including land, sea, and air; information systems, including telephone and broadband; and power systems, including electricity and natural gas.

Part II

Presented Papers:
Manufacturing in the U.S. Economy

4

Keynote Address: The Administration's Manufacturing Policy

Samuel W. Bodman
Deputy Secretary, Department of Commerce

These are momentous times here in Washington and around the world. We are a nation awakened to danger and acutely aware of risk. We are a nation at war. Like many of you, I spent my weekend glued to the television. The images that we are seeing serve as constant reminders of the courage and sacrifice of the men and women who are defending our nation's most precious and steadfast ideals: freedom, equality, and hope. In these uncertain days, we can all be certain of the resolve and resiliency of the American people, the great skill and bravery of the fine men and women of our military, and the strong and courageous leadership of their commander in chief. I have seen President Bush in action and I can tell you that we are most fortunate to have him at the helm. He is a decisive leader totally dedicated to protecting the American people. As our armed forces confront this great threat to peace and freedom in Iraq, we all must push forward with our work here at home. And so we are here today to discuss a topic that is of significance to all Americans—to our economy, to our health, to our security, and to our way of life—the U.S. manufacturing sector. It's a topic of great importance to me, to Secretary Evans, and to President Bush.

The secretary and I look forward to getting a full report on this event and to reviewing the Academies' analysis. I trust that this forum will provide valuable insights into the major trends that will influence manufacturing in the coming decades, with the goal being to highlight future opportunities as well as challenges. I understand that over the course of the next 2 days you will discuss, among other issues, the economic significance of manufacturing to both rural and urban America, as well as some of the major drivers that affect manufacturers, like labor costs and training, globalization, and technological advances. You also will examine the policy and regulatory structures that our nation's manufacturers confront.

I know that you'll be hearing from a host of experts on this wide array of topics, and I appreciate this opportunity to offer my two cents. Let me start off by restating the obvious: The U.S. manufacturing industries are vitally important to our economy and to our nation. The manufacturing sector directly employs more than 18 million people in this country. Manufacturing drives economic growth and prosperity. Over the past 50 years, large productivity increases in the manufacturing sector have powered this country's economic boom. In the last decade alone we have seen enormous productivity gains from the manufacturing sector. For example, in durable goods—the heart of technology-intensive manufacturing—productivity surged 39 percent from 1994 to 2001, more than twice the 16 percent growth of the economy overall. Our prosperity and future growth are tied to the performance of the nation's more than 300,000 manufacturing businesses. While we often focus on the impressive economic statistics, manufacturing is more than just an engine for growth. It is about research and innovation, higher incomes, and quality-of-life improvements for all Americans.

Our nation's manufacturing industries account for about two-thirds of private research and development expenditures. Even during the industrial downturn of the last 2 years,

manufacturing industries have maintained a high level of research and development spending. More than 90 percent of all U.S. patent approvals originate in the manufacturing sector. And our manufacturing sector consistently meets the changing needs of national defense and homeland security. The bottom line is that manufacturing matters to our economic health and to the citizens of this country. Yet, there is no doubt that this important sector is hurting, and has been for some time. The manufacturing industries have experienced 30 consecutive months of declining employment, with a total job loss of over 2 million.

President Bush believes that a robust manufacturing sector is essential to our economy at all levels—state, regional, national, and global. He also knows that the past 2½ years have been tough ones for many U.S. manufacturers. The President recognizes that as global competition continues to evolve for our industries, so too must our policy and regulatory structures. Many U.S. companies are taking effective actions to respond to low-cost competitors, to counter rising energy prices and health care costs, and to meet other challenges. And government policies also must adjust to enable—not impede—U.S. companies as they grow, innovate, and create new jobs. I have heard the President say many times that government doesn't create wealth, people do. He believes—and Secretary Evans and I share this view—that our job in government is to create the right environment for businesses to flourish and prosper.

This administration is taking important steps to create just such an environment. Collectively, our policies aim to stimulate economic growth and create jobs; remove counterproductive red tape; foster free and open trade; prime the pump of innovation by increasing the federal investment in research and development; secure and enhance the nation's vast and varied infrastructure; and ensure a strong domestic capability to meet the needs of national defense and homeland security.

I'd like to highlight a few top priorities for you. First and foremost, I can tell you that this administration is focused on getting our economy going at full speed. America has the strongest, most resilient economy in the history of this world. Yet right now, our economy is not creating enough jobs and is not growing as fast as any of us would like. The President knows that American workers are the backbone of our economy and that business is the engine of growth and prosperity, keeping our country moving forward. And that is precisely why he has put forward a plan that will spur economic growth and create jobs. The plan works on two fronts: it encourages business investment and it ensures that consumption will continue to grow. The President proposes to speed up tax relief to individuals and families, putting more money in consumers' pockets. Ninety-two million taxpayers would receive an average tax cut of about $1,100. The plan also encourages job-creating investment in American businesses by tripling the expensing limits for small businesses (from $25,000 to $75,000) and abolishing the double tax on dividends. Today, this country has the highest effective tax rate on dividend income (about 60 percent) of any G-7 nation. By making such a huge claim on the profits of our nation's employers, the federal government undermines competitiveness. By ending double taxation, we will cut this rate nearly in half (to 35 percent), freeing an estimated $20 billion for our economy and making business investment a far more attractive proposition. The President's plan makes good sense, and it is fair. This economy needs it, our nation's employers need it, and American workers need it.

We can have the best policies, the best environment for manufacturing, and still not compete in the future unless we excel in both developing and effectively integrating technologies. Technology certainly has a prominent role in the performance and long-term prospects for all U.S. industries, especially the manufacturing sector. It's been said that technological progress shaped the 20th century. Many believe that it will define our new century. When we talk about technology, we should not only consider information technology and

biotechnology. To be sure, increasing computational power and connectivity offer enormous potential to convey knowledge, transact commerce, and raise productivity. And biotechnology is full of incredible promise that is only now starting to be realized. But technology spans a much larger spectrum, as all of you know. It encompasses materials and machine tools, energy systems and systems engineering, aerospace and atomic clocks, automobiles and autonomous combat vehicles, food processing and chemical processes, and on and on. The point is simply this: Advances in science and technology present us with an incredibly rich—and ever-growing—array of manufacturing opportunities. From somewhere within this wealth of possibilities will come the next technology revolution, the "next big thing." Make no mistake: Our competitors are not standing idly by. From Europe to China, our companies are facing fierce and fast-paced competition. As U.S. industry races toward the "next big thing," we need a strong manufacturing sector.

As I mentioned at the outset, U.S. manufacturers fund a sizable component of the nation's innovative capacity, the driver of future national prosperity. The federal government also has a critical role to play in fostering innovation and in realizing the tangible benefits that begin with advances in science and technology. Federal funding of basic research takes us further into the technology frontier, where the seeds of new opportunities are planted. U.S. leadership in many key areas—pharmaceuticals, semiconductors, Global Positioning Satellites, the Internet—often began with federally funded research performed at universities, in industry, or at government laboratories. The President is committed to maintaining America's technological leadership. Since taking office, the President has proposed record levels for research and development: $123 billion in 2004, up more than 25 percent since taking office. The future of our manufacturing sector and the future of our national economy require no less.

There are certainly many other topics that I could discuss with you today that influence our manufacturing base, for example, our aggressive efforts to promote free trade. We know that trade is an engine of economic growth. It spurred our most recent economic expansion, accounting for roughly one-quarter of U.S. economic growth in the 1990s. About 12 million jobs in this country, many of them in the manufacturing sector, depend on exports. On the topic of trade, I have to mention a big victory for the American economy: trade promotion authority, or TPA, as we call it here in Washington, which the President signed into law last summer. While TPA lapsed, the United States was sidelined in negotiations. We are pushing forward on negotiating trade agreements. In December, we concluded free trade negotiations with Chile and Singapore. And we are pursuing negotiations with Morocco, five Central American countries, the Southern African Customs Union, and Australia. We continue to work with our trading partners to open markets, to bring about real and lasting tariff elimination, and to reduce technical barriers to trade, like standards that are developed and applied in ways that obstruct market access. We are being very aggressive about this. So aggressive, in fact, that some of our chief trade officials in the Commerce Department are no longer welcome in certain countries!

I believe that now is a very appropriate time to take a comprehensive look at the state of U.S. manufacturing. We are doing our part at the Commerce Department. A cross-agency senior leadership team is preparing an assessment of the issues influencing the long-term competitiveness of U.S. manufacturing industries. Others are launching similar and, we should make sure, complementary efforts, such as the President's Council of Advisors on Science and Technology and several members of Congress. I believe that the National Academies bring a unique and critical perspective to this issue. Unlike political or business leaders, scientists are trained to pursue the truth. Rather than telling us what we want to hear, we are counting on you to tell us what we need to know. And to do this you will have to ask some tough questions and then follow the facts wherever they may lead. For example: Do we have the right metrics for

measuring manufacturing competitiveness? Many point to the loss of two million jobs as an indicator of manufacturing decline. And whenever two million Americans lose their jobs, we are all very concerned. Yet we have to ask if total employment is the best gauge for the future. Technology is enabling increases in productivity and capital substitution for labor. Emerging technologies promise dramatic changes in the manufacture of many products. So as we assess our manufacturing strengths and challenges, let's make sure we are counting the right things. Another question: Do our policies permit the evolution and responsiveness so critical to a market economy? America has succeeded by rewarding risk and permitting failure. This means that the manufacturing sector of tomorrow will be very different from that of yesterday or today. Do our policies protect the status quo or do they enable our manufacturers to lead the global changes that are inevitable? And are our manufacturers leveraging the best in new technologies to maintain leadership, especially with respect to new processes? Are we investing in the right research and development? Are our manufacturers able to understand and integrate these innovations to achieve competitive advantage?

We may not know the answers, but we certainly must not fear the questions. I know you will tackle these and many other issues. What we all do know and agree on is that manufacturing is—and will remain—vital to our economy and to our nation. And I'll end on that note. Again, I look forward to your conclusions and recommendations. I thank you for allowing me to share a few of my thoughts with you. And I wish you all a productive conference.

5

U.S. Manufacturing at the Crossroads

Michael E. Baroody
National Association of Manufacturers

Manufacturing took a particularly strong hit during the recent recession. However, manufacturing is extremely important to the economic competitiveness of the United States. Steps are currently being taken to reinvigorate manufacturing, stimulate more robust and durable growth, and increase employment.

MANUFACTURING IN THE UNITED STATES

Manufacturing is a critical contributor to the state of the economy. The National Association of Manufacturers (NAM) is the nation's largest industrial trade association, representing 14,000 members, including 10,000 small and medium-sized companies. The recent economic downturn hit manufacturers much harder than the rest of the economy, both in terms of depth and duration. Manufacturers began slipping into recession in the third quarter of 2000, well ahead of the rest of the economy. And by the time that manufacturing output began to increase again in the beginning of 2002, industrial output had fallen by 8 percent over the previous 18 months. This is a significantly worse situation than that faced by the rest of the economy. Overall, gross domestic product (GDP) slipped less than half a percent during the first three quarters of 2001, the second-mildest recession in 50 years.

And while the overall economy grew a modest 3 percent last year, the increase for manufacturing output was only 1.7 percent. Thus, the manufacturing "recovery" is slower than the first year of any recovery over the past 40 years and less than one-fifth the average 10 percent growth during the initial 12 months of the past six expansions. Since July 2000, manufacturing employment has fallen by 2 million over the course of 30 consecutive monthly declines. By contrast, employment in the rest of the economy has grown by 954,000, with a brief, but sharp, drop in employment immediately following the events of September 11, 2001, sandwiched between months of modest employment growth.

CURRENT ECONOMIC OUTLOOK

During the manufacturing downturn that began in June 2000 and ended in December 2001, 1.4 million manufacturing jobs were lost. This 8 percent decline in the manufacturing employment rolls matches the average decline during the past six recessions. However, for 2002 overall, another 592,000 manufacturing jobs were lost. This stands in stark contrast to the average increase of 352,000 in manufacturing employment that has typically taken place during the first year of previous expansions. These figures clearly show that the recovery has thus far largely bypassed the manufacturing sector, which was hit hardest in 2001. The largest employment declines have taken place in the electronics and industrial equipment industries. Each of these sectors has lost more than 350,000 jobs. Together they account for more than a third of the manufacturing job losses since mid-2000.

Manufacturing was hit harder than the rest of the economy because the recession was

mainly caused by a collapse of business investment and exports, which declined by 9 percent and 11 percent, respectively, in 2001.[1] Recovery has evaded manufacturers for the same reason. By contrast, consumer spending has held up reasonably well, growing by 2.8 percent in 2001. In 2002, the recovery was largely driven by consumer spending, which accelerated modestly to a growth rate of 3 percent.[2] At the same time, business investment declined by 3 percent and the export of goods increased slightly, by 2 percent, remaining 8 percent below the level of 2 years ago. This stands in stark contrast to the 10 percent growth in exports during the first year of recovery following the 1990 to 1991 recession. Weak business investment and weak export growth have constrained the recovery for manufacturers. In short, the expansion to date has been narrow, unbalanced, and historically sluggish.

Despite historically low interest rates and the fact that a bonus depreciation stimulus package was passed last year, there remain significant inhibitors to economic growth. Some of the challenges facing manufacturers are long-term problems that need to be addressed to create a better environment for manufacturing in America. For example, manufacturers are competing in a deflationary environment, with pricing power falling at an average annual rate of 0.9 percent since 1995. By contrast, the inflation rate for the economy overall has averaged 2 percent since the mid-1990s. At the same time, heavy regulatory and legal costs are undercutting business competitiveness. Combined, a heavy regulatory and legal burden in 2002 cost U.S. firms $697 billion, or 6.7 percent of GDP.[3] Manufacturers are especially hard hit by these burdens. The cost of regulatory compliance alone adds up to $8,000 per manufacturing employee. This is 67 percent higher than the average cost to business overall. In addition, manufacturers' health-care costs rose at an average of 13 percent over the past year.

According to 80 percent of NAM's membership, there was a moderate to serious shortage of qualified applicants in 2001. This signals that a persistent skills gap remains a problem for manufacturers. U.S. share of world manufactured exports has fallen from 13 to 11 percent since 1997 due to the rise in the value of the dollar. And while the dollar has fallen since its peak last February, it still remains 15 percent above its historic level. Businesses have also become increasingly uncertain about the short-term outlook, evidenced by the fact that the ISM business activity index dropped 9 percent from May to December 2002. This lack of confidence has curtailed investment spending, which is the main reason why the current recovery has underperformed when compared to past recoveries.

Business confidence has been undercut since the final quarter of the 2001 recession for a number of reasons. First, the attacks of September 11, 2001, and the entry of the United States into a war on terrorism have created an elevated degree of uncertainty overall. Second, the emergence of several major financial scandals in 2002 undercut consumer confidence and sent the Dow Jones Industrial Average plummeting 32 percent between March and October 2002. As a result, consumer confidence fell to a 9-year low by October 2002. Despite healthy growth in real incomes throughout 2002, consumer uneasiness deepened. This dichotomy has caused businesses to put on hold their spending plans for fear that expected demand may not materialize. Third, the war in the Middle East, and its possible effects on world oil supplies and prices, has further elevated both business and consumer uncertainty.

Simultaneously, some important fundamentals of the economy have improved and have primed the economy for faster growth once uncertainty dissipates. First, there has been a steady and strong acceleration in productivity and associated gains in real incomes in 2002. By the third quarter of 2002, business productivity growth was 5.6 percent higher than a year

[1] NAM GDP estimate based on published data through the third quarter and a fourth quarter projection.
[2] Q4/Q4 percent change.
[3] NAM estimate based on reports by the Council of Economic Advisors and the Small Business Administration.

earlier, the fastest quarterly growth rate in 36 years. This increase in productivity has, in turn, increased real wages. During the first three quarters of 2002, real disposable income grew 3.9 percent over the previous year. This is more than double the modest 1.8 percent growth in 2001 and is a solid foundation for consumer spending going forward once confidence improves.

Second, this rise in productivity has rapidly pushed down unit labor costs, which has, in turn, led to a recovery in profits. In fact, for the first time since 1949, the labor cost per unit of output has declined four quarters in a row beginning in the fourth quarter of 2001. As a result, corporate profits have begun to make a recovery. Manufacturing profits declined by $75 billion from the third quarter of 2000 to the first quarter of 2001. By the third quarter of 2002, nearly two-thirds of this decline was recovered. Similarly, after dropping $138 billion between the fourth quarter of 1999 and the third quarter of 2001, overall corporate profits have rebounded 60 percent. This recovery in business profits should prop up business investment spending and counter some of the general uncertainty that continues to exist in corporate America.

Third, the dollar has depreciated 9 percent since February 2002, although it still remains 14 percent above its 1997 value. This, combined with slightly faster expected economic growth abroad in 2003, should prop up an export recovery which, to date, has been very modest. Further depreciation is needed, however, for manufacturers to regain their international competitiveness. Fourth, after inventory levels reached a 5-year high in mid-2001, manufacturers aggressively worked off excess stocks over the past year. Manufacturers' inventory-to-sales ratios are therefore near a decade low. These lean inventory stocks mean that firms will respond to stronger demand with increased production.

Increased uncertainty and an improvement in the fundamentals will work at cross purposes in 2003. While real income growth should keep consumer spending on track, this could be derailed by further shocks to confidence. As a result, businesses will continue to hold back spending plans. Therefore, an acceleration in the economic recovery is not likely to take place this year without significant fiscal stimulus to counter the threat of uncertainty. This has important ramifications for the manufacturing sector. Without a meaningful increase in business investment spending, further manufacturing recovery will continue to remain on hold.

NAM strongly supports the economic growth plan of President Bush. This plan offers a creative mix of incentives that will encourage aggressive investment in the stock market and new capital investment by business, which will, in turn, create more jobs. Specifically, the proposal to eliminate double taxation of dividends will boost business and consumer confidence, reduce the cost of investment capital, and encourage business to invest more in new plants and equipment. Small businesses will especially benefit by the proposal to increase the allowance for expensing capital investments from $25,000 to $75,000, indexed to inflation. This increased allowance will provide a powerful incentive for small manufacturers to increase investment and create jobs. NAM also endorses the President's support of regulatory and legal reforms as a critical key to stimulating the economy and creating jobs. Removing unnecessary impediments to growth is as important as providing economic incentives.

NAM'S 2003 PRO-MANUFACTURING AGENDA

U.S. manufacturing is innovative, productive, and efficient. For decades it has been the center of strength of the American economy and its prospects for future growth. With the best workers in the world, technologies that are on the global cutting edge, and research and development efforts capable of keeping it there, manufacturing has made the United States the world's high-quality, low-cost leader in a wide variety of products and has made the United States the world's largest goods exporter despite the most intense global competition in history.

Currently, manufacturing is at a crossroads. The industry lags behind the rest of the U.S. economy, and recovery from the recession is slow. This recession, unlike previous post-World War II economic downturns, has uniquely affected manufacturing and caused the loss of two million manufacturing jobs. Reasons include geopolitical uncertainties, the ongoing war on terrorism, and slow economic growth worldwide. However, other factors contributing to the manufacturing slowdown require policymakers' attention. Addressing these factors could do much to reinvigorate manufacturing, stimulate more robust and durable growth, and increase employment. These factors are:

- The fact that U.S. manufacturing is at a distinct disadvantage in global competition due to unfair trade practices, export constraints, and artificially distorted currency values, such as in China, where the currency is undervalued as much as 40 percent;
- Intense foreign and domestic competition that makes it impossible for U.S. manufacturers to raise prices for their products, thereby fatally compromising their ability to meet rising costs associated with government regulations, runaway litigation, and employee health insurance; and
- Accelerating technological change that could make it increasingly difficult to achieve high productivity growth because of inadequate capital investment and workforce skill deficiencies.

NAM recommends the policy agenda described below in 2003 to address the factors listed above, strengthen the economy, and encourage growth.

Taxes

To encourage capital investment, productivity, and job creation, currency depreciation should be accelerated and taxes on dividends should be reduced. The tax relief enacted in 2001, including estate tax repeal, should be made permanent and the scheduled marginal rate cuts accelerated. The ongoing impasse with the European Union over the World Trade Organization (WTO) ruling on taxation of extraterritorial income (FSC/ETI case) must also be addressed, and further reforms in the international tax arena should be enacted to enable U.S. companies to effectively compete in the global marketplace. A permanent research and development tax credit to benefit the largest number of companies is also needed as well as pension reforms that encourage greater participation in the private retirement system. Finally, to ensure that these tax law changes benefit all manufacturers, action is needed to repeal the corporate alternative minimum tax, or the "anti-manufacturing tax."

Global Competitive Conditions

The United States must insist that foreign markets become open and that trade follow global rules. The United States should advance the WTO Doha Round, including the "zero-tariffs" proposal, the Free Trade Agreement of the Americas, and additional bilateral trade agreements. U.S. policy governing export controls and unilateral sanctions must be modernized, and an exchange rate regime should be promoted that is based on economic fundamentals and the free operation of markets. Given the rapidly rising importance of China in world trade, the Bush administration should seek a particular commitment from China to the market valuation of its currency.

Training and Skills

Jobs in U.S. manufacturing are among the best jobs in the world. They are rewarding and increasingly demanding of skills. Both today's workers and tomorrow's workers now in school need improved systems of education and training through stronger implementation of the Workforce Investment Act, improved vocational education, and a strengthened, reauthorized Higher Education Act.

Technology

Most research and development is in manufacturing, the key technological and economic advantage of the United States. This advantage can be preserved and enhanced by improved tax treatment of research and development expenditures, stronger protection for intellectual property in a globally competitive environment, adequate funding of federal science programs, and a strong patent system.

Reformed Health Care System

Increased federal mandates and liability exposure for employers will raise costs and reduce insurance for workers. Policy makers should focus on lowering health care costs through improved quality and greater access to health care for all Americans. Medicare should be reformed in a way that allows addition of a prescription drug benefit to a strengthened program. Reform of medical liability law must also be a priority.

Asbestos Litigation Reform

The current system on asbestos litigation is dysfunctional. It compensates individuals who are not sick at the expense of individuals who are, bankrupting companies in the process and threatening the jobs and retirement savings of hundreds of thousands of manufacturing workers. Medical criteria legislation, like that advanced by NAM's Asbestos Alliance, is urgently needed.

Reform of the Legal System

Reform of the legal system is a durable priority for manufacturers that can be advanced in the 108th Congress. Prospects for class action reform and medical malpractice legislation, among others, can be furthered by widespread manufacturing participation in NAM's Fair Litigation Action Group (FLAG) program, which is designed to enable member companies to inform and enlist their workers in the effort to hold members of Congress accountable for enacting needed reforms.

Energy Policy

Enactment of a balanced, comprehensive, national energy policy is overdue and is essential to ensuring durable and sustainable economic growth in manufacturing and the broader economy. A reliable energy supply at affordable prices is essential, as well as increased efficiency, a strengthened infrastructure, and investments in research and development and new technologies. Greater cooperation in a North American Free Trade Agreement (NAFTA) energy alliance would benefit all three partners. NAM supports President Bush's climate research and voluntary greenhouse gas reduction initiatives but opposes mandatory greenhouse gas reporting. NAM vigorously opposes the Kyoto Protocol and any

domestic actions leading to quotas or caps on fossil energy use by utilities or by industry.

Environment

The United States must continue to make environmental progress while maintaining economic growth in a competitive world marketplace. To achieve these dual goals, environmental policy must continue to evolve from decades-old command-and-control prescriptions to approaches that encourage innovation, investments, and partnerships. When environmental regulation is necessary, rules must be based on sound science and accurate data and must allow maximum flexibility to meet performance standards using the most cost-effective means. Specific priorities for the manufacturing community include New Source Review reform, sensible multi-emissions legislation, and science-based air quality standards.

Transportation

Just-in-time operations are a vital component of modern manufacturing. Just-in-time is based on a reliable and satisfactory transportation infrastructure. NAM supports adequate investment in the national transportation infrastructure, especially improved intermodal connectors and facilities, as well as other improvements to make freight travel more timely and efficient.

6

Innovation and U.S. Manufacturing

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"To live well, a nation must produce well."[1]

Over the past 50 years, a revolution in manufacturing has occurred that is as significant as the industrial revolution of the 19th century. From 1950 to 2000, the growth of average productivity in manufacturing in the United States was 2.8 percent per year. For the past two decades, this growth rate has been accelerating, with the growth of average manufacturing productivity exceeding that of other sectors by more than 1 percent per year (Table 6-1). Simply stated, a U.S. manufacturing worker can produce four times as much per hour today compared with 50 years ago. This productivity gain is the result of competitive pressures, the advent of new technologies, and a series of product and process innovations. As a result of this productivity gain, Americans have a much higher standard of living, with products becoming more useful and more affordable. In order to utilize this new manufacturing capacity, U.S. firms (and others) have expanded their marketing abroad, creating a rapid increase in global trade.

TABLE 6-1 Percent Average Annual Productivity Gains in the United States

	1950-1960	1961-1970	1971-1980	1981-1990	1991-2002	1977-2002
All U.S. Business	3.3	3.2	1.9	1.7	2.2	1.8
Manufacturing	2.0	2.6	2.6	2.9	3.6	3.0

SOURCE: Bureau of Labor Statistics, U.S. Department of Labor. 2003. Major sector multifactor productivity index. Available at http://www.bls.gov/data. Accessed November 2003.

The perception of a crisis in American manufacturing is the result of one of the most difficult realities of large gains in productivity: Additional capacity almost always exceeds increased consumption. This results in an inevitable shift of labor. Industries become more productive as they mature, and competitive pressures increase. These two factors require companies to decrease their workforce and often result in movement of commodity industries overseas. The end result is a loss of jobs in the United States. Displaced workers must shift to new occupations requiring new skills and abilities. History has shown that this shift can be either detrimental or beneficial to workers; the most important determinant of benefit is the presence of innovative new industries that create high value for their markets. The sustainability of growth in the U.S. manufacturing sector is based on the ability of the United States to continue to innovate. Innovation is therefore the key to a vibrant U.S. manufacturing base and continued generation of new jobs.

Industry-creating innovations can come in many forms—from plastics to consumer

[1] M. Dertouzos, R. Lester, and R. Solow. 1989. Made in America. Cambridge, Mass.: The MIT Press. p. 1.

electronics to the Internet—but they all depend on the ideas of individuals. As technologies become more complex, the role of science and technology education in the creation of new innovations becomes ever more important, because technological breakthroughs depend on the understanding of technology. The greatest challenge facing the United States manufacturing sector is the limited knowledge and ability of its people to create new innovations. Failure to continuously strengthen our knowledge base will therefore result in a declining ability to provide for the wants and needs of our people.

IMPORTANCE OF MANUFACTURING TO THE U.S. ECONOMY

It is difficult to overestimate the importance of manufacturing to the United States economy. According to the 1997 U.S. economic census, the payroll of the American manufacturing sector is 14 percent larger than the next two largest sectors (finance and insurance, and retail trade) combined, despite having 15 percent fewer employees![2] Although some have speculated that other industries, such as financial services and trade, will replace manufacturing in the future, an examination of the characteristics of different economic sectors refutes this argument. Only four economic sectors generate material wealth: agriculture, mining, manufacturing, and construction. Other sectors, such as services and trade, redistribute this wealth and are therefore built on the products created by the wealth generators. Of the four wealth-creating sectors, manufacturing plays a unique role because, unlike agriculture and mining, it is not directly limited by natural resources and, unlike construction, most manufacturing products are easily transferable across national and international borders. Manufacturing therefore is and will continue to be the fundamental basis for the economic health and security of the United States.

The economic impact of the manufacturing sector is not limited to direct employment of workers. A recent University of Michigan study concluded that in 1998 more than 6.5 spin-off jobs (such as trade, service, and indirect manufacturing) were created for every direct automotive manufacturing job.[3] This fact illustrates the importance of characterizing manufacturing as a generator of wealth, instead of as a source of direct employment. When manufacturing is viewed as a generator of wealth, the importance of new innovation is clear. Direct employment in many maturing industries will shrink as productivity increases, and indirect employment can be expected to follow suit. The effects of layoffs in the manufacturing sector will be multiplied by layoffs in other sectors. Conversely, if new, high-value industries are created, the indirect impact of manufacturing can be expected to increase, because high-value industries create more wealth among workers and society. The federal government can help the manufacturing sector by measuring it as a generator of wealth instead of as a direct employer.

Because of its impact on other industries, manufacturing is the fuel that drives the economy. In today's world of global competition, the economy of a nation without manufacturing will not move forward, it will become stagnant and decay over time. States compete for manufacturing jobs, and other countries are willing to import any capacity that the U.S. doesn't want—manufacturing matters!

LACK OF NEW INNOVATION AS A CHALLENGE TO U.S. MANUFACTURING

As noted above, the growth of new industries is one of the key determinants of opportunities for a displaced worker. America's workforce wants to work and takes pride in self-

[2] 1997 Economic Census: Summary Statistics for United States. 1997. NAICS Basis. Lanham, Md.: Bernan Press.

[3] George A. Fulton, Donald R. Grimes, Lucie G. Schmidt, Sean P. McAlinden, and Barbara C. Richardson. 2001. Contribution of the Automotive Industry to the U.S. Economy in 1998: The Nation and Its Fifty States. Ann Arbor, Mich.: University of Michigan. p. 28.

sufficiency; displaced workers will seek the best opportunities. If innovative, high-value industries are present, workers will find jobs within them. If they are not present, workers will be forced to take lower-paying service jobs. Faced with competitive pressures and globalization, U.S. manufacturing firms must increase productivity in order to survive. However, without nurturing of our knowledge base, there is no assurance that innovation will continue producing new industries, and even less assurance that those new industries will be based in the United States. This is the most serious challenge to the future of U.S. manufacturing.

The United States is the most prolific innovator in the history of nations. Abundant natural resources and geographic location are not enough to explain this success. Previous government policy decisions, such as implementation of the free-market system, public education, and infrastructure investment, have been crucial to economic advancement and the generation of new ideas and have helped to harness the willingness and abilities of our people. The attitudes and ideas of our people have been our greatest economic assets and will become more important as innovations are required to balance the pace of increasing productivity. Future government policy that stimulates innovation will help ensure the creation of new industries. We must provide the incentives to build the foundation for those new industries.

Most of the innovation that results in new industries is based on the combination of new technology and market needs. Technology can be defined as the practical embodiment of knowledge—the useful application of basic science. Thus, in order to create new technological innovations, our workforce must understand existing technology. Education is a lifelong process, and Americans must be endowed with technical knowledge to promote continuous improvement. This does not mean that everyone needs to be trained as a scientist, but rather that a commitment should be made by industry, government, and higher education to increase the knowledge of every worker. The skills of the people are what drive us forward; there should therefore be no illiteracy or lack of numeracy in manufacturing. Channels and incentives should be created to encourage everyone to enhance their skills. Just as no child should be left behind in America's elementary education, no worker should be left behind in lifelong education.

This enhancement of skills will require investment on the corporate and national level. Any knowledge that is attained in a current job can be expected to help people rise to the challenges of future industries and will help everyone. An investment in anyone is an investment in the nation. Experience has shown that the confluence of new knowledge and existing products and processes results in better products and more efficient processes—the fruits of innovation. Better education gives workers new tools to improve their jobs, making themselves, their companies, and the United States more competitive in the global market.

STIMULATING INNOVATION BY INVESTING IN DEVELOPMENT

The path to commercialization of a new technology has three major steps: research, development, and innovation. Research is the mechanism by which new knowledge is discovered. Development is the application of this knowledge to technology that solves practical problems. Innovation is the application and commercialization of developed technology into specific markets, through which industries are born. Each of these steps must be approached differently and each step involves significant risk. The federal government has shown a willingness to bear the risk of basic research by funding projects through agencies such as the National Science Foundation and the National Institutes of Health and has built paths and mechanisms to perform such research in national labs and universities. Entrepreneurs and existing industries have shown a willingness to bear the risk of commercialization of developed technology and have built paths and mechanisms, such as venture capital, to encourage such commercialization. However, there are very few organizations willing to bear the risk of

development, and even fewer mechanisms designed to encourage it. This is unfortunate, because investment in research is squandered without sufficient development funding to balance the research portfolio.

Development projects have traditionally been viewed as the domain of industry, but the competitive pressures of the past 20 years have resulted in a business climate that places a premium on immediate profits. While this push improves many aspects of business, it is detrimental to the development of new technology. For various reasons, development periods for certain advanced technologies, such as new materials, can span 10 to 20 years.[4] For a company that requires a 17 percent return on investment, a 15-year development period means that the potential must exist to earn more than $10 per dollar invested. This is unreasonable for most industries. Furthermore, entire industries may disappear during a period of 15 years; businesses therefore face significant market risk with advanced development projects. In fact, the pharmaceutical industry, which has a clear market for its products, is one of the few industries that has shown an ability to sustain 10- to 15-year development periods.

Development is considered to be the "valley of death." It has earned this name for two reasons. First, many scientific results never make it into application because of the lack of development funding, and many development projects fail early because companies are unable to see the returns necessitated by long development time frames. Second, academia, where a large portion of federal research is performed, does not respect or reward development. In fact, following a path of development can kill a career. It is virtually impossible to get tenure at a top U.S. research university with development projects. Development requires a different type of creativity than science, and that type of creativity is not valued in the current university environment.

The federal government can help create innovation in the manufacturing sector by creating policies that bridge the "valley of death" by encouraging development of basic science and by implementing programs that share the risk of development with the private sector. The Department of Defense (DoD) has an excellent track record of technology development, in part because it has the right ratio of research to exploratory development—that is, roughly equal. By maintaining this ratio, DoD avoids squandering its research. The federal government can improve innovation by encouraging other research funding agencies to meet the same research to development funding ratio as DoD.

Because DoD has clear needs, it requires that each research proposal include a section on potential applications. This forces scientists to focus on realistic and practical uses of new knowledge. The federal government can improve innovation by requiring most research proposals to include such sections, but should also require a cost-benefit justification. Taxpayers deserve a return on their investment in research.

Small businesses and individuals have proven to be very effective technology developers. Unfortunately, few small businesses can afford to engage in long-term development projects because of capital constraints. The Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs take advantage of the intelligence, incentives, and flexibility of small groups by sharing the risk of long-term development. The federal government can improve innovation by expanding these programs to provide incentives for risk taking with medium and large businesses as well.

CONCLUSION

The manufacturing sector is crucial to the U.S. economy. It is the sector with the largest

[4] T. Eagar. 1995. Bringing New Materials to Market. MIT Technology Review. February/March.

payroll, and every direct job in manufacturing creates several indirect and spin-off jobs. Because of this, manufacturing is the economic foundation of other sectors and cannot be measured solely in terms of direct employment.

Competitive pressures and globalization have forced the manufacturing sector to make large investments in improving productivity. Increases in productivity and efficiency bring higher standards of living to societies and better prices for consumers but also result in reduction of direct manufacturing jobs because capacity often outstrips demand. This reduction is an inevitable outcome of increases in productivity and is painful in the short term, since workers are forced to find work elsewhere. However, if innovative, high-value industries are present, displaced workers can actually improve their situation by moving to those industries. Innovation is the key to continued increases in the manufacturing sector and is therefore the key to improvements in the overall standard of living in America. Conversely, a lack of innovation is the most serious challenge facing the U.S. manufacturing base, because global competition will continue to force increases in productivity, movement of commodity manufacturing overseas, and displacement of American labor.

The U.S. workforce must understand current technology in order to create new product and process innovations. This understanding will become more important as technologies become more advanced, and the mobility of the workforce will be limited by the knowledge of individual workers. The United States must invest in continuing education for its workers if it is to maintain its competitive advantage.

Long-term development projects are a "valley of death" for many advanced technologies because there are no clear channels by which to pursue development. Industry cannot afford the risk of development projects with 5- to 20-year time frames. Small businesses, which are some of the most effective technology developers, lack the resources to even attempt such projects. The culture of academia is skewed heavily toward science, and the type of creativity necessary for development projects is neither encouraged nor rewarded.

The federal government can enact structural changes to improve the ability of industry and academia to foster industry-creating innovations. These changes deal primarily with the limitations of people in dealing with technology and the lack of technology development structure and include:

- Measuring manufacturing as a generator of wealth instead of as a direct employer to help policy makers understand the true impact of changes in the manufacturing sector;
- Improving continuing education for manufacturing workers to improve direct product and process innovation and to prepare workers for future industries;
- Balancing federal research budgets between research and development so that research expenditures aren’t squandered by failure to fully develop the new knowledge; and
- Requiring researchers to include potential applications and cost-benefit justification to ensure a favorable return on taxpayer investment.

Part III

Presented Papers:
View from Three Manufacturing Sectors

7

Trends in Rural Manufacturing

Chad Wilkerson
Federal Reserve Bank of Kansas City

The recent economic recession has hit the U.S. manufacturing sector particularly hard. Nearly all types of factories—high-tech and low-tech, durable-goods-producing and nondurable-goods-producing—have been affected in some way. But the slump has hurt the rural areas[1] of the United States especially, because manufacturing remains more prevalent in rural areas than in metropolitan areas. This paper examines the importance of factory activity to rural areas across the country and examines how rural factories have performed relative to their urban counterparts in recent years. The paper also discusses the short-term outlook for rural manufacturing, as well as ongoing challenges posed by increased global competition and rapidly emerging technologies in production.[2]

MANUFACTURING IN RURAL AREAS

Prior to the national recession of the early 1980s, the manufacturing sector accounted for approximately 20 percent of employment and 25 percent of personal earnings in both urban and rural areas of the United States.[3] Since then, as the U.S. economy has become more service-oriented and reliant on imports for many of its manufactured goods, the manufacturing sector's share of economic activity in metropolitan areas has declined by nearly half. By contrast, manufacturing's share of earnings and employment in rural areas has, at least until very recently, hardly fallen at all.

Economic studies have documented several causes for the relatively steady presence of rural manufacturing.[4] For one, rural areas have generally been more attractive to manufacturing firms because wages, property taxes, and land costs are all lower than in most metropolitan areas. Looking just at wages, rural factory workers earned only about two-thirds as much on average as urban manufacturing employees in 1999. However, the average earnings for a rural manufacturing job outpaced the average earnings for all other rural jobs by about 50 percent. These comparatively high wages, along with the prestige of having a sizable plant in a small town, continue to make manufacturing desirable to many local economic developers.

A shift in some kinds of manufacturing from urban to rural areas beginning in the 1980s also helped maintain the importance of manufacturing to rural America. Import competition, particularly from Asia, became intense for many American manufacturers in the 1980s, forcing them to look for cheaper methods of production. One way to cut costs was to move some operations from cities to towns, where labor costs were cheaper. This trend helped make up for the loss of firms in some traditionally rural industries, such as textiles and leather, which moved

[1] Rural areas are defined here as areas not included in metropolitan statistical areas (MSAs).
[2] C. Wilkerson. 2001. Trends in rural manufacturing, The Main Street Economist. Available at http://www.kc.frb.org/RuralCenter/mainstreet/MSE_1201.pdf. Accessed November 2003.
[3] Bureau of Economic Analysis, Regional Economic Information System. Available at www.bea.doc.gov/bea/regional/data.htm. Accessed November 2003.
[4] For example, D. Roth. 2000. Thinking about rural manufacturing: A brief history. Rural America 15(1):12-19.

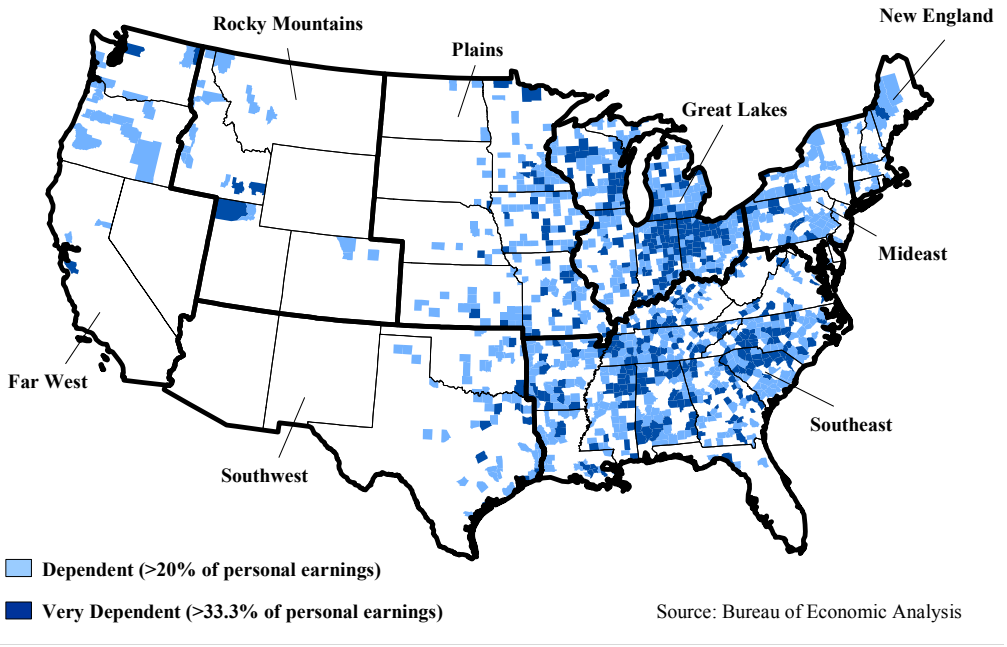

FIGURE 7-1 Local and regional economic dependence on manufacturing, 2000. SOURCE: Bureau of Economic Analysis, Regional Economic Information System. Available at www.bea.doc.gov/bea/regional/data.htm. Accessed November 2003.

to lower cost foreign countries due to similar pressures of international competition.

Finally, rural areas did not experience the same boom in some types of service activity—such as for business, legal, and telecommunications services—that metropolitan areas enjoyed during the 1980s and 1990s. Thus, manufacturing remains relatively more important in rural areas than in cities. It should be noted, however, that the rapid growth of business, legal, and telecommunications services in cities was due in part to the outsourcing of many of these services by manufacturers, both urban and rural. Thus, the actual decline in manufacturing's importance to metropolitan areas may be overstated somewhat by data on the manufacturing sector alone.

Manufacturing has remained important to more than just a few of America's rural areas. In fact, according to the most recent data available, more rural counties depend on manufacturing than on any other sector of the economy. Nevertheless, the importance of rural manufacturing ranges widely from region to region. And recent changes in manufacturing's importance have differed across the country.

Like urban manufacturing, most rural manufacturing continues to concentrate in the eastern half of the United States. Among the nation's eight economic regions as defined by the Bureau of Economic Analysis (BEA), manufacturing's share of rural economic activity is highest in the Great Lakes region (Figure 7-1). Rural factories in this traditional manufacturing stronghold still accounted for 20 percent of jobs and 30 percent of personal earnings in 2000—percentages that are very similar to those of 20 years ago. Moreover, manufacturing's presence in the region strengthened during the 1990s, allowing steady job growth to continue. Rural factory employment in the 1990s also rose considerably in the Plains and Rocky Mountains regions. However, many of the new plants in the Plains states are in the relatively low-paying food processing industry, and manufacturing in the Rocky Mountain states remains a very small part of the economy.

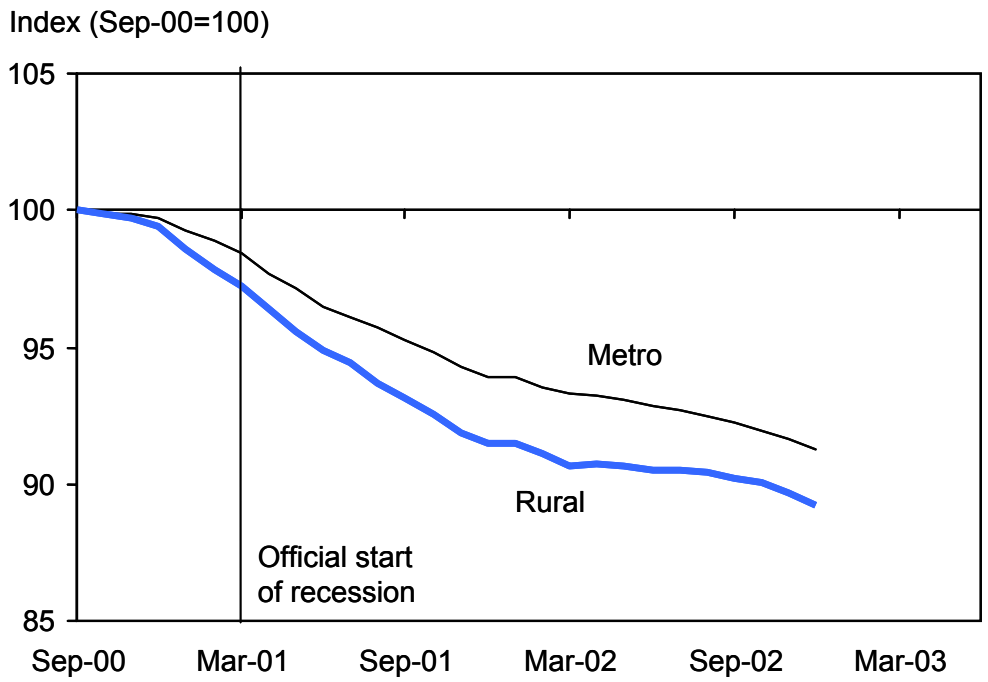

FIGURE 7-2 Decline in U.S. manufacturing employment in rural and metropolitan areas between September 2000 and December 2002. SOURCE: Bureau of Economic Analysis, Regional Economic Information System. Available at www.bea.doc.gov/bea/regional/data.htm. Accessed November 2003.

In contrast to the interior regions of the country, rural factory jobs in the nation's coastal regions declined in the 1990s. New England continued to lose a large number of jobs at rural plants producing nondurable goods, such as textiles. Rural areas of the Mideast region suffered from declines in many durable goods industries, such as steel. The rural Southeast—which has the second-highest concentration of manufacturing activity among regions—also began losing factory jobs in the mid-1990s, particularly in textiles and apparel, industries that have been especially hard hit by free-trade agreements. Finally, over the past decade the rural Far West lost jobs in several manufacturing industries, including its important lumber industry.

EFFECTS OF THE RECENT RECESSION

The recent recession has been a rough one for the nation's manufacturers, particularly rural ones. Since the end of 2000, U.S. manufacturing employment has fallen more than 10 percent—a loss of nearly 2 million jobs—and was declining slightly even before the recession (Figure 7-2). Factory employment has fallen even more sharply in rural areas during the recent downturn. This sharper decline, combined with the fact that manufacturing makes up a larger share of rural jobs and, especially, rural earnings, has depressed total economic activity in rural areas more than in metropolitan areas over the past couple of years.

A major reason why manufacturing has declined more in rural areas recently is that some industries experiencing the sharpest declines are more concentrated there. In particular, employment in the textiles, apparel, and leather industries—which are nearly three times more concentrated in rural areas than in metropolitan areas—has dropped considerably in the last 2

years (23 percent), even after declining throughout the 1990s. Likewise, employment in lumber, furniture, and paper manufacturing—which is also three times more important in rural areas than urban areas—has declined more than most other industries after posting decent job growth during the expansion of the 1990s. Recent activity in the traditional rural industries has not been all bad. Employment in food-related manufacturing—which is nearly twice as concentrated in rural areas as in metropolitan areas—has not declined at all over the past 2 years, showing once again that food demand is fairly resilient in economic downturns. Moreover, not all industries that are more concentrated in cities have outperformed those more prevalent in rural areas. Employment in electronics and instruments manufacturing, for instance—which is twice as concentrated in urban areas as in rural areas—has dropped 16 percent since late 2000. Nevertheless, rural areas have borne a disproportionate share of the recent manufacturing difficulties.

As during the expansion of the 1990s, the performance of rural factories in 2001 and 2002 differed somewhat across geographic regions. Notably, however, the decline in rural manufacturing hit all regions hard and was as bad as or worse than the slump in urban manufacturing throughout the country. Rural factories in the Midwest (Great Lakes and Plains regions) held up as well as their urban counterparts, shedding roughly 8 percent of their workforces from the end of 2000 to the end of 2002. Rural areas of these regions were undoubtedly helped by a relatively high concentration of food-related manufacturing and low concentration of textile and wood manufacturing. On the other hand, rural factory employment in the eastern, southern, and western United States fell approximately 40 percent more than did urban factory jobs in those parts of the country.

The performance of rural manufacturing in the recent recession—that is, an earlier and sharper decline than in urban manufacturing—differs from trends in the two previous national recessions. During the relatively brief recession of 1990-1991, manufacturing employment at the beginning of the downturn fell almost equally in rural and urban areas before picking up in rural areas as the recession neared its end. Rural manufacturing employment then surpassed its late 1980s peak twice during the 1990s, while urban factory jobs never recovered. The decline in factory employment during the more lengthy and painful recession of 1981-1982 also showed little difference between urban and rural areas. But, like the 1990-1991 recession, rural factories began adding jobs more quickly than urban areas at the end of the downturn, again reflecting some shift in manufacturing from urban to rural areas to reduce labor costs.

OUTLOOK FOR RURAL MANUFACTURING

The short-term outlook for rural factories coming out of this recession appears bleaker than it did following past recessions. Rural areas have suffered much more from plant closures than have cities during the recent downturn and face ongoing challenges from globalization and the rapid introduction of new technologies. The longer-term outlook for rural manufacturing depends largely on how it responds to these challenges.

The recent trend in factory closures does not bode well for rural manufacturing. While the share of factory layoffs in metropolitan areas over the past 2 years that are a result of plant shutdowns has remained similar to pre-recession levels, the share in rural areas has risen considerably. From 1996 to 2000, plant shutdowns were responsible for 20 percent of all urban manufacturing layoffs and for only a slightly higher percentage of rural factory layoffs. By the third quarter of 2002—the most recent data point available—plant closures still accounted for less than a quarter of factory layoffs in cities but were responsible for half of all rural manufacturing layoffs. Given these figures, it looks as though a sizable portion of rural manufacturing as it existed in the 1990s may be gone for good.

To be sure, many rural manufacturers were facing serious challenges even before the onset of the recent recession, largely as a result of the globalization of the economy. The opening of world trade through tariff and trade agreements had been eroding U.S. employment in several rural industries—particularly textiles, apparel, and leather manufacturing—well before 2000. A strong dollar in recent years and the recent recession only exacerbated this situation. Free trade means that many products traditionally produced in rural areas can now be made much less expensively in foreign countries, due to their lower labor costs. Rural factories' biggest historical advantage—cheaper labor—has largely been taken away. As a result, they must find new comparative advantages.

Fortunately, the rapid introduction of new manufacturing technologies may offer new sources of comparative advantage. Technologies that help firms produce and ship high-quality goods more quickly, for example, can potentially give them an advantage over geographically distant firms. In addition, technologies that allow for different types of goods to be produced easily by the same production line could give advantages in supplying customers that have changing needs. Many of these and other types of new technologies—such as those that improve communication flows within factories, more efficiently manage inventories, and automate production runs—have already been instituted recently by many small firms.[5]

Still, factories in rural areas struggle to adopt many of the new technologies, due largely to an inadequately trained workforce. The 1996 Rural Manufacturing Survey, performed by the U.S. Department of Agriculture, showed that the chief concern of both urban and rural manufacturers is typically the quality of their workforce.[6] Contrary to popular perception, the survey found that, in general, rural manufacturers were no less satisfied than their urban counterparts with their workers' skills. Both urban and rural manufacturers increasingly require their workers to have many nontraditional skills, such as problem-solving and interpersonal skills. But the survey did reveal a discrepancy between urban and rural factories. Rural workers tend to lack computer skills. Training workers to adapt to ever-changing methods of production promises to be a difficult task for rural plant managers for years to come.

More recently, other challenges besides workforce quality and globalization have emerged that threaten to slow rural manufacturers' adoption of new technologies. Most notably, rising insurance costs have forced many small manufacturers to cut back on technology investment (Figure 7-3). One small firm participating in the manufacturing survey conducted by the Federal Reserve Bank of Kansas City reported, "We are canceling plans for capital expenditures in order to be able to continue to provide health insurance and afford property and casualty insurance." Another plant manager stated, "Insurance costs have depleted cash that was earmarked for capital expenditures." While concerns about poor sales and excess capacity have also contributed to a lack of investment over the past year, firms tend to recognize the cyclicality of these issues.

A couple of recent surveys by industry groups help put the impact of rising insurance burdens on rural factories in perspective. According to members of the National Federation of Independent Business, the single most important problem facing small business in the first quarter of 2003 was the cost and availability of insurance.[7] This is in contrast to the first quarter of 2002, when insurance costs and availability ranked sixth among a list of problems, behind taxes, quality of labor, government requirements, competition from large business, and poor sales. Moreover, a recent survey by the National Association of Manufacturers found that small manufacturers have had a much more difficult time coping with rising health insurance costs

[5] According to a 1999 manufacturing survey undertaken by the Federal Reserve Bank of Kansas City.
[6] H. Frederick Gale, Jr., David A. McGranahan, Ruy Teixeira, and Elizabeth Greenberg. 1999. Rural Competitiveness: Results of the 1996 Rural Manufacturing Survey. U.S. Department of Agriculture.
[7] Available at http://www.nfib.com/PDFs/sbet/Feb_SBET.pdf. Accessed November 2003.

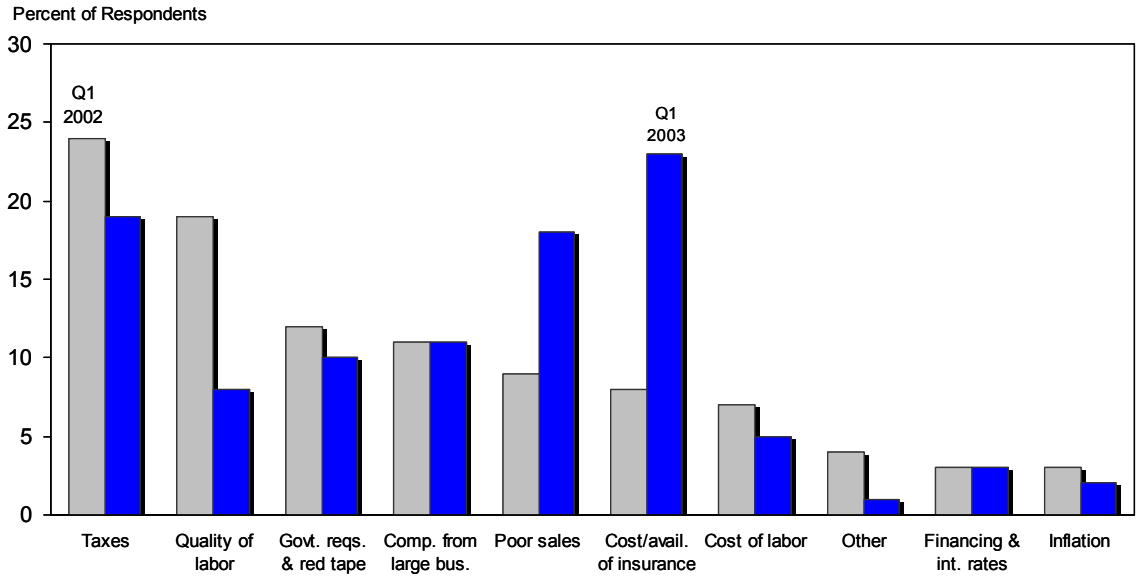

FIGURE 7-3 Survey responses indicating concerns for small manufacturers, 2001 and 2003. SOURCE: National Federation of Independent Business, Small Business Economic Trends. Available at http://www.nfib.com/. Accessed November 2003.

than have larger firms.[8] Since nearly all rural manufacturers are also small manufacturers, the difficulties caused by rising insurance costs have likely hit them disproportionately.

CONCLUSION

Manufacturing remains a driving force in many of the nation's rural areas, but it also faces many challenges. Even before the difficulties caused by the recent recession and rising insurance costs, rural factories were dealing with the effects of globalization and the rapid change of technology. It remains to be seen how rural factories cope with these challenges. Given the importance of manufacturing to rural areas, however, one thing is certain: How well rural manufacturers are able to meet these challenges will profoundly affect the economic well-being of a large number of Americans.

[8] Available at http://www.nam.org/Docs/ManufacturingInstitute/25223_Health_Care_Part1.pdf. Accessed November 2003.

8

Issues for Small Manufacturing Enterprises

Anthony C. Mulligan
Advanced Ceramics Research, Inc.

Small manufacturing enterprises are important to the U.S. economy for a number of reasons. Since the early 1980s, manufacturing employment has become increasingly concentrated in smaller plants and decreasingly concentrated in larger companies. In 1994, 65.8 percent of total U.S. manufacturing sector employment came from companies with fewer than 500 employees.

CHARACTERISTICS OF SMALL MANUFACTURERS

Although there are a number of different types of manufacturing companies, this paper will focus on commodity product manufacturing; job shop manufacturing; and high technology manufacturing. Commodity product manufacturing involves the manufacture of products such as printers and houseware products, much of which is moving overseas. Job shop manufacturing involves the machining, molding, and stamping of basic parts. High technology manufacturing consists of high end products such as optics, materials, biotechnology, sensors, and medical devices.

Understanding the small manufacturer's point of view on manufacturing issues requires an understanding of the markets for their products. Commodity product manufacturers sell to the end user, as well as to wholesale entities or distributors. In addition, they sell to larger manufacturing enterprises that then incorporate the product or service into their own products or services. Some of these larger companies may have business relationships with the Department of Defense (DoD). Job shop manufacturers tend to be dependent for business on component suppliers to larger enterprises. This type of SME may also do some value-added work for large enterprises. Job shop manufacturers do not in general have direct sales to DoD but may do work for DoD through prime contractors. High-technology manufacturers may be dependent on supplying components or systems to larger enterprises. For example, a high-technology manufacturer may improve semiconductor processing through the development of new equipment or parts. If necessary, such an SME may sell directly to retail or wholesale outlets. High technology manufacturers may work either directly with DoD or through a prime contractor.

ISSUES FOR SMALL MANUFACTURERS

There are a number of common issues of interest to small manufacturers that need to be addressed. Small manufacturers have a small client base and are therefore highly dependent on the expected revenue from each client. If anything goes wrong with one of these clients, it

NOTE: The author would like to acknowledge: Manufacturing Extension Partnership (MEP); MEP Management Services, Inc.; various SME members of the Small Business Technology Coalition; Small Manufacturing Executives of Tucson; and the Southern Arizona Industry and Aerospace Alliance.

can seriously jeopardize the business. Small manufacturers have small management teams that struggle to meet all the demands on them. Many small manufacturers have been forced to become leaner and, as a result, have limited legal, marketing, and human resource personnel. This leanness makes them more vulnerable to potential lawsuits that may arise from the increasingly complex liabilities related to products and services, workforce issues, federal regulations, and corporate issues. In an SME, capital is typically dedicated to operations, with limited access to capital for improvements such as equipment upgrades, facility expansions, marketing and sales force expansions, or the incorporation of new technology. Small manufacturers are usually fighting for survival and must therefore focus on day-to-day operations, rather than planning future growth.

Retirement is an issue of concern to smaller manufacturers. There are no mechanisms in place for transferring knowledge from retiring employees, and there is a smaller pool of talent available for the next generation of senior managers. Another alarming issue facing small manufacturers is the lack of education of entry-level production personnel who graduate from high school without the basic reading and writing skills required for the jobs. Most small manufacturers believe that this problem is compounded by a trend to reduce vocational education in high schools. In order to cut costs, many high schools have dropped shop classes. Due to safety and insurance issues, shop classes are more costly than, for example, computer laboratories for software development. There are shortcomings in the remaining vocational courses because high school graduates do not have the knowledge or desire to learn the manufacturing trade. As a result, the biggest problem faced by small manufacturers is a lack of trained production workers.

The rising cost of health insurance is a serious issue for small manufacturers. Small companies are, for the most part, family-owned and typically cover all health insurance costs for their employees. While the costs of health insurance are increasing each year, some years by almost 50 percent, health services seem to be decreasing. In the end, small manufacturers are forced to trade off production capability for health insurance, resulting in perhaps one less person that the company can hire.

Globalization of manufacturing results in new challenges for small manufacturers. With manufacturing moving overseas, sales follow suit. It is difficult for small manufacturers to provide effective service overseas. For example, with domestic clients, you can visit 3 or 4 customers per day. Because most of the computer industry has moved to Asia, it now takes up to 4 days to visit one customer in that industry. This makes it more difficult to compete with local manufacturers. In addition, larger companies are moving around, making the market more unstable and causing relationships to change every 1 to 2 years. Finally, the current affairs of other nations have an increased impact on business abroad.

Another major trend is forcing small manufacturers to change from being component suppliers to being systems suppliers. Previously, a large company would purchase several types of brackets from different companies. Today, contracts being awarded to large companies often require a reduction in administrative costs, with the result that the large company prefers to bundle contracts and orders. Large companies therefore want to buy preassembled systems from one company. This trend is not just relevant for DoD but also for companies such as General Motors and IBM.

Small manufacturers must also reconsider their relationship with government organizations, for a number of reasons. First, if an SME works exclusively with DoD, profit margins are typically tight and the SME becomes extremely vulnerable to program changes. If a program is cancelled without warning, the small companies that spent time building up for it will almost always go under as they do not have the infrastructure to support the loss. Second, big

delays in receiving payments can cause problems for small companies. Cash flow becomes a problem because wages must be paid. Third, fewer competitions result in intense pressure to bid low. Major competitions are seen as "must win." The result is thin margins, greater risk, and overruns. Government agencies often impose cost caps on cost-type development contracts, making it difficult for small manufacturers to make profits. Government agencies often impose, and companies accept, production cost curves before development is complete; these often prove to be optimistic.

Finally, DoD is still struggling to transition its acquisition and business practices to either a commercial business model or a hybrid model. Numerous efforts and initiatives have thus far failed to produce an industrial policy that addresses a changed industrial reality and helps small manufacturers. DoD and independent agencies frequently state that without a clear vision and committed mandate, DoD and its prime suppliers could be in a precarious position with regard to technology and people. Small manufacturers have a vital role to play in addressing these shortcomings, but do not presently have a voice within DoD acquisition groups.

CONCLUSION

The involvement of small manufacturers is essential to a strong, competitive, and cutting-edge DoD. In order for small manufacturers to prosper, increased integration of supply chains is needed, as well as easier access to technology and better access to capital. Public awareness programs must be created to make working for small manufacturers more appealing to the new work force, including both experienced management and technical staff. A mid-level brain drain is occurring throughout the supply chain. This is a void that small manufacturers can fill, working with each other in partnerships and virtual environments, and working with DoD and major prime original equipment manufacturers.

9

Drivers and Challenges for U.S. Aerospace Manufacturing

John Tracy
The Boeing Company

Manufacturing at the Boeing Company is driven by sales to the United States aerospace industry, and one of the major manufacturing challenges faced by Boeing is the highly cyclical nature of sales in this industry. The past 2 years have witnessed a downward swing in the cycle, with aerospace sales dropping by about $15 billion. This translates into a wide variation in the number of products delivered by Boeing each year. For example, 526 commercial transport planes, Boeing's most common product, were delivered 2 years ago compared with 380 last year. Sales projections for this year estimate a further decline, to 270 deliveries.

Sales of Boeing's high-value products, such as satellites, are no more predictable. During the late 1990s, the global industry delivered approximately 30 to 40 satellites each year. It was predicted that Boeing would deliver 70 satellites in 2002, but there were only two sales that year. Because of the cyclical nature of the aerospace industry, the fallibility of predictions regarding the sale of high-value products such as satellites, and the varying number of products manufactured by Boeing each year, Boeing must develop systems that can handle wide fluctuations. Upfront planning of manufacturing processes, tools, and capital equipment is a major challenge for the aerospace industry. The satellite industry is currently operating at only 12 percent capacity. Currently, the aerospace industry is undergoing a period of contraction, with Boeing itself representing a consolidation of at least three major aerospace companies that existed 10 years ago.

MANUFACTURING AND AEROSPACE INDUSTRY EMPLOYMENT

Manufacturing is a major driver for employment in the aerospace industry, with productivity increases having a dramatic effect on the number of jobs that exist. Employment in the aerospace manufacturing industry is currently the lowest since World War II (Figure 9-1). Discounting the surge in employment during World War II, it is the lowest since the 1930s. Employment is down 48 percent from 1989 and down 13 percent from September 11, 2001. This indicates that the employment trend is influenced not only by productivity increases but also by the economic downturn that resulted from the events of 9/11.

The high average age of workers within the aerospace industry presents additional challenges. Currently, the average age of the engineers who support manufacturing work is 54 years, and the average of the blue-collar team that actually put the product together is 51 years. The imminent retirement of many of these engineers and blue collar workers, combined with the inability to hire new workers in the current economic climate, presents a tremendous challenge of transferring knowledge and skills.

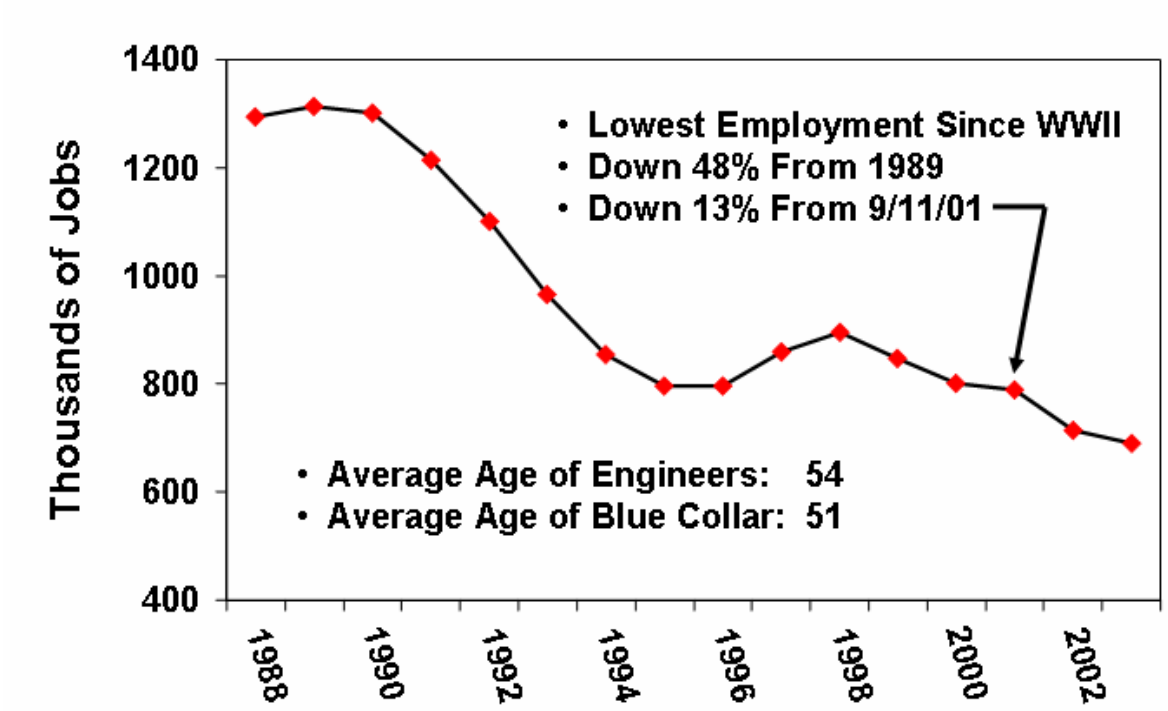

FIGURE 9-1 Aerospace manufacturing industry employment in the United States, 1988 to 2002.
SOURCE: Bureau of Labor Statistics and Aerospace Industries Association.

U.S. AND GLOBAL AEROSPACE INDUSTRIES

In 1985, the U.S. aerospace industry constituted 72 percent of the global aerospace market. However, by 1999, this had decreased to 52 percent. Although the United States has dominated the global aerospace industry in the past, the rest of the world is catching up as they realize that aerospace industry jobs are key to their own economies. Jobs in the aerospace industry are desirable because they are high paying and high technology. The civil aviation industry and the products that enable it form 9 percent of the gross domestic product. This creates jobs not only domestically, but throughout the world. For example, during the development of the Boeing 777, approximately 700,000 people worldwide were involved in some way, for example, through supply chain networks. The manufacture of commercial transports therefore has an enormous impact on the global economy.

Boeing is the largest exporter within the United States, and the U.S. aerospace industry is the single largest contributor to the nation's positive surplus of trade. However, between 1998 and 2000 there was a drop in the surplus of trade by almost 50 percent as a result of foreign competition (Figure 9-2). The product that drives the single largest portion of the trade surplus is commercial transport planes. The largest driver for commercial transport sales is airline passenger traffic. During the past 30 years, passenger growth has been constant and the demand for commercial transports has grown. However, over the past few years, there has been a significant decline in passenger traffic in the United States. Several U.S. airlines have declared bankruptcy as a result. In Europe and the rest of the world, however, passenger growth has regained the place that it held prior to September 11, 2001, and global airlines are therefore not suffering to the same extent as U.S. airlines.

In the long term, there is a huge market for the aerospace industry. Currently, about

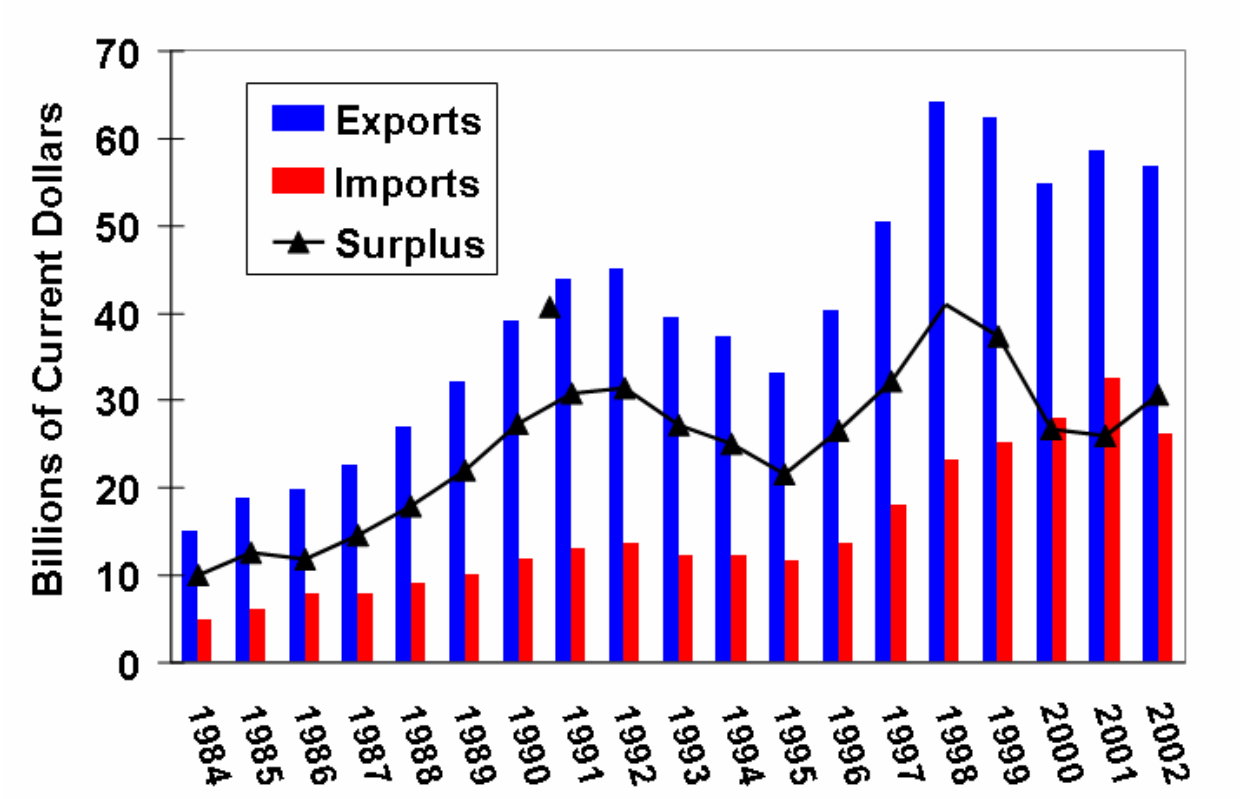

FIGURE 9-2 Total imports and exports of the U.S. aerospace industry, 1984 to 2002. SOURCE: Aerospace Industries Association, based on data from the Department of Commerce.

10,000 commercial transports operate worldwide. Due to aging of that fleet, it is estimated that a total of 4,500 replacements will be required by 2009 and a total of 9,000 replacements will be required by 2019. This estimate assumes no growth in passenger and freight travel. With an estimated modest growth rate of 3.7 percent per year in passenger and freight travel, an additional 4,500 planes would be required by 2009. Over the next 20 years, this market for commercial transports alone is predicted to be worth about $1.8 trillion.

MANUFACTURING PROCESSES AT BOEING

To keep pace with the competition, Boeing faces several manufacturing process challenges. The order and delivery cycles for transport aircraft since 1958 are fairly regular, between 10 and 12 years long, but are always out of phase. During periods when the airline industry reaps profits, orders for new transport aircraft are placed. However, due to the length of time required for manufacturing, by the time the planes are ready, the airline companies are often facing a low market and therefore withdraw their orders. The ability of Boeing to shorten the manufacturing and design build time is a critical challenge. Manufacturing optimization goals at Boeing include a reduction in cycle time by 60 percent and a reduction in build hours by 50 percent.

PRIORITY MANUFACTURING TECHNOLOGIES

The aerospace industry is a very mature industry, and Boeing has been building airplanes for almost 100 years. Technology solutions within this industry are therefore

evolutionary rather than revolutionary when compared with other fields such as biotechnology, where technology is exploding. However, some areas of manufacturing technology that are a high priority for improvement include:

- Single source of production data;
- Integrated design/build/quality and supplier processes;
- Simplified manufacturing planning; and
- Design for manufacturing.

Boeing has already made progress in a number of these areas, including the integration of design and manufacturing. Several computer-based models are currently available that are used by engineers to design products. Duplication is avoided and efficiency significantly increased when the same computer-based model is used on the factory floor (to show the technicians how to put the product together) and by the inspectors (to show them how to inspect the product). In addition, progress has been made in validating systems through electronic simulation. Previously, prototypes and "iron birds" were built that looked just like the airplane but that couldn’t fly. These were used to ensure that plumbing was routed correctly. Today, virtual manufacturing is used to virtually demonstrate the prototype instead. This results in both time and cost savings.

One of the biggest manufacturing challenges encountered by Boeing is the drilling and filling of holes. Two years ago, Boeing was drilling, at great expense, approximately 1.2 million holes per day, or over 365 million holes per year. In the past, expensive machine tools were used that were often bigger than the airplanes. New developments in lasers and computers have enabled these machines to be replaced by smaller machines that achieve the same productivity and can be operated by a single individual. In addition, Boeing has reduced the number of holes and fasteners in its products by the use of new welding processes (friction stir joining), new design approaches, and new, simple manufacturing technologies. As a result, the quality of the product has been increased by a factor of 20.

Lean manufacturing approaches, based on the Toyota production system from the early 1990s, are now being used by the aerospace industry to eliminate waste, eliminate unnecessary inventory, and to eliminate "monuments," i.e., large and bulky items that cannot be moved around and that thereby limit the flexibility to make changes in the rate of production. Boeing is currently spending a lot of time on lean activities. One example is in the production of composites. Certain pieces of large and capital-intensive equipment, such as autoclaves and nondestructive testing equipment, have been completely eliminated by the use of new materials approaches.

On planes such as the 737 and 747, the aerospace industry has shifted to the use of moving production lines in order to shorten assembly cycle times. This requires modification of all of the systems that support the manufacturing activity, which in turn has resulted in a rethinking of the entire production system. For example, computer modeling and laser trackers have replaced large fixtures and tools for assembly.

New materials technologies, such as fiber-metal laminates, new aluminum alloys, metal-matrix composites, and new composite processing, are appearing every day. A major challenge for Boeing is to make sure that product manufacturing processes are adaptable enough to handle these new materials technologies. The challenge is to integrate these new technologies with existing manufacturing processes. In the past, this process took approximately 10 years because of the time it took to create a knowledge base for designing parts with these new

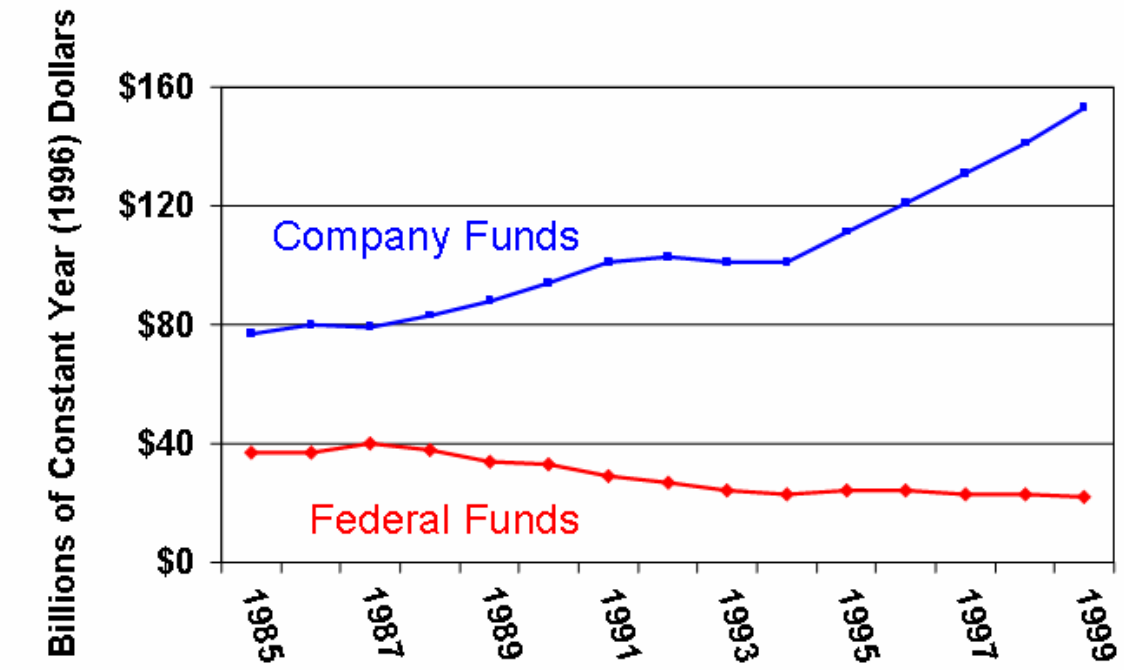

FIGURE 9-3 Funding for manufacturing industry research and development in the United States, 1985 to 1999.

materials and learning how to build with them. Currently, there are several programs at Boeing focused on reducing this lag time.

Changing the part count and the design process can have a huge impact on manufacturing and manufacturing costs. There is currently a debate at Boeing over new ways of thinking about common parts. For example, a strut is a part that holds the engine onto a commercial transport. It consists of hundreds of pieces. New ways of using casting technology can reduce this number of pieces by 90 percent and can reduce the number of fasteners needed by 80 percent. This will improve the durability of the product.

CONCLUSION

Boeing's near-term manufacturing priorities are reducing and standardizing holes and fasteners; improving composite processing; shortening assembly and cycle times; improving support services by technology applications; monolithic structures; turning suppliers into partners; and integrating design and manufacturing. In addition to these near-term priorities, Boeing has identified a number of long-term goals, including simplifying joining techniques; introducing advanced composites by eliminating autoclaves and inspections; lean integrated service support; making production processes ready to adapt to new materials; reducing the part count; and integrating the production system. During the past 15 years, the U.S. manufacturing industry has nearly doubled its spending on manufacturing research and development, while federal funding has decreased (Figure 9-3). Industry funds, however, are focused on very near term needs. Federal funding is needed to focus on the high-risk activities that may have a large impact on the industry in the long term.

Part IV

Manufacturing Globalization

10

Manufacturing Globalization: Is the Glass Half Full or Half Empty?

Margaret Eastwood
Motorola

GLASS HALF EMPTY

If you walk through almost any store today and read the labels on the merchandise, you will find: “Made in China”; “Made in Indonesia”; “Made in Mexico”; “Made in Hungary." Whether you are in a toy store, an electronics store, a sports store, or a general department store, chances are there will be fewer items labeled “Made in the USA” than ever before. From the viewpoint of the U.S. economy, it is very easy to think of the globalization of manufacturing as a “glass half empty.” Newspapers report on U.S. balance-of-trade deficits, factory closings, and big job layoffs at the same time that they advertise the products from many countries that are in demand by U.S. consumers.

Two primary factors are responsible for the movement of manufacturing to sites outside of the United States: substantially lower labor costs and production of acceptable quality. Lower labor cost has always been available elsewhere, but previously it was often paired with substandard goods that did not meet minimum customer expectations. Today, this has changed, and many non-U.S. factories produce products with equal or superior quality compared to U.S. factories.

The electronics industry is an example of an industry that has experienced a shift in manufacturing locations in recent years. In the early 1990s, semiconductors, computers, cell phones, and similar products saw an upsurge in both their market and production in the United States. It seemed as though technological advances were being introduced daily. Computers and cell phones evolved from big-ticket special purchase items shared by the entire family to must-have items acquired for every member of the family. Semiconductors proliferated in everyday items from microwave ovens to automobile airbags. Initially, the majority of these products were produced in the United States. Production swelled for a number of years, only to be cut back near the end of the decade as competitive pressures forced the transition to lower cost locales. Factory closings in the United States followed, along with the loss of many jobs.

It can be argued that the loss of these jobs was not necessarily a bad thing, if it is assumed that they were all held by unskilled workers, laboring at mind-numbing assembly lines in unpleasant, hazardous environments. For several reasons, however, that is not an accurate assessment. First, state-of-the-art electronics factories in the United States today, particularly those owned by large, multinational companies, have a very sophisticated workforce probably running a highly automated line in a clean environment complying with demanding health, safety, and environmental regulations. Less obvious, however, are the vast number of degreed engineering jobs and research and development infrastructure organizations that were added and then lost during this same decade. Those engineers were the primary source of innovation and competitive advantage in the industry. Manufacturing engineers created new processes,

equipment, and materials that enabled design engineers to realize leading-edge products.

For example, coincident with the emergence of many consumer electronics products, and contributing to their success, was the widespread introduction of surface mount technology (SMT). This technology allowed semiconductor chips and associated circuitry to be packed more densely on circuit boards, thereby helping to shrink the size of the overall products. When first developed, however, SMT was a new technology with many problems to be overcome. Manufacturing research and development (R&D) laboratories were created to improve and refine the techniques and materials and to make them robust and reproducible. Many of these laboratories were internally funded organizations, but the National Science Foundation, the National Institute of Standards and Technology, and other government organizations contributed R&D funds to spur development.

Because commercial suppliers did not already exist, an entire industry of equipment manufacturers for SMT devices was established. Engineers designed this new equipment, and value was created in these new offerings. Auxiliary parts and material suppliers also emerged to support this trend. Universities got into the act, expanding their manufacturing and industrial engineering programs. Encouraged by funding from major corporations, programs like the Massachusetts Institute of Technology's Leaders for Manufacturing Program provided a new level of skills and knowledge in their graduates. Universities located near major manufacturing sites frequently had joint development programs, summer intern opportunities, and instant job openings for their graduates.

During this period of research and development, trial and error, refinement and fine-tuning, having the factories located near the engineering base made life a lot easier. The high margins available from selling the resulting leading-edge top tier products were sufficient to sustain the U.S. manufacturing. As the SMT technology and corresponding industry matured, however, its availability was no longer restricted to a few big corporations with manufacturing R&D departments. Once the commercial supplier base was in place, well-tested processes documented and understood, and many people trained in the technology, manufacturing of this type of product could successfully be done by anyone. No additional breakthrough improvements were forthcoming to provide competitive advantages or premium margins. Electronics manufacturing became a commodity.

As with all commodities, cost became more and more important. Many companies set up manufacturing operations in places like China or utilized a supplier already there. Third-party manufacturers, such as Flextronics, Solectron, and others, leveraged their low-cost factory locations, economies of scale, and purchasing muscle to provide a successful manufacturing service. Although individual companies could set up their own factories in low-cost locations, many chose to spend their employees' time, talent, and capital budget on other things, such as product design or marketing, that provided more differentiation and customer value.

Unfortunately for the U.S. economy and workforce, electronics is just one of many industries that has followed this general pattern. Over the years, steel, textiles, toys, and machine tools are among the products whose production has moved predominately elsewhere. Each shift has caused major disruptions to the people, municipalities, local governments, and companies involved. A constant influx of new products/technologies/industries is needed to compensate for this outflow.

Currently, promising areas such as biotechnology and nanotechnology are touted to be the emerging fields that will boost the U.S. economy as other industries have done in the past. Cities as diverse as Boston, Massachusetts, Ann Arbor, Michigan, and San Diego, California, have organized industrial, educational, and governmental programs to foster these industries in their regions. This would start a new cycle of development, supply base creation, and eventual

high-volume, profitable production. Many other nations, however, have also targeted these two areas for their own next big wins. The United States does not have a monopoly on the talent necessary to bring these promising technologies to market and cannot be confident that we will be superior enough in these technologies to provide the stimulus and economic success that is envisioned. The success of software developers in India, engineers in Russia, product design teams in China, and help desk call centers in the Philippines indicates that globalization has expanded to many engineering and skilled functions well beyond manufacturing. Government policies have also shifted. Industrial policy in competing regions can hurt the ability of U.S. industry to capture an area such as nanotechnology. The European Union, for example, is more fully functioning now as a coordinated body, funding research programs and influencing standards and trade policies to assist their constituent membership.

GLASS HALF FULL

Manufacturing globalization is already a reality. The question therefore becomes how to turn it into an advantage for U.S. companies, workers, and government organizations. How do we look at the situation to see the glass half full? What new actions or activities should we engage in to capitalize on the changed business environment?

One way to change the view is to stop focusing on the cost side of the business equation and instead look at the revenue side. Many U.S. companies have discovered that their biggest business growth opportunities are within the same regions that supply the low-cost labor that has attracted manufacturing. Many companies, for example, moved their manufacturing operations to China because they were concentrating on low cost. But China is one of the largest markets in the world, with over one billion potential consumers. Producing a product in China can increase the probability of successfully selling to those consumers and/or local industries. Understanding the customer has always been a basic tenet in successful marketing and product design. This is much easier to do when you have frequent visits and personal relationships with a cross section of the consumers/industrial concerns with whom you hope to do business. Having your own manufacturing operation (or a third-party partner) within the country gives a company much closer access to learning about product needs.

When targeting a foreign market, it is tempting to hope that one size fits all, and that the same product that was successful in the United States will be a big hit in Beijing or Berlin. Although that may be true for some products, it is not true for all. Business and personal relationships gained through manufacturing arrangements are also beneficial in aspects of successful business dealings other than designing the right product. Cutting through red tape, getting priority service, recognizing and signing contracts with the most desirable suppliers or distributors might all require intervention or assistance from the local production organization.

Seeing the glass as half full can arise from a completely different circumstance. Readily available third-party manufacturing capability has stimulated the emergence of a new class of companies that only do product design, with perhaps some sales and marketing. Although this business model is applicable to large, established companies as well as startups, it offers particular benefits to emerging companies. They are free to concentrate all their time and talents on creating new, innovative products, without the burden of fixed costs or overhead associated with manufacturing. Yet they have access to high-class production and supply chain management services equal to any of their larger competitors. This business model has been quite prevalent in the creation of “fabless semiconductor companies.” With the cost of wafer fabs approaching $1 billion, the barriers to entry are extremely high. Third party semiconductor foundries remove this barrier, and numerous creative U.S. companies now provide optimized products for niche markets that would not have been financially feasible without access to cost-

effective outsourcing.

Large, established companies, too, are seeing the glass as half full by applying manufacturing outsourcing. As long as manufacturing cannot provide a distinctive competitive advantage to the firm, they stand to gain by channeling their time, money, and talent to those functions and activities that will result in a competitive advantage. That might be innovative marketing, superb customer service, or some other activity that blossoms when it becomes the center of attention and budget.

Yet another glass half full strategy is to capitalize on the "first mover advantage." For some products or services, being the first to market with a viable product is a critical success factor for both short- and long-term profitability. In general, prices (and margins) are the highest when a new product is first introduced. When a company captures the initial wave of customers, it may have the opportunity to set a de facto standard or corner the best patent rights. In addition, its monopoly serving the first wave of customers may allow it to ramp up to gain economies of scale more quickly than its competitors can. Locating manufacturing outside the United States, away from the development organization, can hinder, rather than help, the achievement of first mover advantage, since coordination and communication might be too cumbersome. Done effectively, however, product launch preparations can be done in parallel across the organization, cutting time and helping to meet the first-to-market goal.

In addition, if globalization is institutionalized and supported by the supply chain organization, the corporate computer system, and other company infrastructure, an organization has access to best in class partners, suppliers, and contributors from anywhere in the world. Rarely is a single company best in class in every function. But with the right partnering, the resulting virtual organization can pool the necessary talents to ensure the successful first-mover advantage or other competitive position. For major corporations that are already sophisticated internationally with their facilities and customer base, finding these partners, understanding the international law, and negotiating agreements are all possible. For a small to medium-sized company, however, gaining the knowledge, hiring staff with these special skills, and attempting operations on such a broad scale may be prohibitive. Yet these small to medium-sized companies are pivotal to the employment and economic base of the country, and the ones most vulnerable to the negative impacts of globalization.

One program that strives to make it easier for all companies to work more effectively with global partners is the Intelligent Manufacturing Systems (IMS) program.[1] IMS is an industry-led, global, structured, collaborative manufacturing R&D program that includes large and small companies, users and suppliers, and universities and research organizations. Members of IMS include Japan, Canada, Australia, the European Union, Norway, Switzerland, Korea, and the United States. Every IMS project must include participants from at least three regions. The basic intellectual property rights guidelines are already in place and apply equally to all participants. Projects typically cover the precompetitive phases of development. Since 1995, over 200 large companies, 120 small and medium-sized enterprises (SMEs), and 220 academic/research organizations have worked on R&D projects worth over $300 million. Thirty completed or active projects and 40 proposed projects have been undertaken.

IMS has a formal structured process that greatly facilitates the involvement of companies and academic organizations, regardless of their size or previous global experience. Each country has a secretariat to assist its participants. Some countries offer special funding, although the United States utilizes traditional government funding structures. All secretariats offer a matchmaking service, which queries the secretariats in other regions to find the perfect partners with the same research and business interests to join a new project. Benefits of global

[1] Details about IMS may be found at http://www.ims.org.

IMS collaboration include access to advanced global manufacturing skills, technologies, and resource bases; exposure to global best practices; shared risks and rewards; intellectual property rights agreement guidelines; leveraging of R&D investments; building of relationships that facilitate entry into new markets; learning to think and act globally; and avoid innovating in the dark.

GOING FORWARD

New industries such as biotechnology and nanotechnology are the potential engines for future value creation, job creation, and economic success. The development of these new industries, as well as the growth of current industries, must occur in the new global environment. Development programs, competitive strategies, and investment decisions by government and industry need to be made with an understanding of global opportunities and risks. Only by working with today's environment rather than yesterday's reminiscences will we be able to fill the glass rather than watch it empty.

11

Manufacturing Globalization at United Technologies Corporation

John F. Cassidy, Jr.
United Technologies Corporation

This paper presents the perspective of a private company, United Technologies Corporation (UTC), on the globalization of manufacturing. It also presents the company's vision of where things are and how they should be dealt with to ensure economic stability within the United States, as well as growth in manufacturing. UTC provides high-technology products and services to the building systems and aerospace industry throughout the world. UTC's industry-leading companies are Pratt & Whitney, Carrier, Chubb, Otis, UTC Power, Hamilton Sundstrand, and Sikorsky. Much has been said recently about changes in manufacturing patterns and the effect on the global scene. Globalization has been occurring for decades. Globalized manufacturing will become larger and more volatile through expansion.

METRICS

Metrics are developed to measure changes that are occurring. Figure 11-1 shows that traditional manufacturing countries, such as the United States, Germany, and Japan, had a good annual percentage growth rate in the 1980s and 1990s, while countries such as China and Mexico showed room for increasing growth, especially up to 2002. It can be argued that the rate of growth will always look much larger for countries that are starting out at a low level, when compared to more established countries. However, the overall rate of growth looks promising for countries such as Mexico and China and it would appear that countries such as Germany and Japan are in serious trouble. The United States has an expanding albeit smaller manufacturing base. Other nations are growing faster, but this need not be a major concern if the United States can maintain its pace of growth.

It is important for companies to determine what to do with metrics once they are developed. It has been said that it is a matter of changing the definitions to meet the changing markets. UTC believes that understanding the data and solving the fundamental problem are more important than focusing on definitions. Figure 11-2 provides a good example of this issue. Between 1994 and 2002, UTC had a large presence in the United States. Value produced went up in the space created or allotted for manufacturing in the United States. The rest of the world shows a larger increase over the years, but the reason for this is infrastructure. As a global company, UTC wants to be there in other parts of the world to make ourselves successful. So depending on how you look at it one can say that the productivity in the United States is still very high despite increasing growth outside of the country.

In this global market, UTC has approximately 90,000 employees involved in various manufacturing activities, from receiving orders to shipping product. Overall, UTC has $28.4 billion in annual revenue with about $10.4 billion of buy and $9.7 billion of operations value-added. UTC has 57 million square feet of manufacturing area divided among manufacturing facilities in 28 states and 36 countries. For a company of this nature, one of the largest issues is wages. Figure 11-3 shows the vast differences in wages around the world. China, although

currently on the low end of wage levels, is in a category by itself because it also represents a large market. China recently became the world's largest market for air conditioners. China is a country in which the market will expand and in which there will be manufacturing jobs without the need to cross boundaries.

There are concerns that globalization of manufacturing causes the loss of jobs and is counterproductive to the local economy. UTC believes that nothing could be further from the truth. Global manufacturing enables engineering and manufacturing responsibilities to be distributed in such a way that the product is built efficiently. For decades, United Technologies has engineered and manufactured products in Europe and Asia. In recent years virtually all markets around the world demand that products be engineered to meet local requirements and preferences. Currently United Technologies has 125 engineering centers in the United States, Europe, Australia, Asia, and South America. The non-U.S. activities leverage the primary work done in the United States and create export sales. Last year United Technologies exported $3 billion of goods and services while its imports totaled $500 million.

An example of the advantages of global manufacturing is UTC's purchase of PZL-RZESZÓW (Poland), which has been part of Pratt & Whitney-Canada for 27 years. When UTC won a $1.8 billion contract to build F16 jet engines over a period of 10 years, it bought PZL-RZESZÓW and created a lower cost source location. It became a privatized manufacturing arm of UTC, manufacturing some parts of the F16 engines, among other things. Without this investment, UTC would not have been manufacturing this product. The domestic manufacturing locations (e.g., Connecticut, Georgia, and Maine), where other parts of the F16 engine will be built, would not have been manufacturing them either. Rather than focusing on individual pieces of the overall manufacturing scheme, it is important to understand and visualize the whole picture and the total flow of the manufacturing process.

Previously, it was believed that products made outside the United States were lower cost

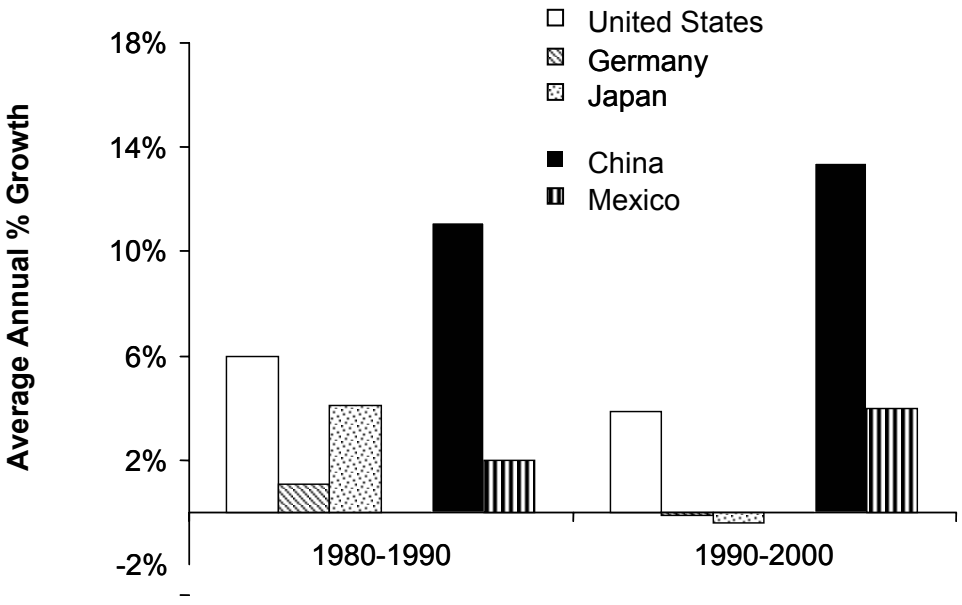

FIGURE 11-1 Average annual percentage growth in manufacturing for five countries in the periods 1980 to 1990 and 1990 to 2000. SOURCE: The World Bank 2002 World Development Indicators. Available at http://www.worldbank.org/data/.

because they were of inferior quality. At PZL-RZESZÓW a bevel gear for the PT6 turbo engine is made; this same bevel gear is also made near Montréal. The main difference is the price, with the one made in Canada costing $921 and the one made in Poland costing $256. In order to succeed, UTC must take into account this price differential.

Other ways of dealing with this price differential include a renewed commitment to increase productivity. This should not be done by focusing on a specific fix-all manufacturing cell, but rather by adjusting to corresponding issues. It is important to be careful, because if a cell becomes too efficient, then inventory overflow occurs. Inventory begins to pile up because the downstream process cannot accept it.

An example where UTC has increased productivity by an overall investigation of a process is the wiring harness assembly. A value-stream map was used in an end-to-end approach, to become more efficient and increase the drive for manufacturing. Initially, this was a slow process with a total cycle time of 403 days and a processing time of 30 days. After using the value-stream map, the total cycle time was cut down to 21 days and the total processing time down to 18 days. By methods such as this one, it is possible to remain competitive in the global manufacturing arena.

CONCLUSIONS

In 1997, Peter F. Drucker said:

> In a transnational company, there is only one economic unit, the world. Selling, servicing, public relations, and legal affairs are local. But parts, machines, planning, research, finance, marketing, pricing, and management are conducted in contemplation of the world market. . . . national boundaries have largely become

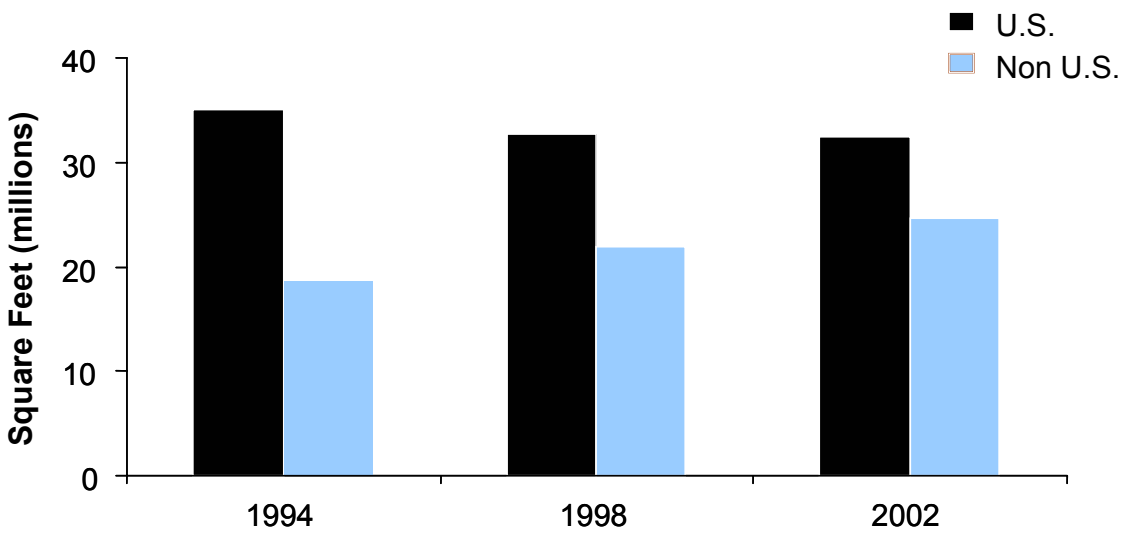

FIGURE 11-2 Millions of square feet of manufacturing area in the United States and abroad.
SOURCE: Census Bureau, Department of Commerce.

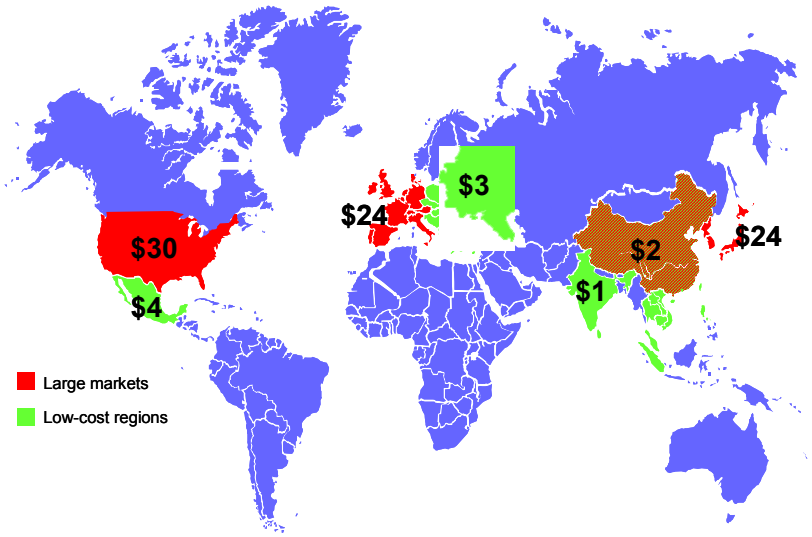

FIGURE 11-3 Manufacturing direct labor cost (in billions of U.S. dollars) in different parts of the world identified as having a large market, low labor cost, or both. SOURCE: United Technologies Corporation.

irrelevant.[1]

His statement fits well with the theme of this paper. A company must have a vision of a global market, as well as maintaining productivity in the United States. In order to compete with the $2 per hour wages found in other parts of the world, the bar must be raised for the United States by creating new products and markets that do not yet exist and educating the workforce. As an example of new product/market creation, UTC has 250 fuel cells providing electricity around the world. These fuel cells have 250 kilowatts of power and a lifetime of 40,000 hours. By creating a supply chain around this product, the cost of the unit can be decreased. As an example of the importance of educating the workforce, UTC pays for any employee to attend school on any subject, in addition to giving them a bonus when they complete a degree. This system creates incentives and motivation for individuals to excel, as well as creating loyalty to the company. In the long run, this makes for a more productive and efficient company capable of competing in the global manufacturing market.

[1] Peter F. Drucker. 1997. The global economy and the nation-state. Foreign Affairs 76(5).

12

Insights on Outsourcing: The Electronic Manufacturing Services Industry for the Aerospace and Defense Markets

Charles W. Wade
Technology Forecasters, Inc.

Contract manufacturing, also known as electronic manufacturing services, gained acceptance in the mid-1980s and is now an integral part of the worldwide electronics industry. Contract manufacturing started with United States-based companies primarily supporting the computer systems and peripherals industry on a consigned material basis. Outsourcing has now expanded into a global operation, providing design, manufacturing, supply chain management, test, and order fulfillment services for the computer, telecommunications, medical, instrumentation, automotive, aerospace/defense, and consumer industries.

Even with the difficult economic conditions that affected the electronics business in the new millennium, the electronic manufacturing services (EMS) industry has continued its acceptance in the global marketplace. From an overall market standpoint, the worldwide EMS market is forecast to grow from $92 billion in 2002 to over $170 billion in 2006, a 16.5 percent compound annual growth rate (CAGR) (Figure 12-1).

This increase in electronic manufacturing outsourcing is a result of the positive business impact realized by original equipment manufacturers (OEMs) in the current outsourcing environment. OEMs that are outsourcing will have a competitive advantage. The expansion of outsourcing will be driven by synchronization between OEMs and EMS providers that will uncover additional cost savings and service enhancements, which will in turn drive additional benefits for the OEMs; increased competitive market cost pressures; and better management tools for the OEM/EMS relationship, which will reduce the perceived risk of outsourcing additional services.

OEM OUTSOURCING REQUIREMENTS

In studies conducted by Technology Forecasters, Inc. (TFI), several factors have been identified that OEMs want when they consider outsourcing of manufacturing. These include cost reduction and improved asset utilization; quality improvement; agility and/or flexibility; timeliness and delivery assurance; technology advancement; vertical integration leveraged from the EMS; business and/or risk management; global footprint; long-term relationships. As the leading strategic consulting firm servicing the EMS sector, TFI is in a unique position to evaluate the needs and requirements of OEMs served by the EMS providers. For 15 years, TFI has been conducting customer satisfaction interviews for EMS companies. In each interview, TFI representatives ask EMS customers qualitative and quantitative questions to measure the current level of satisfaction and ascertain the future needs of their business.

In a previous TFI study, the current needs and requirements of 72 OEMs were analyzed. The organizations surveyed included the entire spectrum of OEMs, ranging from the largest electronic firms in the world to start-up companies servicing small niche electronic markets. In

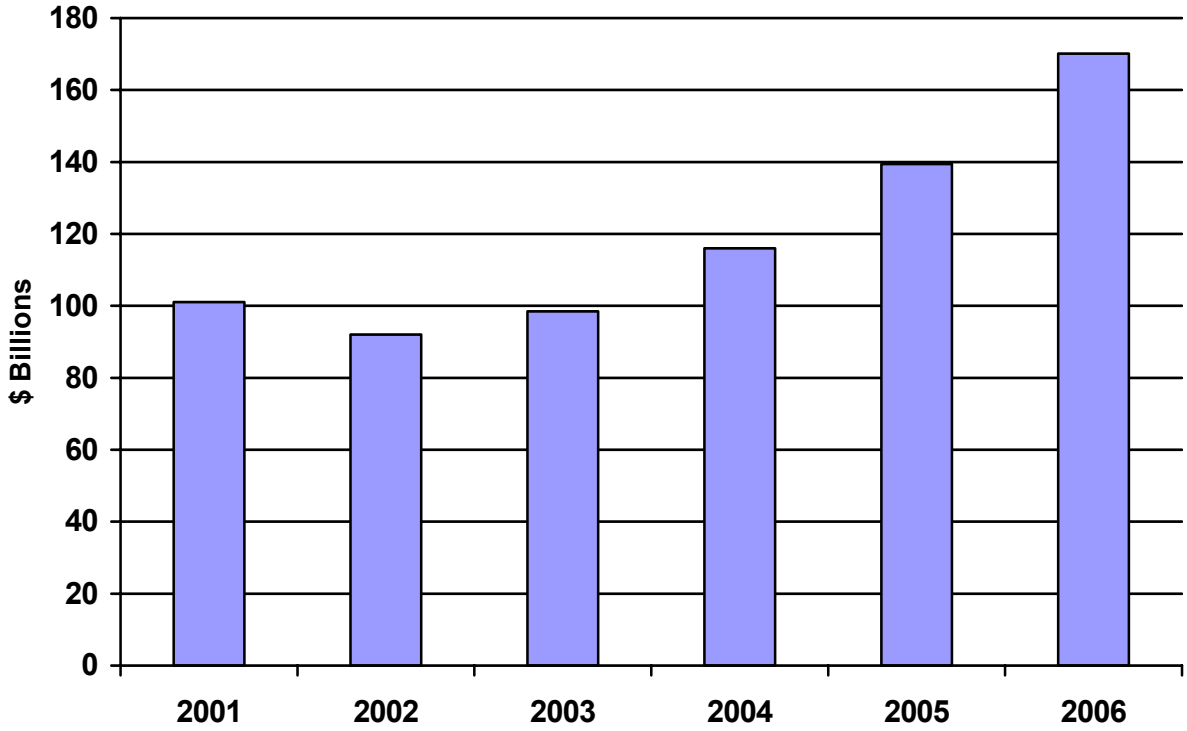

FIGURE 12-1 The global market for electronic manufacturing services. SOURCE: Technology Forecasters Quarterly Forum, December 2002.

response to questions on what constitutes EMS value and services, TFI received a total of 323 responses on items that are significant factors in choosing and maintaining a relationship with an EMS supplier. The top items in the OEM's perception of EMS value and service are cost/price, quality, and dependable delivery.

COMMON MISTAKES IN OUTSOURCING

While consulting with over 60 OEMs on how to establish outsourcing programs, TFI identified five key outsourcing mistakes that prevent effective implementation. Table 12-1 presents these mistakes and their possible impacts.

OUTSOURCING CYCLE

In consulting with clients, TFI recommends a four-phase approach to implementing the outsourcing process: assess, design, implement, and improve. Critical to the success of outsourcing is communication between all levels at the OEM and the EMS partner. Figure 12-2 illustrates this process cycle.

AEROSPACE AND DEFENSE EMS MARKET STUDY

The aerospace/defense industry is a major component of the U.S. economy, with 4,400 U.S. companies engaged in this industry in 2001, a total output of more than $200 billion and

TABLE 12-1 Common Outsourcing Mistakes and Their Potential Impacts

Mistakes	Potential Impacts
Incomplete, inaccurate, or late request for proposal	▪ Longer wait for proposal and longer product development cycle, leading to delayed product introduction. ▪ Extra cost loaded into the contractor's bid to remedy the bill of materials and other vague or incorrect instructions and to cover unforeseen changes in areas of uncertainty. ▪ A forced renegotiation of the contract based on "surprise" requirements.
Lack of consensus among OEM stakeholders	▪ Delayed decision to outsource by months and in some cases years. ▪ Duplicating outsourced functions internally to please dissenters. ▪ Compromise on decisions, yielding incomplete benefits of outsourcing.
EMS suppliers chosen casually and not strategically	▪ EMS is too small to handle the OEM's growth and geographic requirements (for cost savings), too large for the OEM, or service is lacking. ▪ The economic cost of finding a new partner and switching is significant.
Micro-managing the EMS supplier	▪ Insistence on a bill of materials containing needlessly more expensive parts. ▪ Directing manufacturing of key elements of the products to geographic regions that do not yield maximum cost savings.
Inefficient management of EMS and unclear performance expectations	▪ Lack of standards for how the OEM program managers interact with the EMS suppliers causes duplicative or insufficient instructions. ▪ Performance targets, including cost reductions, are unclear and unmet.

employment of over 3 million.[1] Companies in the aerospace/defense products industry manufacture a wide range of products, including computer systems, tanks, guided missiles, aircraft, navigation systems, arms, and ammunition. These companies sell primarily to the U.S. government, although private sector markets still exist. At the request of members of the Quarterly Forum for Electronics Manufacturing, Outsourcing and Supply Chain, TFI conducted a study on EMS activity in the aerospace/defense electronics market.[2]

OUTSOURCING CYCLE

In consulting with clients, TFI recommends a four-phase approach to implementing the outsourcing process: assess, design, implement, and improve. Critical to the success of

[1] Harris InfoSource. 2002. Aerospace/Defense Industry Report. Published at http://www.researchandmarkets.com/reportinfo.asp?cat_id=17&report_id=2891. Accessed November 2003.

[2] The Aerospace/Defense Electronics Market: Unique Hurdles and Timely Opportunities, June 2003 Quarterly Forum.

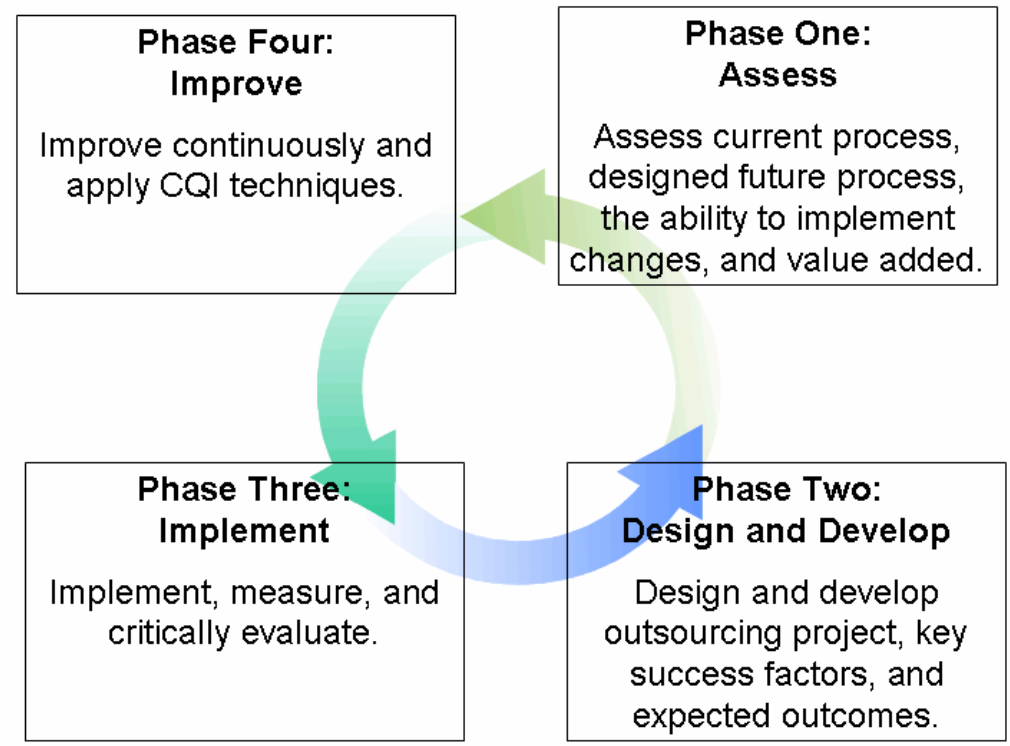

FIGURE 12-2 The outsourcing cycle. SOURCE: Technology Forecasters, Inc.

outsourcing is communication between all levels at the OEM and the EMS partner. Figure 12-2 illustrates this process cycle.

AEROSPACE AND DEFENSE EMS MARKET STUDY

The aerospace/defense industry is a major component of the U.S. economy, with 4,400 U.S. companies engaged in this industry in 2001, a total output of more than $200 billion and employment of over 3 million.[3] Companies in the aerospace/defense products industry manufacture a wide range of products, including computer systems, tanks, guided missiles, aircraft, navigation systems, arms, and ammunition. These companies sell primarily to the U.S. government, although private sector markets still exist. At the request of members of the Quarterly Forum for Electronics Manufacturing, Outsourcing and Supply Chain, TFI conducted a study on EMS activity in the aerospace/defense electronics market.[4]

The North American Industry Classification System (NAICS) is the U.S. government's official system for categorizing industrial data. The aerospace/defense industry uses 14 NAICS codes, and production is spread over a wide range of activities. Products contributing heavily to total industry revenue and employment include electronic computers; communications equipment; search, detection, and navigation equipment; aircraft; and aircraft engines.

The defense industry has been a bright spot in the current U.S. economy as it has been

[3] Harris InfoSource. 2002. Aerospace/Defense Industry Report. Published at http://www.researchandmarkets.com/reportinfo.asp?cat_id=17&report_id=2891. Accessed November 2003.
[4] The Aerospace/Defense Electronics Market: Unique Hurdles and Timely Opportunities, June 2003 Quarterly Forum.

TABLE 12-2 Key Drivers and Obstacles to Outsourcing of Aerospace/Defense Electronics

Driver	Obstacle
Higher military budgets due to terrorism and increased tension in the Middle East and North Korea.	Continuing slump in the travel market and financial fragility of major carriers leads to lower commercial aircraft production.
Higher unit sales of replacement equipment during military build-up and hostilities.	Security considerations and bureaucratic procedures slow shift to outsourcing.
Success of high-tech military equipment in military action will lead to further development and procurement of such systems.	
Likelihood of significant military upgrading in Europe.	

bolstered by large budgets aimed at transforming the military for a war on terrorism and perceived foreign threats from nations such as Iraq and North Korea. This military buildup will not be able to offset the ongoing crisis in commercial aviation, however. These economic conditions will present both opportunities and challenges for aerospace/defense contractors and EMS suppliers participating in this market.

The aerospace/defense industry had faced a slump in segment growth since the mid-1990s but experienced a resurgence by the end of 2000, with increases in employment and exports. The events of September 11th, however, seem to have resulted in an almost instantaneous shift in direction for the industry. With defense contracts likely to increase substantially over the next 5 to 10 years, companies producing war-ready products and systems are likely to see an increase in revenue. Despite this defense sector growth, September 11th has negatively affected others in the industry. Nearly all airlines are losing money, tens of thousands of workers have lost their jobs, and the crisis shows no signs of improving in 2003. One casualty of the airline struggle will be orders for new aircraft. Already, surplus aircraft account for 13 percent of the world's jetliner fleet.[5] For both Boeing and Airbus, further production declines are likely. The Airline Industries Association (AIA) predicts that Boeing will cut aircraft production to about 280 aircraft in 2003, a 26 percent reduction from 2002. In January, Airbus announced plans to produce 300 jet aircraft in 2003. If Airbus meets this goal, it will surpass Boeing in aircraft deliveries for the first time.

Aerospace and Defense Outsourcing Markets

As the aerospace/defense market continues to grow, the need for EMS suppliers will also increase. TFI projects that aerospace/defense EMS revenues will grow from $4.0 billion in 2001 to $7.7 billion in 2006. This CAGR of 14.0 percent is below the EMS industry average of 16.5 percent. During this period, TFI predicts that EMS market penetration of the aerospace/defense industry (defined as the percentage of the cost of goods sold that are outsourced) will increase from 11 to 16 percent. This trend in outsourcing of aerospace/defense electronics manufacturing to EMS companies is influenced by a number of important driving forces and obstacles (Table 12-2).

Although the aerospace and defense sector represents only about 4 percent of the total

[5] Business Week Online. 2003. Defense & Aerospace: Woes Not Even War Will Ease Available at http://www.businessweek.com/magazine/content/03_02/b3815714.htm. Accessed November 2003. January 13.

EMS market, it offers some interesting possibilities for outsourcing. The electronics portion of a military system is usually a discrete black box. Therefore, the EMS company does not necessarily have to be involved in the manufacture of the larger system. In addition, military specifications, once the most stringent of design and manufacturing requirements, have now been surpassed by commercial quality standards. At most EMS companies, quality levels are sufficient to support this market due to the acceptance of IPC[6] Class III standards.

Aerospace and Defense Use of Outsourcing

With the growing acceptance of electronic manufacturing outsourcing, almost all major U.S.-based aerospace/defense contractors are outsourcing to some extent. The following aerospace/defense companies currently outsource some manufacturing: Lockheed Martin; Boeing; Northrop Grumman; Raytheon; General Electric; Harris; Motorola; EADS; Rockwell Collins; United Technologies; and Honeywell.[7] In a survey of aerospace/defense contractors, the following were identified as the top criteria by which they select an EMS supplier: exceptional quality; technical capability; acceptable/certified processes; financial stability; effective cost management; component management/engineering; delivery performance; and aerospace/defense experience.

When surveyed on the reasons why they would choose not to outsource or to limit their outsourcing, aerospace/defense contractors cited maintaining required quality and fear of losing control of the project as their highest concerns. Security issues, complexity of the product, concerns about an outsourcing partner's technical capabilities, cost factors, available in-house capacity, and documentation transfer issues were also mentioned as major factors for choosing not to outsource.

EMS Participation in the Aerospace and Defense Markets

The aerospace and defense markets are attractive to EMS suppliers, and a number of service providers have strategically targeted this market segment. Table 12-3 identifies a number of EMS providers that have significant aerospace/defense business either in terms of total revenue or percentage of revenue.

When EMS companies were asked what their major challenges were to supporting aerospace/defense contractors, the most frequently mentioned factors were contract management and dealing with government regulations. This included managing documentation requirements, audits, process certification, and status reporting. Although meeting required quality standards was listed as a factor, most companies felt that their existing quality program met or exceeded the requirements for government contracts. Dealing with obsolete component issues and the issue of parts traceability indicated a strong need for component engineering and material management and control. These issues were followed by managing security requirements, lack of adequate market information, a high amount of engineering changes, low-volume, high-mix production, and required capital investment. The capital investment included specialized test equipment, conformal coating capabilities, and material management and control systems.

CONCLUSION

The global EMS market will grow to $170 billion by 2006. The aerospace/defense portion

[6] In 1999, IPC changed its name from Institute of Interconnecting and Packaging Electronic Circuits to IPC. The name IPC is accompanied by an identity statement, Association Connecting Electronics Industries.

[7] These companies were identified from annual reports, analysis reviews, and EMS customer lists.

TABLE 12-3 EMS Companies Reporting Significant Aerospace/Defense Business

EMS Company	Headquarters	Estimated 2002 Total Revenue (millions of $US)	Estimated Aerospace/ Defense as Percentage of Total Revenue
Sanmina-SCI	San Jose, CA	12,473	5
Pemstar	Rochester, MN	700	2
Suntron	Phoenix, AZ	300	2
Sparton Electronics	Jackson, MI	180	40
Sypris Electronics	Tampa, FL	145	100
LaBarge	St. Louis, MO	130	30
XeTel	Austin, TX	120	20
Metric Systems	Ft. Walton Beach, FL	120	80
SMTEK	Thousand Oaks, CA	80	10
Corlund Electronics	Tustin, CA	70	10
MTI Electronics	Menomonee, WI	65	15
Harvard Custom Mfg.	Salisbury, MD	60	35
Nortech Systems	Wayzata, MN	60	20
Teledyne Electronics	Lewisburg, TN	60	30
SMS Technologies	San Diego, CA	45	10
Raven Industries	Sioux Falls, SD	35	50
Micro Dynamics	Eden Prairie, MN	30	20
Ramp Industries	Binghamton, NY	25	20
General Technology	Albuquerque, NM	25	95

of the EMS market will experience moderate growth over the next 5 years. In addition to technical capability, quality and dependable delivery at a competitive price remain the primary factors for contractors when selecting and continuing to use contract manufacturing partners. Responsiveness and customer service is increasing as a critical issue in total customer satisfaction. Total supply chain and material management is one of the fastest growing areas of importance in today's electronics market.

From the EMS perspective, finding effective ways to navigate the requirements and regulations of government contracting is essential to participation in the aerospace/defense market. Also, providers must adhere to the industry’s quality standards. The need for an effective material control system and component engineering capabilities to support this market will be critical.

Clear communication between aerospace/defense contractors, EMS suppliers, and other members of the supply chain concerning needs and requirements is critical for the survival of all. Only through open and honest dialogue can each stakeholder gain the benefit of understanding the technical and business issues facing each group in the current global electronics market.

Part V

Presented Papers:
The Human Element in Manufacturing

13

Keeping America Competitive: How a Talent Shortage Threatens U.S. Manufacturing

Phyllis Eisen
National Association of Manufacturers

Manufacturers in the United States are innovative, productive, and efficient. For decades the manufacturing sector has been the center of strength of the American economy and its prospects for future growth. Nonetheless, manufacturing faces several forces that have sparked a period of transformation. Global pressures are squeezing U.S. manufacturers as they face brutal competition from around the world. To continue to succeed, U.S. manufacturers must compete less on cost than on product design, productivity, flexibility, quality, and responsiveness to customer needs. These competitive mandates put a high premium on the skills, morale, and commitment of workers.

Relentless advances in technology have infused every aspect of manufacturing—from design and production to inventory management, delivery, and service. Today's manufacturing jobs are technology jobs, and employees at all levels must have the wide range of skills required to respond to the demands of an increasingly complex environment. Demographic shifts portend great change ahead. The "baby boom generation" of skilled workers will be retired within the next 15 to 20 years. Currently, the only source of new skilled workers is from immigration. The result is a projected need for 10 million new skilled workers by 2020.[1]

In addition, a long-term manufacturing employment and skills crisis is developing, one with ominous implications for the economy and national security. The loss of more than 2 million manufacturing jobs during the recent recession and anemic recovery masks a looming shortage of highly skilled, technically competent employees who can fully exploit the potential of new technologies and support increased product complexity.[2]

THE GROWING TALENT SHORTAGE

A study in workforce issues in manufacturing was conducted by the National Association of Manufacturers (NAM) at the onset of the recent recession and published in its report *The Skills Gap 2001: Manufacturers Confront Persistent Skills Shortages in an Uncertain Economy*.[3] The study revealed that more than 80 percent of the surveyed manufacturers reported a "moderate to serious" shortage of qualified job applicants—even though manufacturing was suffering serious layoffs. In sum, what manufacturing is facing is not a lack of employees, but a shortfall of highly qualified employees with specific educational backgrounds and skills.

NOTE: "Keeping America Competitive: How a Talent Shortage Threatens U.S. Manufacturing," a white paper prepared by the National Association of Manufacturers, the Manufacturing Institute, and Deloitte & Touche.

[1] A.P. Carnevale and R.A. Fry. 2001. The Economic and Demographic Roots of Education and Training. A paper commissioned by the Manufacturing Institute, Washington, D.C.

[2] National Association of Manufacturers. 2001. The Skills Gap 2001: Manufacturers Confront Persistent Skills Shortages in an Uncertain Economy. Washington, DC: National Association of Manufacturers.

[3] Ibid.

The most critical shortages of employees identified were in production and the direct support of production, including engineering and skilled crafts. Manufacturers also cited shortages in technical skills; inadequate basic employability skills; and inadequate reading and writing skills among both job applicants and incumbent workers. These skill deficiencies impaired manufacturers' ability to maintain production levels to meet customer demand, implement new productivity improvements, or deploy quality initiatives. In fact, some manufacturers said they could not accept new orders because they lacked the workers to produce their products. This shortage of skilled workers particularly hampered smaller firms. Some reported hat they could not schedule needed second or third shifts for the same reason. Others reported that they had advertised extensively for employees with specific skills—such as welders or electricians—and could not find acceptable candidates, or they hired entry-level workers whose skills were barely adequate.

While manufacturing's current situation is difficult, it may soon get worse. A research study conducted by the Educational Testing Service shows that the U.S. economy as a whole may face a growing shortage of skilled workers in the coming decade. The shortage for jobs requiring at least some degree of postsecondary education or training will exceed 10 million in the second decade of this millennium. This projected shortfall in the skilled-labor force is largely due to the interaction of demographics and technology and the failure of the educational system to keep up with the needs of manufacturing. Unfortunately, the sector's need for technically savvy employees comes at a time when experienced "baby boomer" employees will be retiring in large numbers and are being replaced with a relatively smaller pool of U.S.-based workers who often lack the appropriate technical skills.

These factors, when taken together, deepen the concern that many manufacturers did not successfully compete for talent in the 1990s and even in the current recession. Competition will only intensify in the next decade. This means that competent managers, engineers, technicians, skilled craftspeople, and front-line workers will be in even greater demand.

American Youth Are "Turned Off" by Modern Manufacturing

To uncover the reasons behind the talent shortfall and identify why fewer young people appear to be entering careers in this sector, the NAM, the Manufacturing Institute, and Deloitte & Touche recently conducted two major research studies. The findings reveal a troubling picture. Among a geographically, ethnically, and socio-economically diverse set of respondents—ranging from students in middle-school through college, parents, and teachers to policy analysts, public officials, union leaders and manufacturing employees and executives—the sector's image was found to be heavily loaded with negative connotations and universally tied to an old stereotype of the "assembly line," as well as perceived to be in a state of decline.

When asked to describe the images associated with a career in manufacturing, student respondents offered phrases of the kind listed in Table 13-1, such as "serving a life sentence," being "on a chain gang" or "slave to the line," or even being a "robot." Even more telling, most adult respondents said that people "just have no idea" of manufacturing's contribution to the American economy.

The research also explored what today's young people were looking for in their careers, how they make career choices, and how well today's educational programs support successful preparation for careers in manufacturing. With near unanimity, respondents across the country saw manufacturing opportunities to be in stark conflict with the characteristics they desire in their careers—and as a result, they do not plan to pursue careers in manufacturing.

TABLE 13-1 Student Respondents' Perceptions of Manufacturing Careers Versus Their Aspirations

Perception of Manufacturing Careers	Desired Career Characteristics
Assembly line	Interesting
Repetitious/boring/tedious	Creative/non-cookie cutter
Not something you dream about	Emotionally rewarding
Not ambitious/settling for less	Good quality of life
Serving a life sentence	Freedom to choose
Chain gang/slave/torture	
Dangerous/dark/dirty	
Hard work/long hours	
Low pay	Prestige
No benefits	Financially rewarding
No chance for promotion/dead end	Opportunities for growth/advancement
Sector in decline	Stable, high-growth sector
Jobs leaving the country	Ample U.S.-based jobs

Our Education System Is a Weak Link

The research also emphatically showed that the U.S. education system exacerbates the negative perception of manufacturing because it is largely out of step with the career opportunities emerging for young people in today's economy, including those in manufacturing. The United States sends more than two-thirds of its high-school graduates to college, but half of them drop out. The educational system fails to engage these students and help them enter alternative postsecondary programs. For those who do graduate, one-third fail to find employment requiring a 4-year degree. Meanwhile, many well-paid and rapidly increasing manufacturing jobs remain unfilled, including those requiring 2- and 4-year technical degrees or short-term skill certificates.

THE MANUFACTURING REALITY

The good news is that, as a whole, the reality of modern manufacturing is far different, far more complex, and much more attractive than the negative stereotypes identified by the research studies. Manufacturing is the productive core of the American economy, driving technological advance and providing enormously varied, exciting, and well-compensated careers.

Much More Than Assembly Lines

Employing professionals and skilled and semiskilled workers in nearly every imaginable specialty—from graphic designers, sales executives, and physicians to scientists, lawyers and marketing managers—manufacturing companies offer one of the broadest ranges of possible career paths. These employees are also well compensated, with the average manufacturing worker earning $46,000 per year in wages and an average total compensation package of $54,000 in 2000. Both of these figures are more than 20 percent higher than comparative averages for all U.S. workers.[4] In addition, 83.7 percent of manufacturing workers received

[4] U.S. Department of Commerce Bureau of Economic Analysis.

direct health-care coverage through their employers in 2001. Only the government provides healthcare coverage to a greater proportion of its workers.

Contrary to perception, assembly-line jobs are only a relatively small, and declining, part of modern manufacturing. Today, most modern manufacturing companies are light, clean, airy, pleasant, and safe places to work. Since the 1990s, workplace injuries have dropped by 30 percent.

In keeping with their focus on innovation, manufacturing companies also invest heavily in research and development and increasingly use the most advanced, cutting-edge technologies the world has to offer. Manufacturing accounted for 62 percent of all R&D performed in the United States.[5] This is telling, as R&D is the single most important source of the technological advances that lead to higher productivity and increased living standards for all Americans.

From 1992 to 2000, manufacturing productivity grew at double the pace of overall productivity growth. During this same period, manufacturing was responsible for one-third of the overall economy's growth in productivity. This increased productivity was in turn passed through to workers in the form of higher real wages and enabled the economy to grow faster without inflation.

Manufacturing's Place in the Economy

Also contrary to perception, the number of manufacturing jobs has remained roughly constant since the 1940s.[6] It is true, however, that manufacturing's share of non-farm employment has decreased, from 35 percent in 1947 to 14 percent today. Because of rapidly increasing productivity, manufacturing has sustained its overall share of a growing economy with the same absolute number of workers.[7]

Manufacturing also has one of the highest "multiplier" effects in terms of job creation. This means that every $1 million in final sales from manufactured products supports eight jobs in the manufacturing sector and an additional six jobs in other sectors, such as services, construction, and agriculture. In total, manufacturing jobs support 9 million jobs in other sectors.[8]

It is also true that the manufacturing sector as a whole is not in decline. Historically, the manufacturing sector has driven much of the U.S. economy's growth, although this contribution is not always recognized. From 1992 to 2000, manufacturing GDP grew at 4.6 percent annually—faster than the overall U.S. economy, which grew at 3.6 percent annually. Manufacturing also represents a significant and growing portion of the U.S. GDP, contributing a full 22 percent during this same period (Figure 13-1). By comparison, the service sector contributed 14 percent to economic growth, while transportation and utilities supplied 10 percent.[9]

Manufacturing's share of gross domestic product (GDP) as adjusted for inflation has been stable since the 1940s. For more than a half-century, the ratio of manufacturing output to GDP has ranged from 16 to 19 percent. GDP tells only part of the story, however, because it is measured by final sales. Forty-three percent of the nation's economic activity is composed of intermediate activity: the production of goods and services that go into making up final sales. Well over half of manufacturing activity takes place at this intermediate level—for instance,

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[5] National Science Foundation, 2000.
[6] National Institute of Standards and Technology, Washington, D.C., 2001.
[7] U.S. Bureau of Labor Statistics, 2001.
[8] National Association of Manufacturers' calculations from U.S. Department of Labor data, 2000.
[9] National Association of Manufacturers' calculations from U.S. Labor Department data, 2001; from 1992 to 2000, manufacturing contributed a full 22 percent to the U.S. GDP.

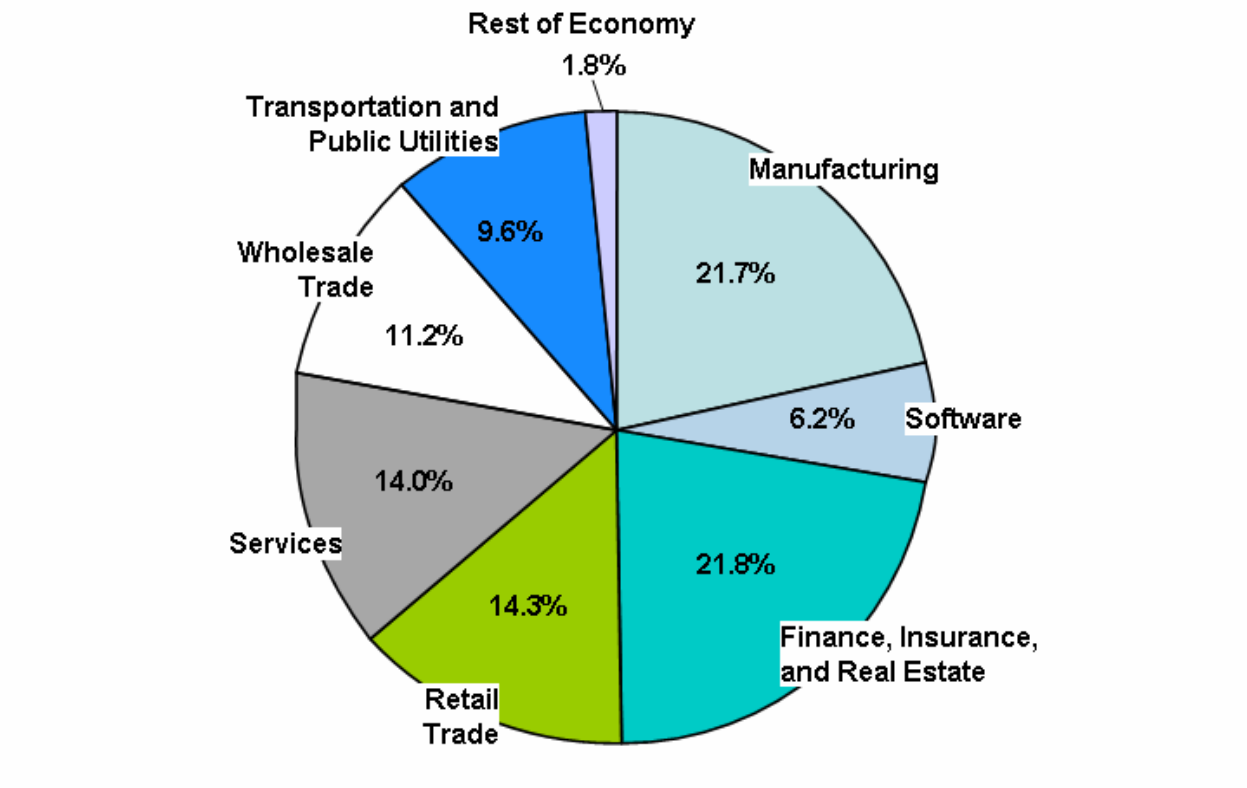


FIGURE 13-1 Manufacturing's contribution to the U.S. gross domestic product in 2000. Source: National Association of Manufacturers' calculations from U.S. Labor Department data, 2001; National Association of Manufacturer's calculations from U.S. Department of Commerce data.

primary metals and components of other products. When manufacturing's intermediate activity is combined with final sales, then manufacturing's share of the nation's total economic output rises to more than 25 percent.

Another way of looking at manufacturing's contribution to the economy is through its multiplier effect. For every $1.00 of a manufacturing product sold to a final user, an additional $1.26 of intermediate economic output is generated. Manufacturing's multiplier effect is greater than the general multiplier effect of 98 cents for all industries and far greater than that of the service sector, which generates only 74 cents of intermediate activity per $1.00 of final sales—40 percent less than the additional intermediate output generated by $1.00 of manufacturing final sales.[10]

In addition, it is important to remember that the United States is the world's largest exporter of goods and services. Manufacturing is responsible for 64 percent of the U.S. exports, making the United States the world's largest manufacturing exporter, and manufacturing's exports have grown rapidly in recent decades.

THE FUTURE OF MANUFACTURING

Manufacturing is, however, a cyclical sector and one that is undergoing a period of

[10] U.S. Department of Labor. 2001. National Association of Manufacturers' calculations from U.S. Department of Commerce data.

profound transition. It is also a sector in which many of the negative images revealed in the qualitative research remain accurate for some companies. In the United States today, there are some unattractive manufacturing jobs. As in other sectors, some manufacturers continue to fail to meet their responsibilities to their employees, shareholders, communities, and the environment. Happily, both the averages and the trends in modern manufacturing are starkly different. The responsible manufacturing community condemns such practices and offers careers that provide competitive wages, benefits, and opportunities for self-fulfillment and self-advancement.

Yet, the sector's cyclical nature is evident in the fact that it tends to suffer recessions earlier and come out of downturns later than other sectors. In the most recent recession, which has been particularly severe, manufacturing lost approximately 2 million jobs. This unhappy "availability" of unemployed manufacturing workers—or even the anticipated influx of "echo boomers"—is not a solution to manufacturing's long-term workforce problems. Demographics make the current situation almost irrelevant. By 2005, we will be feeling repercussions from the retirement of a major portion of the working population. In addition, as the economy recovers, manufacturers will once again expand their businesses and seek technically skilled workers to help them attain their business goals in a global economy.

While history indicates that some of the job losses from the recent recession will be permanent, new jobs will also be created in a cyclical recovery. Clearly, for the workers involved, such layoffs are severely disruptive. But history also indicates that many will be rehired in an upturn. Indeed, the question that many respondents raised is just how many new, higher-skill manufacturing jobs can be filled in the United States, given the shortage of skills in the labor force. Thus, what manufacturing faces is not a lack of employees but a lack of well-qualified employees with specific educational backgrounds and skills.

Several important trends have also sparked a period of transformation, including the movement of labor-intensive jobs offshore in response to cost pressures from global competitors in countries such as China. The configuration of manufacturing careers is projected to shift toward higher-skills professions: management; marketing; sales and services; and maintenance operations, with higher technology becoming even more pervasive. Thus, careers in the manufacturing sector will become, on balance, even more attractive and desirable.

This projected pattern of future development is reinforced by a study performed by the National Research Council.[11] It concluded that by 2020 manufacturing will remain one of the principal means by which wealth is created and that it is critical that the United States be prepared to implement advanced manufacturing methods in a timely way.

This study also proposed that the evolving competitive climate will require agile, rapid responses by manufacturers to market forces, because sophisticated customers around the world will increasingly demand customized products. "The basis of competition will be creativity and innovation in all aspects of the manufacturing enterprise." Skilled workers will be a critical factor in national and organizational competitiveness. The study concluded that "workers in this climate will need a wide range of skills, including strategic planning, market analysis, engineering design, supply chain management, finance, production planning, and order fulfillment. Although not everyone in the manufacturing enterprise will be expert in all skills, the more skills an individual has, the more valuable [he or she] will be to the organization."

As the total number of manufacturing jobs has remained roughly constant for decades, many departing jobs have been replaced by new jobs created domestically by American firms or

[11] National Research Council. 1998. Visionary Manufacturing Challenges for 2020. National Academy Press, Washington, D.C.

by foreign firms establishing operations in the United States. Moreover, the jobs moved or created in other nations by American firms vary widely in nature. Some are labor-intensive operations no longer sustainable by manufacturers in the United States—manufacturers that cannot significantly raise prices because of global competition. In fact, they must reduce costs to survive by relocating to low-wage nations.

More commonly, American manufacturers are expanding their operations abroad to respond to the opportunities presented by growing economies everywhere, especially in advanced nations. In 2000, more than 70 percent of newly acquired or established foreign affiliates of American firms were in advanced, high-wage nations—chiefly in the European Union, not in low-wage developing countries. This effect has sometimes been described as the "high-wage paradox," with high-wage nations increasingly outperforming low-wage economies in attracting U.S. manufacturing foreign direct investment (FDI) flows, despite a common perception that FDI is mainly a means to access cheap labor. In 2000, only 17 percent of total U.S. manufacturing FDI flows went to low-wage economies, down from 29 percent in 1998.[12]

It is important in a global economy that American manufacturers establish a presence in large and growing markets around the world. Successful foreign manufacturers are doing the same thing, expanding their operations in the United States and elsewhere. The net effect is that in 2000, U.S.-based job-creating investment in business plant and equipment by both domestic and foreign firms totaled $1.2 trillion—more than seven times the amount invested by American firms abroad.

Yet, the greater challenge to America is not low-cost goods from low-wage producers in developing countries, but rather high-quality goods made by high-skilled workers in advanced and emerging economies. The potential exists that manufacturers will increasingly move production operations overseas to seek the technological talent that is being strategically and purposefully prepared in places like the European Union, the Pacific Rim (including China), and South Asia (particularly India)—if they cannot find this talent here.

THE CHALLENGE

To remain strong and continue to thrive in a highly competitive environment, U.S. manufacturing must surmount many challenges. High on that list is a need to attract a new generation of manufacturing employees prepared for 21st century jobs. Our research results were clear: Manufacturing is severely challenged by an old, negative image; an education and training system that does not understand or promote careers in manufacturing; and public policies that are not supportive of a robust manufacturing sector.

Unless the industry finds a compelling way to communicate a positive image and address education and training issues effectively, manufacturing could experience a shift from merely having a talent shortage to facing a serious labor crisis. This could foreshadow a significant decrease in manufacturing's competitiveness and accelerate the movement of American productive capacity and well-paid manufacturing jobs overseas. These events could deliver a decisive blow to an already fragile economy and even undermine national security.

By pulling together as so many other industries have done, a number of highly effective programs could be launched, including national advertising and public relations campaigns, career-planning development efforts, localized school outreach, plant tours and educational programs. In addition, if manufacturers want a greater share of the talent pool, then they must compete more effectively by marketing jobs that offer respected and fulfilling career paths.

[12] Deloitte Consulting and Deloitte & Touche LLP. 2001. Globalizing Through Turbulence: Global Investment Trends of U.S. Manufacturers.

Given the urgency of the situation, the National Association of Manufacturers has committed to doing its part to help make manufacturing a preferred career choice by 2010. As part of this effort, it plans to work with the administration, Congress, the press, educators, parents, and students in a long-term strategy for the renewal of manufacturing and the transformation of how it is viewed as a career choice. The National Association of Manufacturers will implement the following targeted activities at the community level:

- Advocating public policies that will maintain and strengthen the manufacturing sector;
- Launching an awareness campaign to promote the desirability of manufacturing careers in modern manufacturing firms;
- Filling the career-information void with copious data for counselors, teachers, parents, and students; and
- Working to make education and training in both the private and public sectors more relevant to manufacturing's needs.

The urgent goal is to energize and focus the sector's many resources to solve its common problem. To that end, the NAM has issued four challenges:

- To the President of the United States: Declare U.S. manufacturing a national priority.
- To the U.S. Congress: Establish "National Manufacturing Day" to recognize this priority.
- To manufacturers in the United States: Open your plants and facilities to young people, teachers, and parents on National Manufacturing Day.
- To educators in the United States: Bring your students and guidance counselors to a modern manufacturing facility on National Manufacturing Day.

U.S. manufacturing can emerge from this period of transition stronger and better equipped to compete on a global basis and maintain its core contributions to the American economy. The NAM invites all interested parties to join in this effort.

14

Economic Challenges to American Manufacturing: A Labor Perspective

Ron Blackwell
AFL-CIO

American manufacturing, particularly from a laborer's point of view, is in crisis. Approximately 54,000 new manufacturing jobs were lost in February 2003. That was the 30th consecutive month of lost jobs in manufacturing. At this point, manufacturing employment numbers in the United States are the same as they were in 1961. The question is whether we can do everything that we want to do as a nation, employing that number of people in manufacturing products for the nation and the world. An analogy is often made between the transition from agriculture to manufacturing and the transition from manufacturing to services. There is an important difference between these two transitions, however. The United States is an agricultural-product-exporting nation. Agricultural products are one of our most successful exports. The manufacturing sector, in contrast, is currently undergoing a trade deficit of nearly 5 percent of the country's gross domestic product (GDP), with no signs of improving.

Manufacturing is an important industry for many states, and manufacturing activity is spread diffusely across the country. The question is whether or not, if the current economic course is held, the United States will continue to have the manufacturing base that it needs. From the labor point of view, the answer is, absolutely not.

EMPLOYMENT TRENDS IN MANUFACTURING

There was an enormous burst in employment of manufacturing production workers in the 1960s (Figure 14-1). Before that, in the 1950s, and after that, in the 1970s, there were ups and downs, but employment remained fairly stable. During the 1979 recession, there was a sharp decline in the number of production workers, which continued through the early 1980s. At that time, actions by the Federal Reserve Board drove interest rates up, drove the value of the dollar up, and drove manufacturing straight down in terms of employment. The U.S. manufacturing industry did recover somewhat in the 1980s. However, the most recent recession, between 2000 and 2003, although it has been fairly short and shallow for the economy as a whole, has been devastating for manufacturing. It is nothing less than a depression in American manufacturing, rural or urban distinctions aside.

The relationship between manufacturing productivity and wages is an important one for the American labor movement. Two important phases can be distinguished in the postwar period (Figure 14-2). From 1949 to 1973, there was rapid economic growth and rapid productivity growth, with rapid wage growth matching productivity growth step by step. The American middle class was built during this period when real family incomes doubled. There has never been such a growth in the living standards of people in the history of the world. Since the early 1970s, however, manufacturing growth has slowed and wages have actually fallen. An enormous gap has opened up between the productivity of American workers, still the most

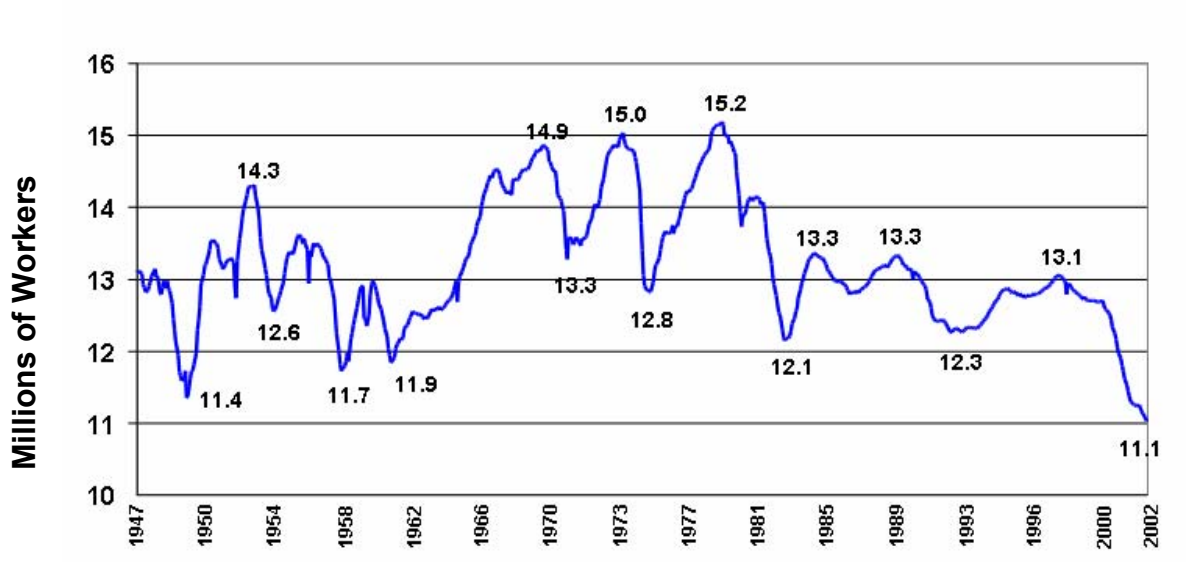


FIGURE 14-1 Number of production workers employed by the U.S. manufacturing sector, 1947 to 2002. SOURCE: Department of Labor.

productive manufacturing workers in the world, and the wages that they earn.

This gap is one of the labor movement's most serious concerns, along with maintaining production. Workers in the manufacturing sector earn on average $24.30 per hour, in comparison with $22.06 per hour for workers in non-manufacturing sectors and $19.74 for workers in the service sectors.[1] Within manufacturing jobs, there is a considerable advantage to being in a union, because both wages and benefits are higher for workers represented by a union.[2] Unfortunately, there is a declining union density and varying amounts of union representation in most industrial sectors.[3] This declining power of worker representatives in manufacturing has caused the gap to open up between compensation and productivity. In addition, over the past decade there have been significant changes in production workers across industries (Figure 14-3).

SHORT-TERM, CYCLICAL CHALLENGE

The current recession is not like any previous postwar recession. It was not caused by the Federal Reserve Board acting to stamp out inflation. Rather, this recession was caused by a decrease in business spending, especially in manufacturing, following an overinvestment in manufacturing during the 1990s. The decline in production during this recession caused capacity utilization to dive from 81.7 percent in June 2000 to 72.9 percent in December 2001 (Figure 14-4). Between March 2001 and December 2002, manufacturing employment dropped from 12.3 million to 11 million. This decrease of 1.3 million production workers represents over 90 percent of all jobs lost during this recession. The recession is therefore a manufacturing-driven phenomenon. The decrease in business spending in the manufacturing sector has brought the entire economy into a recession and has created a short-term crisis in the

[1] Lawrence Mishel, Jared Bernstein, and Heather Boushey. 2003. The State of Working America, 2002/2003. Ithaca, New York: Cornell University Press.
[2] Bureau of Labor Statistics, Department of Labor. Available at http://www.bls.gov. Accessed November 2003.
[3] Kate Bronfenbrenner and Robert Hickey. 2002. Overcoming the Challenges to Organizing in the Manufacturing Sector. Unpublished report submitted to the AFL-CIO.

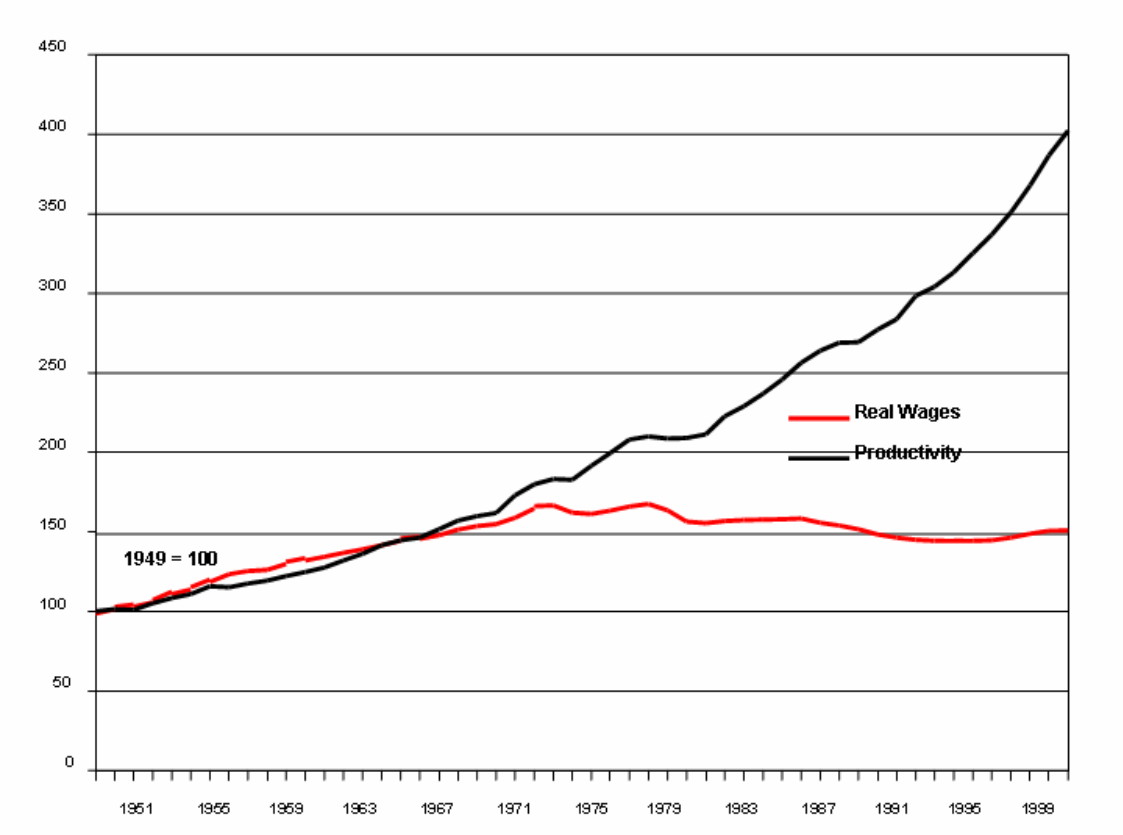


FIGURE 14-2 Manufacturing productivity and real-wage indices, 1949 to 2000. SOURCE: Department of Labor.

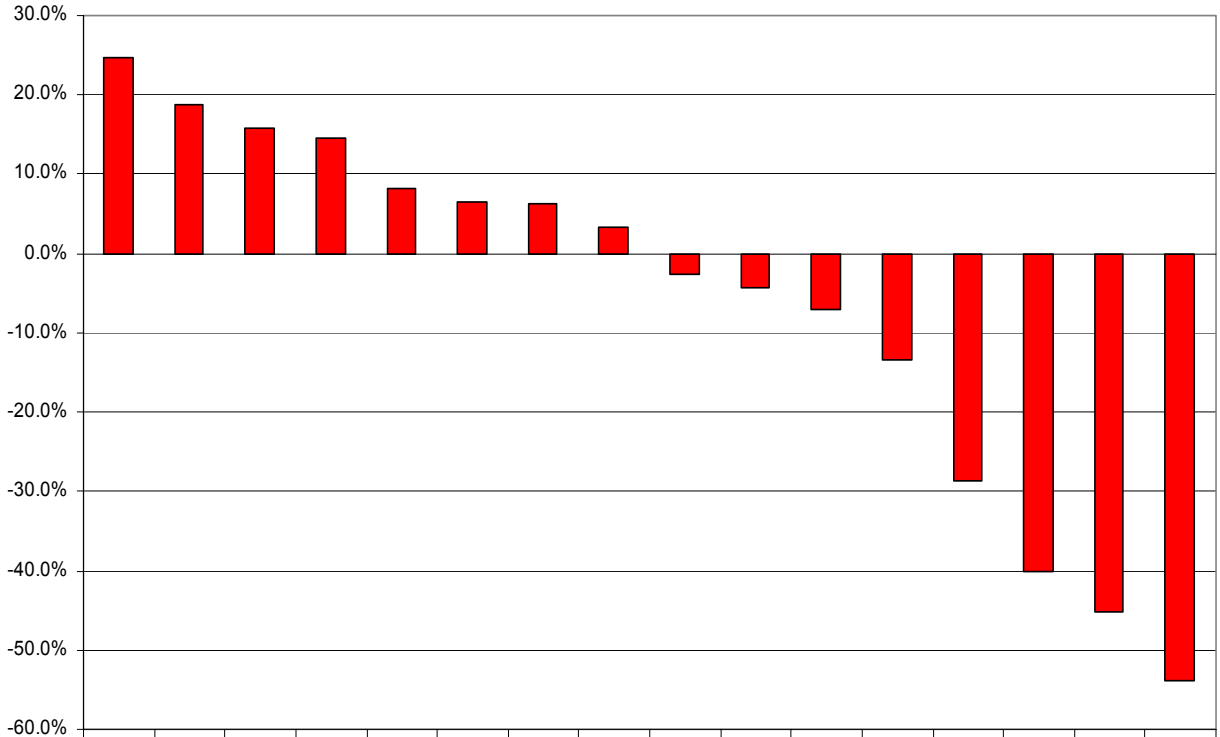
manufacturing sector.

The short-term, cyclical challenge that we face is a manufacturing-led recession with what I will call a manufacturing-constrained recovery. Before we can solve the short-term problems faced in this recession, it is essential to deal with the problems of manufacturing. In particular, it is essential to deal with the problems of manufacturing capacity, because manufacturing constraints will be reached before the economy recovers.

There has been a lot of discussion about economic growth and President Bush's plan for stimulating the economy. The American labor movement disagrees with the predicted economic impact of this plan. The economy is more open than in earlier recessions, with imports and exports as a percentage of national income being much higher. Therefore, if the government spends money now, in the form of new government spending or tax increases, a large part of the money will be spent on goods not manufactured in the United States. The same initial expenditure will not result in the same stimulus as before. If we try to expand the economy without dealing with manufacturing problems, politically unsupported levels of budget deficits will be generated long before there is any traction in labor markets.

LONG-TERM, STRUCTURAL CHALLENGE

The two major imbalances that existed in the economy going into this recession were private sector debt, which will not be addressed here, and the trade deficit. The trade deficit



	Total Private Sector	Fab. Structural metal	Motor vehicles	Rubber and Plastics	Lumber/ wood prod.	Food and kindred	Furn. + fixtures	Indust. mach. + equip.	Elec. equip.	Paper prod.	Primary metal ind.	House-hold applianc	Textiles	Aero-space	Apparel	Leather
%	24.6%	18.8%	15.8%	14.5%	8.2%	6.5%	6.2%	3.3%	-2.7%	-4.4%	-7.0%	-13.5%	-28.7%	-40.1%	-45.3%	-53.9%

FIGURE 14-3 Change in employment of production workers across different industrial sectors, 1989 to 2000. SOURCE: Economic Policy Institute and Bureau of Labor Statistics.

represents an enormous imbalance in our external accounting, nearing 5 percent of the GDP last year. Such a trade deficit would shake the currency of any country except the United States. This trade deficit is entirely the result of the balance of trade in manufactured goods. Each day, the United States borrows $1.3 billion to pay for the goods that are consumed here but not produced here. When this money isborrowed, the interest must be paid. In 2001, the United States owed $2.3 trillion, or close to 23 percent of the GDP, from this practice of consuming beyond our means. By 2006, unless these policies and practices are changed, it is estimated that the United States will have built up a debt equal to 40 percent of the GDP.

This is the long-term, structural challenge that the United States is facing. There are several ways of responding to this challenge. One option is to continue to borrow indefinitely, which is how the politicians in Washington, D.C., seem to treat this problem. The second option is to consume less. We may be forced to do this if other countries won't continue to lend us the money to buy these things. The third, and preferred, option is to produce more so that we can pay for the goods that we consume and support a higher standard of living. Maintaining the standard of living of the United States therefore depends directly on what we do or fail to do about manufacturing.

LABOR'S STRATEGY

To deal with both of these challenges, labor's strategy is to join the campaign to restore the industrial base of the United States. In this sense, labor shares the perspective of the

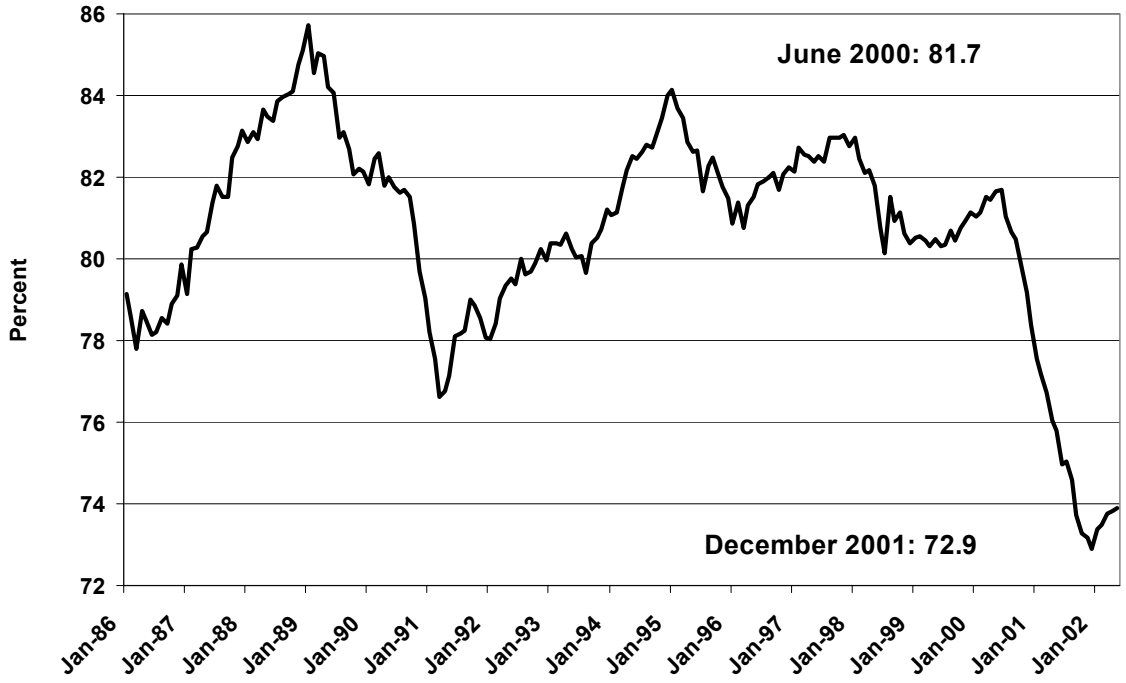


FIGURE 14-4 U.S. manufacturing capacity utilization, January 1986 to May 2002. SOURCE: Federal Reserve Board.

National Association of Manufacturers, although there is probably little agreement on the means by which this should be accomplished. In addition, as the American labor movement, it is important to recognize the need to organize the workers that remain in American manufacturing industries. Unless the workers are organized, the gains from increased manufacturing productivity won't be distributed very broadly.

There was a time in the 1960s when, even in modest industries such as apparel, manufacturing production workers, for example sewing machine operators, were at least 50 percent more productive than their competitors internationally. American workers are the most productive workers in the world, and yet they don't earn enough in this industry to support a family above the poverty level. The reason for this is that these industries have been hit by international competition. American workers are put in direct competition with some of the most oppressed, impoverished, and exploited workers in the world in a trade regime that neither respects nor protects either workers' rights or human rights. New changes in manufacturing technologies allow this fundamental imbalance to take place. Unless policies are found to address this issue, there is no solution to the problem of manufacturing going forward.

At that time, companies in Japan were competing with companies in the United States, and it was a challenge for America and for American competitiveness. Eventually, however, this trend progressed from the textile and apparel industry into the electronics, automobile, and most other manufacturing industries. Many companies then made the decision to outsource. Now we are in a situation where manufacturing is still going on, it's just not going on in the United States. From a labor perspective, the health of the companies is important because the welfare of our members depends on the success of these companies. However, these companies can compete with each other in different ways. They can compete in what I will call "high-road"

ways, in which everybody benefits, including the people that work for them and the country itself. Or they can compete in “low-road” ways, in which the only winners are the shareholders or the chief executive officers. Manufacturing companies today are under tremendous pressure from a variety of sources, including increased competition in the product markets. For domestic industries, this pressure may have come about as a result of deregulation and privatization of services and goods. In the manufacturing industry, however, the real challenge has come from the internationalization of production. Labor urges that manufacturing companies face this competition in high-road ways.

15

The Crisis in U.S. Manufacturing: A Union View

Stephen R. Sleigh
International Associate of Machinists and Aerospace Workers, AFL-CIO, CLC

The U.S. economy continues to reel from the multiple impacts of the economic downturn that began in 2000 and that turned into a severe recession for certain sectors of the economy after the terrorist attacks of September 11, 2001. Even before the overall economy stalled, the manufacturing sector had begun a long downward slide. The numbers look grim from a number of vantage points:

- In August 2003, non-farm employment fell by 93,000 jobs. This was the 7th consecutive month of job losses. Manufacturing shed an additional 44,000, with August 2003 being the 37th consecutive month of falling employment in this critical sector of the economy.
- During the 1990s, more than 24 million jobs were added to the American economy. Almost 2.7 million of those jobs have been lost since January 2001.
- All in all, there are currently 15 million unemployed and underemployed workers, a 42 percent increase since President Bush took office.
- In manufacturing, employment is falling in both relative and absolute terms.[1]

A UNION VIEW

As the head of research and strategy for a major North American labor organization, I am involved in many situations that require creative responses to difficult issues. My union, the International Association of Machinists and Aerospace Workers (IAM), represents nearly 750,000 active and retired workers throughout North America. The IAM core industries are aerospace, air transportation, and general manufacturing. The IAM has collective bargaining agreements that spell out the terms and conditions of work for nearly 5,000 employers. The profile of employers is fairly typical for the economy overall, with a few very large employers and many small and mid-sized companies.

The large companies, such as Boeing, United Airlines, and General Electric, attract the majority of public attention with high profile disputes between labor and management. While our relationships with large employers do occupy a lot of our attention, the problems of the 10-person company are just as difficult and time-consuming. The current economic environment, characterized by downturns in all the IAM core sectors, has resulted in the largest 2-year drop in membership in a history that dates back to 1888.

NOTE: The views expressed in this paper are those of the author and not necessarily those of the International Association of Machinists.

[1] Data based on U.S. Department of Labor reports produced by the Bureau of Labor Statistics and summarized in "Employment Situation Report of the BLS," September 5, 2003, Frank Parente, AFL-CIO.

My own work history is a case in point. I served an apprenticeship as a machinist in the mid-1970s, a time when manufacturing jobs at decent wages were readily available, even for individuals like myself who had just graduated from high school with no specialized skills. Shortly after completing my 4-year apprenticeship, I took a job with the Goss Printing Press division of Rockwell International. At the time, Goss was the dominant producer of newspaper printing presses, holding approximately 80 percent of the worldwide market for large offset presses. With manufacturing and service facilities in the United States and the United Kingdom, Goss was well positioned with dominant technology, a solid workforce, and fat profit margins.

After a decade of spin-offs, recapitalizations, and changes in management, however, Goss lost its way. The company was overtaken by both German and Japanese competitors that then sourced much of the manufacturing out to China. In 2001, Goss filed for bankruptcy, closed its U.S. manufacturing facilities, and sourced new production from China, while keeping most of its servicing operation and sales force in the United States. The net effect was the loss of nearly 1,000 skilled U.S. manufacturing jobs and as many as 4,000 ancillary jobs for suppliers and others.

This story has been repeated a thousand times in the last few years. U.S. manufacturers that were once dominant can no longer compete with aggressive manufacturers in Europe, Asia, and, especially, China. The causes may be complex, but the effects are simple: displaced workers, loss of capacity, and reduced tax revenues. Saving manufacturing is important for the United States for many reasons, not least of which is national security. We must maintain the capacity to produce the armaments of democracy. Manufacturing jobs provide important opportunities for new entrants into the workforce; manufacturing jobs have a high multiplier effect and create or support nearly three jobs for each job; manufacturing brings together technical innovation with operational know-how that creates real value for consumers. For these and many other reasons, manufacturing is worth special consideration from economic policy makers and research groups.

POLICY RESPONSES

How should the United States address these issues and ensure a durable recovery for manufacturing? There are a number of common themes for troubled manufacturing companies that could be dealt with through economic policy.

Value of the Dollar

The value of the U.S. dollar must be adjusted and stabilized. U.S. manufacturers are, in effect, paying an export tax, while foreign competitors are receiving a subsidy through exchange rate policies that inflate the value of the dollar. Consumers benefit from such a subsidy by being able to buy inexpensive imports. However, jobs are clearly more important than cheap shirts.

Offshore Manufacturing

Tax subsidies should be limited or eliminated for U.S. companies that move manufacturing capacity offshore. U.S. taxpayers should not be expected to underwrite the export of their own jobs.

Trade Laws

Trade laws should be rewritten to encourage fair trade based on internationally recognized standards of work. Through consensus agreement of all nations, the International

Labor Organization (ILO) has developed a list of core labor standards, including freedom of association and collective action and freedom from forced labor or discriminatory practices. This list should be made a part of all trade agreements. As the economy becomes truly global, attention must be paid not only to financial interests, given priority under current free trade pacts, but also to a broader view of economic activity that includes the impact on the producers of wealth.

Health Care

There must be an increased focus on health care costs and quality. The United States spends more per capita on health care than any other OECD country. For the past 3 years, health care costs have increased at double-digit rates and will continue to increase. Manufacturing companies that are already facing financial problems have no option but to pass these costs on to employees. In the IAM, the leading cause of labor disputes is currently the shifting of health care costs. A difficult situation is thereby made significantly worse. Simultaneously, the health care system is virtually immune from the quality improvements that manufacturers have put in place over the past 20 years. According to the Institute of Medicine, between 44,000 and 98,000 Americans die each year from preventable medical errors. Policy makers must ensure that everyone pays a fair share for health care through a “pay or play” system that requires employers to either provide health care for their employees or pay into a state or federal pool that would cover the nearly 43 million Americans without health insurance. Policy makers must also require the sharing of information from health plans, hospitals, and health care providers on the quality of services provided. Such disclosures would allow consumers to make choices based on more information.

Training and Recruitment

Manufacturing is dying, but it’s not dead! The next generation of workers needs to be recruited and trained for high-skilled and general-production jobs. The average age of blue collar workers in aerospace, for example, is nearly 51 years. We anticipate that fully half of these workers will retire within the next 5 years, resulting in a dramatic loss of skills and knowledge. Acting now to attract new entrants into manufacturing will require a commitment from policy makers to ensure that such a choice is a sound one for new entrants into the workforce.

CONCLUSION

Manufacturing is in crisis. The five ideas outlined above clearly require extensive study and debate. But the time for engaging in such study and debate is short. Every day more capacity disappears, and getting it back will be difficult once it leaves our shores. Most of these issues are not, or should not be, divisive issues between labor and management in manufacturing. Our challenge now is to make the case for policy intervention to save a critical sector of our economy.

16

The Human Component in Manufacturing

Mark Troppe
National Center on Education and the Economy

During the last half of the 1990s, I worked with the Manufacturing Extension Partnership (MEP) of the National Institute of Standards and Technology (NIST). Here is where I really learned to understand the importance of manufacturing and how to work with manufacturing companies. Recently, I was reminded of an experience that occurred early in my tenure at NIST MEP. I was at a company with some MEP field engineers, and we were trying to get a better understanding of why the MEP technical field staff working with manufacturing companies seemed to be less cognizant of the human component of the manufacturing process. They'd go in and offer solutions involving new technologies, plants, and equipment but miss the fact that the plant suffered from terrible labor-management relations or had a hiring process that didn't look for a prospective employee's fit with the organizational culture. One of my hosts, an engineer, pulled me aside as I was expressing frustration with this and said, "Mark, it's not that engineers don't like people. It's that engineers don't like variation in the production process. An engineer's whole focus is to minimize variation, and people are often the greatest source of variation in the process." That was a good insight to learn early on, and I'd like to use it as a starting point for what I'll discuss today.

No discussion on the human side of manufacturing would be complete without mentioning the skills shortages that many are predicting as early as 2010. These shortages could result from demographic changes, a slowdown in the growth of the labor force, increased diversity, and aging of today's manufacturing workforce. It is impossible to overstate the importance of skills and credentials or certifications in improving productivity on the job. The link between education, earnings, and productivity is well documented. Obviously, if you don't have the technical know-how to get the required work done, you're not going to contribute much in a manufacturing setting.

I have some concerns about the public, not private, resources available to provide individuals already on the job with technical training. Most states have customized training funds that are rather flexible and can be used to support improving workforce skills. These funds are especially useful in dealing with the human element of introducing new technologies and production processes. Given today's current budget limitations, however, I am concerned about the continued viability of some of these state programs. While I haven't seen any hard data yet, I worry that these programs must be under tremendous pressure considering the tough choices that governors are faced with across the nation.

Many states are making more explicit links between the resources available for workforce development and economic development planning, strategies, and activities. Approximately 20 states have taken formal steps to reorganize and/or merge agencies with workforce and economic development responsibilities in order to capitalize on opportunities for alignment. Beyond these organizational realignments, there's a lot of encouraging progress on this front, in terms of the creative thinking around sector strategies and reaching out to

employers. Almost everywhere I go manufacturing is cited as one of the key industries for support.

However, state and local government agencies aiming to support manufacturing can sometimes be far removed from the demands of the marketplace. For example, I was in a state a few months ago, and they were rightly proud of the resources their economic development agency had for expanding and improving their manufacturing base. But when I dug a little deeper, I learned that, if you as a manufacturer wanted funding support to pay for training, you had to apply through one office. If you wanted help with process improvement and quality control issues, you had to make a separate application through a different office. And if you wanted assistance or a subsidy in making an investment in a new production technology, it required a third application and a third office. If a progressive manufacturer wanted assistance in these three areas at once, a lot of time would be spent in filling out forms. But how can you separate these three functions in the manufacturing process? Making services accessible to employers is important.

One federal program that provides some funds for training is the Workforce Investment Act (WIA), administered by the U.S. Department of Labor. Originally passed in 1998, it is now up for reauthorization. Under current law, states have considerable flexibility to use a portion of the federal allocation to support training of workers in companies, many in manufacturing. The statute authorizes states to use some of these funds for layoff aversion. As a result, many states use the funds for training involving new technologies or processes that enhance the productivity of companies. In this way, they are in a stronger competitive position and can reduce the need for layoffs or plant closings.

One illustration is the way that the Oklahoma Employment Security Commission is providing $100,000 in WIA dislocated worker funds to the Oklahoma Alliance for Manufacturing Excellence (the Oklahoma MEP center). With these funds, the Oklahoma Alliance is providing lean manufacturing training and in-plant implementation assistance in 20 small manufacturing companies, teaching employees a transferable skill, and helping the companies reduce wasteful steps (and save money) in their production processes. The public funding is more than matched by private investment from the company, and some companies have reduced costs enough to justify keeping their manufacturing operations in the United States instead of pursuing offshore opportunities.

The good news is that the WIA reauthorization process is likely to provide even additional flexibility for use of these funds by manufacturers as the WIA system strives to become increasingly business- or demand-driven. The uncertainty here is what the appropriators will do to overall funding levels, given growing budget deficits and demands for the war effort.

Public policy and public funding in the workforce arena have concentrated primarily in three areas: providing income support to people out of work, matching people to jobs, and providing training to increase skills for better jobs. For the most part, this policy rightly assumes that the public has some responsibility for addressing skill deficiencies—and federal and state labor agencies have acted in this arena. But job placement and training are only two components of the range of people issues facing manufacturing companies in their efforts to keep pace.

It’s important that we not lose sight of the broader context in which those higher level skills are applied, i.e., the workplace, and the people practices that employers engage in, in order to make maximum advantage of the skills and knowledge of the workers:

- Culture—openness to new ideas, continuous improvement, collaboration, information sharing, and common mission/vision;
- Hiring process—recruitment and screening, orientation designed to help employees understand their role and where they fit in the bigger picture;
- Performance management—reviews, incentives such as rewards for contributing ideas to continuous improvement;
- Compensation and benefits—rewarding behaviors consistent with the same mission/vision; and
- Training and development practices—whether companies provide opportunities for workers to obtain the skills needed to be productive and to apply those skills effectively in the workplace.

These are all aspects of the human side of manufacturing. When a company's people practices are aligned with its business strategies, you can see great results. If not aligned, they can derail even the most sophisticated technologies and engineering strategies. All these aspects must be considered as part of a larger context of the manufacturing entity.

No single entity such as a public workforce or economic development agency can effectively address all of the needs on the human side of manufacturing, especially as they relate to other concerns about new products, new technologies, financing, new markets, and the drive for "faster, better, cheaper." Increasingly, however, I am seeing that communities pool expertise and resources from multiple organizations, public and private, to holistically address the needs of manufacturers. Participants at the local and regional levels include workforce and economic development agencies and organizations, local Chambers of Commerce, community colleges and private education providers, literacy councils, state and local chapters of business and industry associations, the local manufacturing extension centers, small business development centers, and organizations promoting entrepreneurship.

The communities that can figure out how to meld the unique mix of resources and expertise that they have into a mature service provider network at the local level—for the betterment of individual employers, particularly manufacturers—will have a comparative advantage over those communities that don't. Moreover, they will result in benefits to participating employers, the employees, and the communities in which they reside.

I'm encouraged by the fact that employer attitudes have changed in recognition of the critical contribution of people to the success of recent organizational transformations. The following quote from *Industry Week* references its competition to identify America's best plants:

> Ask [the leaders of America's Best Plants] the most important element in the pursuit of a world-class level of customer focus, and the same answer is tendered. Ask them the key to attaining perfect quality or how to build an agile organization, and you'll get the same answer again and again: 'people.' People are the power that drives Best Plants.
>
> . . . until the last decade or so, 'people' was not always the answer you would get when you asked [these] questions. Instead, you might hear about automation or strategy or plain old managerial savvy. The way some managers told it, employees were actually a substantial barrier to business success. They didn't want to work; . . . they just wouldn't do what they were told.

> Well, one of the most satisfying aspects of studying the Best Plants is hearing over and over again exactly how foolish that thinking was and is. . . . [Managers] clearly believe that the participation, creativity, and knowledge of every employee was a decisive force in all their accomplishments.[1]

[1] Theodore B. Kinni. 1996. America's Best: Industry Week's Guide to World Class Manufacturing Plants. p. 77.

VI

Presented Papers: The Way Forward

17

Standards and Infrastructure: Foundations of Manufacturing Competitiveness

Arden L. Bement, Jr.
Director, National Institute of Standards and Technology

At first glance, the topic of standards and infrastructure might seem a bit drab. Some of you might even be asking, Why give it equal billing on a marquee devoted to exciting emerging technologies, such as next-generation information technology, nanotechnology, and other candidates for the “next big thing”?

Why, indeed. Well, I am about to assert—and I hope to convince you—that standards, measurements, tests, and the like belong, at least, in the subtitle for every marquee-grade technology and even for technologies that are now commonplace. This technical infrastructure underpins all aspects of manufacturing—from innovation and proof of concept to process development and mastery to supply-chain and marketplace transactions.

The technical infrastructure for current and future manufacturing operations is something we care a great deal about at the National Institute of Standards and Technology (NIST). We are a partner to the manufacturing sector, usually a silent one. Often, NIST’s work is done behind the scenes, and the results of this work become embedded inevitably into products and processes.

To manufacture well, and to be at the forefront of technology development and commercialization, you must measure accurately, precisely, and efficiently. Advances in measurement capabilities speed the emergence and eventual maturation of new technologies. For historical perspective, consider the humble gage block. Gage blocks are simply standardized sets of hardened steel blocks of accurately determined thickness. With their introduction early in the last century, manufacturers greatly improved their ability to produce parts within tolerances. This enabled the rise of mass production and interchangeable parts.

Measurements, in turn, are integral to many varieties of so-called documentary standards—those specifying, for example, the dimensions of screw threads, the diameter of optical fibers, the content of steel alloys, information technology interfaces, electromagnetic compatibility requirements, the performance of machine tools or robots, and so on. In specifying characteristics or performance levels, standards promote efficiency in domestic and international markets. By adhering to agreed-upon standards, for example, businesses can negotiate according to widely accepted criteria for products or services, avoiding ambiguities that might otherwise undermine transactions.

Today, standards are so commonplace that they are taken for granted. In some quarters, they are considered to be about as interesting as watching paint dry. In today’s brutally competitive global economy, however, disregard of the importance of standards can be a strategically costly omission. Remove this inconspicuous platform of technical support, and life as we have come to expect it begins to unravel. Laboratories, companies, and entire industries may become less efficient. Transactions may cost more and take longer to conclude. Products may work with a smaller set of other products and services. Markets will fragment. Today, an

estimated 80 percent of world merchandise trade is affected—for good and, sometimes, for bad—by standards and regulations that embody standards. So, standards are fundamental to this nation's economy and vital to world commerce. In fact, the American Society of Mechanical Engineers ranked the promulgation of standards among the top 10 engineering accomplishments of the last century. Standards shared top-10 honors with such accomplishments as the inventions of the automobile and airplane.

Now, let's fast forward to the present and begin to contemplate future directions for U.S. manufacturing—within the context of the nation's technical infrastructure for innovation, for manufacturing, and for global trade. Simply stated, the better this underlying foundation and the more effectively we use it in research, production, and in the marketplace, the brighter are the nation's prospects for maintaining a vigorous manufacturing sector and for sustaining U.S. leadership in high technology. To be sure, the ingredients of manufacturing competitiveness and economic growth are many, but the quality of our measurement and standards infrastructure ranks high among them.

Consider the intense pressures on existing manufacturers to cut costs, raise quality, and speed product development. Shrinking part and assembly tolerances are a clear physical manifestation of these and other pressures. Over the last half century, dimensional tolerances have decreased tenfold about every decade or so. The push for higher precision and greater accuracy in manufacturing processes is intensifying.

We often hear about the wonders that will be delivered from the bottom up—that is, from the still-emerging capability to build devices molecule by molecule or atom by atom. But high-precision machining processes also are descending onto the realm of nanotechnology. At the same time, large-scale fabrication—from the assembly of jumbo jets to the manufacture of massive earth-moving equipment—is going to dimensional extremes. Today, the longevity and reliability of car engines depend on manufacturing tolerances of a few micrometers—about the width of a single bacterium. In the future, parts manufacturers will, so to speak, be splitting hairs again and again, just as they are in the microelectronics industry.

At NIST, one of our jobs is to help manufacturers achieve smaller, ever-more-exacting tolerances in machining and assembly, which translate into improvements in quality, functionality, efficiency, and productivity. During the 1980s, NIST researchers invented a new type of measurement technology, now known as "laser trackers." Now common in aircraft manufacturing, these three-dimensional measurement systems literally take laser interferometry to great lengths. State-of-the-art laser trackers can measure parts that are many meters long with an accuracy of about 25 micrometers. This technology is yielding many benefits. In the aerospace industry, the instrument is used to do in-process measurements and to correct machine-tool path errors in real time. With the technology, manufacturers are achieving tighter tolerances and cutting cycle time. In addition, aerospace firms use laser trackers to make digital parts from full-scale models. Companies reportedly save $4.5 million a year in reduced maintenance costs for each master model. The laser tracker illustrates how advances in measurement capabilities, which are then solidified in standards, can help existing manufacturers raise the bar in terms of cost, performance, and quality.

For aspiring industries—such as nanotechnology—new measurement capabilities can help to bridge the difficult gap between tantalizing prospect and affordable, process-ready product. The diverse nanotechnology industry—or industries—that people envision will require the 21st century equivalents of the gage blocks that were part and parcel of the emergence of interchangeable parts and mass production. To deliver on the promise of nanotechnology, we ultimately will need industrial measurement systems that are reliable, fast, and affordable. We have a ways to go, but progress is being made. NIST, for example, is developing atom-based

dimensional standards. We can measure the width of lines by counting the number of atoms across. We have built a laser interferometer that can measure distances in trillionths of a meter. That's smaller than the diameter of a single atom. And we have demonstrated a repeatable method for writing features with dimensions as small as 10 nanometers on silicon surfaces. This is one of several promising avenues that we are pursing to create new measurement references for manufacturing nanometer-scale devices. And given the tremendous variety of nanotechnology applications on the research horizon, the assortment of measurement references under development at NIST also is diverse. The chemical processing and biotechnology industries, for example, are the intended beneficiaries of a suite of experimental methods for detecting, identifying, and manipulating individual molecules.

In thinking about ways to help U.S. manufacturers separate themselves from the global pack of competitors, we also must consider how best to exploit existing technological strengths. Clearly, the U.S. lead in information technology (IT), although no longer as secure, is a major source of competitive advantage. However, it has yet to be leveraged with full effect. We are, in fact, a long way from realizing the following vision for 21st century manufacturing put forth in a 1995 National Research Council study. I quote:

> . . . interconnecting manufacturing applications will be as simple as connecting household appliances to a power grid—one need only know how to run the application (equivalent to using a microwave oven) and manage the interface (plug it in and press a few buttons).[1]

This quest, the quest for true IT interoperability, still remains. The ultimate objective may seem a very distant prospect, but we are progressing. And each accomplishment along the way reaffirms the need to persist. I'll illustrate this with the Standard for the Exchange of Product Model Data—STEP, for short. A still-evolving, international standard, STEP provides a neutral format that enables the exchange of design and other product data between proprietary systems. Think of it as universally understood mechanical drawings for the Information Age. NIST played a key role in the standard's development, and we continue to contribute to industry-led efforts to broaden its application and usefulness. U.S. industries are saving millions of dollars a year by using STEP to overcome obstacles to exchanging product data within and between companies. Full implementation of STEP across the U.S. manufacturing sector would yield estimated annual saving of almost $1 billion. Efforts to improve interoperability—as well as software reliability, another important issue—will be repaid many times over. So, when we consider how information technology can be used to enhance all facets of manufacturing performance, I suggest that we think big and set ambitious goals.

At NIST, we are collaborating with IT vendors, with manufacturers who use their products, and with standards bodies on the initial stages of a bold interoperability initiative. With our partners, we are exploring the feasibility of developing the standards and other infrastructural elements that enable self-integrating systems. Self-integration would mean that software applications could negotiate meaning on the fly and exchange information in a completely automated way. For a simple analogy, think of the "electronic handshake" that enables fax machines of different vintages to communicate. Of course, many, many others have grand visions of next-generation IT applications in manufacturing. Given the globalization of manufacturing operations, it makes sense to pursue such visions on an international scale. It is also true that the value of information technology increases exponentially as more people

[1] National Research Council. 1995. Information Technology for Manufacturing: A Research Agenda. Washington, D.C.: National Academy Press. p. 122.

connect. One opportunity for such collaboration is the multinational manufacturing R&D initiative known as Intelligent Manufacturing Systems (IMS). NIST, for example, worked closely with an IMS project that aims to integrate the STEP standard with machine tool control. Projects that span national boundaries provide excellent opportunities to sharpen your global focus on manufacturing systems and processes.

We also must sharpen our focus on standards. Within the business community, there is growing chorus of calls for adoption of globally relevant, internationally recognized standards and elimination of duplicative testing to assess conformance with standards and regulations. Few would argue with this objective unless the resulting standards confer unfair advantage on the technology of foreign competitors. While many U.S. manufacturers and other businesses are alert to this danger, most companies do not participate in the development of standards at home or internationally. While they are idle, these businesses might see the international playing field that we hear so much about begin to tilt away from them, placing them in an uphill struggle for unfettered market access.

I encourage you to learn more about the new standards initiative launched last week by the Department of Commerce. As part of this initiative, the department will host industry-specific roundtables to gather input from companies on the most pressing standards issues and priority foreign markets. I invite the manufacturers here to participate. To ensure the future competitiveness of U.S. manufacturing, we—government and industry—must attend to all the important details.

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Collaborating to Meet Manufacturing Challenges

Rebecca Taylor
National Center for Manufacturing Sciences

The National Center for Manufacturing Sciences (NCMS) is a not-for-profit research, information, and education consortium that provides value-added products and services to enable collaboration and learning among manufacturers. NCMS brings manufacturers and other organizations together to solve common problems, as well as to host forums and discussions that lead to collaborative learning and advancement of manufacturing. NCMS is the largest cross-industry consortium in the nation with over 150 member companies, including General Electric, Raytheon, DaimlerChrysler, Boeing, Eaton, Delphi Automotive Systems, General Motors, and Microsoft. However, most NCMS members are small and medium-sized companies from all sectors of the economy. One strength of NCMS is its diversity. This diversity facilitates collaboration by allowing companies to work with others outside of their own industrial sector.

NCMS also maintains strong partnerships with the public sector, including programs with the Department of Defense (DoD), the Department of Energy (DOE), the Department of Commerce, the National Aeronautics and Space Administration, the U.S. Environmental Protection Agency (EPA), and the National Science Foundation. NCMS has 16 years of experience with public-private sector collaborations, including 40 cooperative research and development agreements and memoranda of understanding; 116 DoD projects totaling $300 million; and 6 National Institute of Standards and Technology Advanced Technology Program projects totaling $115 million. NCMS public-private projects received the prestigious R&D 100 Award for four consecutive years.

NCMS identifies its core competency as a “venture catalyst.” NCMS identifies needs, creates projects, manages intellectual property, and manages the legal and financial side of collaborations so that the organizations involved can get on with the business of collaboration. NCMS has a diverse array of experts, including scientists and engineers from many industrial fields. Another strength of NCMS is the fact that it acts as a neutral broker. By acting as a disinterested third party with no interest in selling a particular technical solution or outcome, NCMS can serve as a buffer between the government and industry, thereby facilitating collaboration.

NCMS PROGRAMS

One of NCMS’ public-private partnerships is the Commercial Technologies for Maintenance Activities (CTMA) program. This collaboration between NCMS and DoD’s maintenance facilities introduces commercial manufacturing technologies into the nation’s depots, shipyards, and air logistic centers. DoD has weapon systems, aircraft, and ships that are running well past their planned lives. Successful sustainment and maintenance of these aging weapon systems involves innovative manufacturing solutions. NCMS works in partnership with the maintenance facilities to solve manufacturing challenges with commercial solutions while advancing the state of technology in both the public and private sector.

NCMS works with EPA on compliance assistance issues. NCMS reaches out to small and medium-sized companies to ensure that they can meet current EPA regulations and to help them meet future challenges. In collaborations with DOE, NCMS is in the forefront of alternative energy research, including fuel cells. In addition, NCMS works with DOE in looking at innovative ways to reduce energy consumption in the manufacturing enterprise.

Two NCMS programs are the Knowledge Solutions program and the Manufacturing Trust. The Knowledge Solutions program offers affordable, full-featured learning and communications services for member companies and the manufacturing community at large. NCMS creates e-learning tools and customizes them to fit the needs of the customer in an efficient and cost-effective manner. The Manufacturing Trust is the newest program area for NCMS. This program is a resource for industry members who share a common interest in improving their ability to defend the integrity of their critical infrastructure systems and trusted collaboration environments. The program provides access to advances and best practices that address critical infrastructure risks, threats, and opportunities for the manufacturing industry while striving to build trust among participants.

MANUFACTURING TRANSFORMATIONS

The landscape of manufacturing is ever changing. Previously, companies had large capital budgets that enabled them to easily make decisions to ramp up production or put in new production lines. Today, due to limited budgets, investments are being scaled back and enterprises are dealing with declining resources for capital investments. Formerly, automation was used to solve a problem. More technology was considered a good thing. Today, companies are increasingly aware of the benefits of having a good balance between machines and workforce. Previously, it was assumed that every problem had a technology solution, that it was just a matter of finding the right machine, system, or practice. Today, decisions must be balanced with business priorities and people priorities. The old model of a manufacturing enterprise was based on complex, integrated systems that produced all parts for an end product in-house. The new model of a manufacturing enterprise is simpler, modular, and looks at innovative production methods to achieve greater benefits.

For a long time, U.S. manufacturers were complacent about their position in the international manufacturing community. Today, however, there is greater interest in collaboration, sharing the risk, and sharing the cost. Previously, the arrival of a new technology would intimidate the workforce and cause them to feel insecure about their jobs. Today, these technologies are made invisible to the workforce to achieve efficiencies without intimidating the workforce.

21ST CENTURY CHALLENGES TO INDUSTRY

The manufacturing industry is currently facing a number of challenges. Increasing demands by primaries on their supply chains is one of the biggest challenges. For example, R&D requirements are being pushed further down the supply chain by the original equipment manufacturers (OEMs). R&D that was previously done in-house by a large company such as General Motors is now required of first-, second-, and even third-tier suppliers, who often don’t have the resources to conduct such R&D. In addition, the primaries are increasingly requiring best business practices from their supplier base. Those practices thus become necessary for companies to do business with the OEMs.

Another important issue is that of global sourcing and logistics. Companies that are dependent on overseas, or even nonlocal, suppliers, face challenges regarding delivery times, shipping, communications, warranty issues, and more. With global sourcing on the rise and

travel budgets being decreased, information conductivity is becoming increasingly important within industries, as well as between companies and their suppliers and customer base.

Information and infrastructure assurance within a manufacturing enterprise will become increasingly important in the coming years. Every manufacturing facility has taken steps for physical security—i.e., fences, guards, and badges—to ensure that persons entering the premises have legitimate business with the company. Less attention has been paid, however, to the security of all other critical infrastructures within the company. Last year, NCMS hosted a meeting with NIST to explore vulnerabilities in the manufacturing enterprise. The original plan was to publish the results of the meeting to raise awareness among manufacturers about the issues. However, the meeting results turned out to be, in essence, a handbook for how to shut down and disable a manufacturing enterprise. Wisely, the group decided not to make this information publicly available. To ensure operational continuity and continued productivity, companies must pay more attention to their vulnerabilities and must take steps to protect their critical assets.

Environmental issues are becoming increasingly important for reasons other than EPA and conventional environmental regulations. Customers are considering the impacts that the products they buy have on the environment. This drives purchase decisions regarding which products to buy and which companies to do business with. Europe, Japan, and some U.S. jurisdictions have become proactive environmentally and have passed laws requiring manufacturers to be responsible for the life of their products. For instance, even if an automobile passes through six owners, the manufacturer has responsibility for disposal or recycling at the end of the vehicle's useful life. Forward-thinking U.S. companies have already faced this new paradigm by beginning to design and manufacture for total life-cycle responsibility and by developing take-back strategies for their products.

TECHNOLOGY INNOVATIONS

A number of technologies are getting a lot of attention from both politicians and the press even though they are fairly novel and do not yet exist as industries. Nanotechnology, for example, is an industry still in its infancy, with not even a degree being offered in the discipline. According to a venture capitalist who helped build Nanophase Technology Corporation, the first nanotechnology firm, funding for the company was an act of youthful naiveté because it just wasn't ready to be a commercial company.

Manufacturability must be considered as the design and innovation process proceeds for these new technologies. Currently, little thought is being given to cost-effective production systems. For example, in the area of fuel cells and hydrogen energy, much attention has been given to demonstrating the technology. However, little thought has been given to the design for manufacturability of fuel cell units so that they can be produced efficiently and cost effectively. In addition, for the fuel cell idea to take hold in automobiles, a national infrastructure to handle refueling of hydrogen cars must be developed.

Homeland security has become very important. With the new challenges facing the nation, new technology requirements have emerged to deal with terrorism as well as chemical and biological threats. Many companies are feverishly working to develop solutions and innovative ways for dealing with these new problems. However, little thought is being given to efficient and cost-effective manufacturability of these technologies, without which they cannot be deployed widely and quickly. The same challenges are facing emerging sectors like microelectromechanical systems and smart materials. To ensure that the United States retains its lead in these sectors, more attention must be paid to design for manufacturability.

MEETING THE MANUFACTURING CHALLENGES

In order to succeed, manufacturing companies must think about how to deal in future with the above challenges. NCMS offers an effective method of dealing with these challenges: collaboration, or partnering with a purpose.

The three R's in collaboration are risk, resources, and resistance. Companies are motivated to collaborate by the reduction in risk, time, and cost involved in developing and deploying new technologies. In addition, collaboration helps a company to be "first to be second." No company wants to be the first to try a new product or process and risk the associated growing pains. Collaboration allows a group of companies to share the risks involved and facilitate the rapid adoption of a new technology. There is risk in sharing resources with a competitor or sharing company secrets with a supplier, but there is also the risk of falling behind if you don't. The best way to get a company to become involved in NCMS is by telling them that their competitors are engaged.

Collaboration requires resources from the company. While a company must commit internal resources to the collaborative project, these are much less than they would be if the project were undertaken alone. By cost-sharing, companies reduce the resources needed to accomplish their technological objectives. Finally, resistance is part of collaboration. Initially, there is resistance to getting involved at all. Once this resistance is overcome, quite often the resistance is from within the company itself. Collaboration is a new way of doing business, and often the legal and financial departments must be educated as well regarding the benefits in order to overcome resistance.

FUTURE MANUFACTURING PARADIGMS

The manufacturing enterprise in 2020 and beyond must adapt to work within the new manufacturing paradigms that are now being created. The better, faster, cheaper paradigm will remain a driving force as companies manage shorter cycle times, increased quality requirements, and customer demands for lower costs. Successful companies will be the ones that can strike a balance between these three challenges.

A broader concept of manufacturing will be used in the future, including software to convert information and materials into useful products, biotechnology in the manufacturing process, and aspects of agribusiness that complement the production process. Creativity and innovation will be the bases for this new concept as societal structures become more knowledge-based, dynamic, fluid, and globally distributed.

"Global swarming" is another future manufacturing paradigm. Previously, for example, in the manufacture of an automobile, ore entered the factory at one end and a car exited at the other. All production was done in one location. Today, the enterprise is dispersed, with smaller units everywhere all working for the collective, or swarm. An automobile company now has suppliers making parts and subsystems all over the world and many research and design functions done remotely, but still controlled by the "swarm." Issues of logistics and supply chains, among other things, become a challenge, but efficiencies are also increased. The same capital equipment can produce more. In addition, this manufacturing model enables tremendous agility and robustness, while requiring central coordination for effective production.

Increasingly, companies must consider how to transfer knowledge from an aging workforce. As experts with vast corporate knowledge exit the workforce, methods must be developed to ensure that institutional memory is captured and made available to future employees. In addition, an aging workforce in the manufacturing sector will focus employer attention on ergonomic and workforce flexibility issues in order to maintain productivity.

Keeping the future manufacturing enterprise secure is critical and should be a high priority for all manufacturers, although it is not currently at the top of the list for most companies. In future, environmental pressures will increase in importance. This increase in importance will not be driven by EPA alone, but will be driven by regulations being implemented by our trading partners. The product take-back legislation mentioned earlier is an example of overseas markets driving environmental concerns in the United States.

In conclusion, all of these paradigms and many others are shaping the future of manufacturing in the United States. The companies that will succeed are the ones that envision the future and start preparing now. As the great hockey player Wayne Gretsky said, “You don’t need to go where the puck is, but where it is going to be.”

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Manufacturing, Energy, and the Future of New Technology

Robert W. Garland
U.S. Department of Energy

The industrial sector currently accounts for about 38 percent of all U.S. energy consumption, at an annual cost of more than $120 billion.[1] Manufacturing processes are amongst the most energy-intensive industrial systems. Energy costs are therefore a major driver for many plants in the United States. In general, manufacturing processes that use heat and force to transform raw materials into durable goods and consumer products and the equipment to carry out these tasks, consume much of the fossil fuel imported by the United States.

By developing and adopting more energy-efficient technologies, U.S. industry can boost its productivity and competitiveness while strengthening national energy security, improving the environment, and reducing emissions linked to global climate change. Toward this end, the U.S. Department of Energy's (DOE) Industrial Technologies Program (ITP) supports technology partnerships aimed at improving industrial energy efficiency. Working with a wide array of state, community, industry, and university partners, this program invests in a diverse portfolio of energy technologies.

Attaining energy independence is a growing concern across the nation. If the United States intends to maintain its current standard of living, the goods we use in the future must be made more efficiently. Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for the United States.

ENERGY INTENSIVENESS

Manufacturing has traditionally been an energy-intensive industry, dominated by fossil fuels. Efficiency enhancements to technologies that are widely used in a broad range of U.S. industrial sectors can have a large impact, even if the improvements are small. Substantial energy and cost savings can be achieved if these enhancements are adopted across entire industries.

About half of the petroleum products and 10 percent of the natural gas consumed by industry are used as feedstock for heat and power. Heat, power, and process heating systems combined offer tremendous savings for many industrial plants. Further, the process of combustion is used in almost every industry, and a better understanding and control of this process can improve energy efficiency, reduce emissions, and enhance fuel flexibility.

The basics behind many manufacturing processes are the motors, steam, and compressed air systems. Applying best practices in these basics can save up to 30 percent of energy used in a plant in a few years. Materials technology is also a key area, and improvements for superior strength and resistance to environmental degradation in high-

[1] Approximately one third of the total energy used in the United States is in transportation and another third is used in buildings. Energy Information Administration. Annual Energy Review. 2002.

temperature industrial environments is important for efficient operations.

Sensors and controls can provide integrated measurement systems for operator-independent control of plant processes. Extending sensor reach and accuracy in harsh environments and improving the integration of processing of sensor data can enable online, automated assessments and adjustment of system parameters.

STRATEGY FOR SUCCESS

Manufacturing firms within the same industry face common technological hurdles to improving efficiency. Many of these hurdles involve basic, energy-intensive processes integral to the industry. Due to the complex technologies involved, meaningful advances in these processes require costly research and development (R&D) efforts that are beyond the reach of many individual firms.

Since 1994, U.S. industries have used DOE's Industries of the Future strategy to set their own R&D goals and priorities. The bulk of the federal budget goes to providing cost-shared support to selected R&D partnerships—partnerships that pool the resources of industry, academia, and government to accelerate the pace of R&D in meeting industry's top needs and achieving national goals for energy and the environment.

The ITP brings firms together in a neutral environment, facilitates consensus building, and supports collaborative R&D to address priority needs. By concentrating on high-risk, high-payoff research in pre-competitive areas, U.S. firms find that they can collaborate effectively to accelerate the pace of technology development.

Formal industry partnerships include developing a broad vision of the industry's future as well as one or more roadmaps reflecting industry consensus on R&D priorities and other activities needed to achieve that vision. The strategy has also generated

- Alignment of public-private investment with industry's R&D priorities;
- Dozens of commercially successful technologies;
- Better industry access to federal laboratory facilities;
- Streamlined contracting processes for industry partners; and
- New industry associations to facilitate and administer collaborative R&D.

The project portfolio includes over 1,000 projects in which the Office of Industrial Technology (OIT) has been involved, including more than 140 projects that have reached the commercial market. Products also include publications, software tools, and databases.

COLLABORATIVE RESEARCH AND DEVELOPMENT

Despite the fact that U.S. industrial facilities run streamlined, technologically sophisticated operations, they still face tough economic, technological, and environmental challenges. Manufacturing typically operates with low profit margins and is dependent on capital-intensive equipment. This limits the availability of R&D funds. Direct price competition with foreign firms that employ cheap labor or receive heavy government support or dispensations also affects R&D expenditures. However, with the increased complexity and sophistication of products and processes, R&D is critical. Finally, there is growing pressure to restrict emissions and effluents, and this also requires technology advances.

Competitiveness is a critical issue for both small and large companies. In order to be more competitive, these companies must work toward:

- Reducing the cost and risk of pre-competitive R&D;
- Acquiring a stronger voice in directing R&D;
- Staying at the forefront of technology and expanding their technical knowledge base;
- Leveraging available funds and information resources;
- Protecting proprietary technologies and capabilities;
- Gaining access to complementary technical expertise and facilities that can help today, as well as in the future;
- Acquiring new patents or licensing agreements; and
- Launching new products or spin-off companies.

Collaborative partnerships can help to focus resources on vital, higher-risk research and can help to ensure that the resulting technologies are successfully commercialized, thereby cleaning the air, conserving resources, strengthening our economy, and improving our quality of life.

SUMMARY

By focusing on process and energy efficiency, U.S. industry can maximize and leverage their resources to tackle projects that would otherwise be beyond their reach. Once commercialized, the resulting technologies benefit all members of industry by:

- Saving energy and materials;
- Facilitating cost-effective compliance with environmental regulations;
- Increasing productivity and reducing waste;
- Enhancing product quality;
- Reducing production costs (and creating a ripple effect throughout the U.S. economy); and
- Boosting competitiveness in the global marketplace.

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Army Manufacturing Technology Program Responds to 21st Century Challenges

Robert S. Rohde
Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology

The Army Manufacturing Technology (MANTECH) Program has seen dramatic changes in project selection and technical direction since oversight responsibility was transferred to the Office of the Deputy Assistant Secretary of the Army for Research and Technology (DASA(R&T)) in the mid-1990s. Today, the Army's transformation path to the Future Combat Systems (FCS) and the Objective Force necessitates another shift in how Army MANTECH operates. That shift involves a strategic, top-down approach for defining MANTECH requirements as opposed to the bottom-up methodology used in the past.

The bottom-up methodology was adopted in August 1997 in response to congressional concerns of insufficient investment levels and Office of the Secretary of Defense Technology Area Review and Assessment guidance to focus on larger, higher impact projects. This substantially modified the approach and priorities of the MANTECH Program.[1] Today's accelerated pace of Army transformation requires the science and technology (S&T) base to transition technology with sufficient performance maturity for the program manager (PM) to enter into system development and demonstration with low to medium risk. The S&T response to the Army's accelerated transformation now requires a top-down identification of MANTECH projects to enable the affordable transition of critical technologies into FCS. This change is driven from the very top of the Army, and the Army S&T leadership is responding accordingly and forthrightly.

ADDRESSING RISKS

In addition to performance, several other factors must be taken into consideration. While a single demonstrator can achieve the performance required by the user, the PM is faced with delivery of multiple units on a timely basis at an affordable cost. Therefore, there is further inherent risk in manufacturing that must be addressed if the technology is to be successfully transitioned to the FCS PM and enter into systems development and demonstration. This requirement has led to a new feature of the revised Army program that is unique in the Services—that is, to meld, where appropriate, both exploratory and advanced development (6.2/6.3) funding with MANTECH (6.7) funding in a single project. Combining these resources enables achievement of both performance goals, as defined by the descriptors relating to manufacturing (Table 20-1). This ensures that technology development achieves the user's needs, is mature enough to meet the PM's needs, and is manufacturable and affordable in the

NOTE: Reprinted, with permission, from *Army AL&T Magazine,* May-June 2003, pp. 30-32.

[1] See "A New Approach to the Army Manufacturing Technology Program," Army RD&A magazine, May-June 1998 and "Army MANTECH Community Recognized at Defense Manufacturing Conference 2001," Army AL&T magazine, March-April 2002.

TABLE 20-1 Proposed Manufacturing Descriptors to Be Added to Technology Readiness Levels

TRL	Manufacturing Maturity Expectation
3	Analyses identify process needs for breadboard system, including development targets for new subprocesses.
4	Key subprocesses demonstrated in lab. Cost as an independent variable targets established.
5	Trade studies and lab experiments define a manufacturing concept and sigma levels needed to meet CAIV targets.
6	Critical manufacturing processes prototyped; targets for improved yield established.
7	Prototype system built on soft tooling; initial sigma levels established.
8	Critical subprocesses demonstrate acceptable yield for pilot line.
9	Pilot line operating at desired initial sigma level.

quantities required to meet fielding goals and timeliness. This approach has also required that the research and development and product engineering communities merge.

ASSESSMENT PANEL

To validate the identification of the most critical areas of investment, the DASA(R&T)/Army Chief Scientist, A. Michael Andrews II, commissioned a blue-ribbon Independent Assessment Panel through the National Center for Advanced Technologies. The panel identified and evaluated the manufacturing technologies necessary for affordable manufacturing and fielding of the Army's Future Combat Systems and other components to the Objective Force. Herm M. Reininga, Vice President of Operations, Rockwell Collins, Inc., chaired the panel. The panel made the following suggestions:

- Incorporate manufacturing and affordability issues in advanced concept technology demonstrations (ACTDs), advanced technology demonstrations (ATDs), and other technology development programs;
- Exploit Integrated Product and Process Development in Army and Defense Advanced Research Projects Agency (DARPA) technology development programs; and
- Use manufacturing readiness level descriptors, similar to the currently employed technology readiness levels.

The panel also identified the following issues specific to the FCS program:

- Advanced technologies likely to be critical to the FCS program,
- Capability gaps in the Army's MANTECH Program with regard to those critical technologies,
- An estimate of the funding needed to close the MANTECH capability gaps in a time frame that was likely to meet the current schedule for FCS development (structured within specific technologies and technology areas), and
- Recognition of the strong relationship between overall FCS Program risk and manufacturing technology resources needed for the FCS Program.

The panel made two recommendations. First, existing requirements, including affordability considerations (especially manufacturing) in Service/DARPA, ACTD, and ATD programs, should be enhanced and enforced. Second, ATD and ACTD manufacturing technology issues should be identified so that they can be effectively addressed, either within the ATD/ACTD or by a separate, coordinated, and focused MANTECH effort. The panel's final report stated, "The collective experience of the members of the Independent Assessment Panel clearly indicate that the resources (time and funding) devoted to these efforts will be paid back manyfold both during the development of the system (e.g., reduced probability of schedule delays and financial overruns) and especially during their service lives."[2]

As a result of this study, the DASA(R&T) initiated major changes to the Army's MANTECH Program. In the project selection process developed in 1997, Army Materiel Command labs and research, development, and engineering centers provided proposals for MANTECH projects in concert with PMs. Therefore, the Army was not anticipating systemic manufacturing problems that were surfacing either during the engineering and manufacturing development phase, production, or postproduction. The new approach resulting from the NCAT study focuses the MANTECH Program on earlier phases of development prior to handoff of technology to the PM. The new strategy concentrates the Army MANTECH investments in the following areas. These areas correspond to top priorities recommended by the NCAT panel. The Army is pursuing these technologies within the funded program.

Sensors

Low-cost, uncooled infrared sensors are of paramount importance because of their many uses in seekers and other weapons, target detection and recognition, surveillance, robotic operations, dismounted operations, etc. The Army investment is in cooled dual-band focal plane arrays. Laser pumping sources are required for solid-state lasers given the applications for solid-state laser radars and high-energy lasers. The Army investment is in laser diode arrays.

Electronics and Power Systems

Pulse power for advanced protection systems and weapons is a critical need for FCS and the Objective Force. Commercially available high-voltage, fast-rise-time capacitors are too large and heavy for Army applications. The Army investment will be in high energy density capacitors. Compact energy and power storage systems are required for hybrid platforms and for advanced protection systems and weapons. The Army investment will be in very high power lithium-ion batteries. Pulse power and compact power electronics for advanced vehicles, weapons, and protection systems also require the ability to switch high currents in high-voltage circuitry. The Army investment in this area is in silicon carbide switches.

The Army requires high-data-rate, on-the-move communications to meet the transformation goals of a lighter, faster, more lethal force. Affordable phase arrays provide the means to achieve these requirements. The Army investment is in microelectromechanical systems (MEMS), electronically scanned array antennas, and ferroelectric phase shifters for affordable phase arrays.

The Joint Tactical Radio System (JTRS) is aimed at developing lightweight, low power, network-centric tactical communications. The Army investment is in wearable software-defined radios that meet size, weight, and power requirements through modularization and the implementation of high-density packaging for embedded applications. Display technology is

[2] Report of the Army Mantech Assessment Panel. 2002. Available at http://www.affordability.org/armymt/index.html. Accessed March 2004.

particularly important for receiving and visualizing the information now available to the individual soldier. The Army investment is in flexible display technologies (transparent conductive and emissive materials) for soldier applications.

Armor

Affordable, lightweight armor for lightweight combat platforms is a critical issue for FCS and the Objective Force. The Army investment in this area is low-cost composites and high-performance appliqué armor. Signature management and low-observable technologies in all bands of interest are, in the words of the independent assessment panel, “likely to be critical to the success of the FCS Program.” The Army investment is in low-observable materials and structures.

Munitions

The accuracy of cannon-launched projectiles as well as advanced missiles can be significantly improved by the use of advanced guidance systems coupled to global positioning technology. The Army investment is in low-cost, high-g-force, high-accuracy MEMS-based inertial measurement units. This was the first program to also combine both S&T development funding with MANTECH funding. Current funding is not adequate to cover all of the NCAT panel recommendations, but the Army’s MANTECH Program has responded within budget guidance. Manufacturing programs that are currently on the Band 1 Unfunded Requirement List include low-cost uncooled infrared focal planes, conformal optics, 3-D laser radar, energetics (propellants and explosives), durable barrel materials, and MEMS for safety, arm, and fuzing.

CONCLUSION

What should be the appropriate level of funding per year necessary for MANTECH to properly address FCS and the Objective Force? There are two sources of guidance available to us. During the development of the "Big Five" weapon systems in the 1970s and the early 1980s, the Army’s MANTECH investment peaked near $200 million per year and was consistently more than $150 million per year for a number of years, declining sharply in the mid- to late-1980s. The NCAT panel also provided us an estimate for funding both Level I and Level II projects of $164 million per year. In the FY04 budget, MANTECH is funded at $66 million, about 40 percent of the NCAT estimate.

Finally, it is important to recognize that MANTECH is an investment for which there is a savings in production cost. There have been a number of studies over the years attempting to quantify this number. Our best estimates, both from industry and government studies, suggest a 10-to-1 average return on investment. In the 1990s, $48 million MANTECH investment in Javelin focal planes resulted in estimated savings of $364 million. Before MANTECH, the unit cost was greater than or equal to $50,000 per unit; after MANTECH it is less than or equal to $5,000 per unit (21,000 units). Clearly there are potentially significant savings in production cost through strategic MANTECH investments.

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Turning New Technologies into Products at Sandia National Laboratories

Gregory F. Cardinale
Sandia National Laboratories

Sandia National Laboratories is involved in a wide range of national security research and development projects. Current programs include nuclear weapons fail-safe technologies; nonproliferation and materials control technologies, such as a foam intended to combat biochemical spills and chemical attacks; national infrastructure projects involving water supplies or energy sources, which are easy to contaminate or attack; and projects to prevent the types of disasters that occurred in Oklahoma City, New York, Washington, D.C., and Pennsylvania. The Sandia vision is to help the nation secure a peaceful and free world through technology. When developing technology programs, Sandia explores commercial market opportunities. This paper describes a successful business development and technology transfer case study, the development of extreme ultraviolet lithography (EUVL). It also presents Sandia's current technology transfer model and a proposed new model. Finally, some venture opportunities with Sandia are discussed.

NEW TECHNOLOGIES

A successful example of Sandia's business development and technology transfer is the nanolithography program, under which EUVL was developed in collaboration with several semiconductor manufacturers. The nanolithography program is a next-generation lithography cooperative research and development agreement (CRADA). Under the program, Sandia, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory developed and built a full-field scanning exposure tool capable of printing features less than 100 nm in size.

Nanoscale devices fabricated at Sandia include radio frequency nanoelectromechanical systems (RF-NEMS), nanofluidics, and molecular electronics or "molectronics," i.e., electronic devices built out of individual molecules. A molecular junction is created by patterning two electrodes with a nanometer-scale gap using the EUVL exposure tool, and then a gold sphere is placed in the inter-electrode spacing. The gap size between the two electrodes is less than 40 nm. The gold sphere is functionalized using wet chemistry with an appropriate solution such as thiol, and the molecule of interest is deposited on the functionalized sphere. By applying an electrical bias to the electrodes, the transfer characteristics of the molecule can be determined. Agglomerates of functionalized gold spheres placed between functionalized, nanometer-scale electrodes exhibit interesting electrical properties.

TECHNOLOGY TRANSFER AT SANDIA

Sandia has traditionally had a business model that was mission-driven, with mission-driven deliverables. In addition, Sandia has participated in research and development

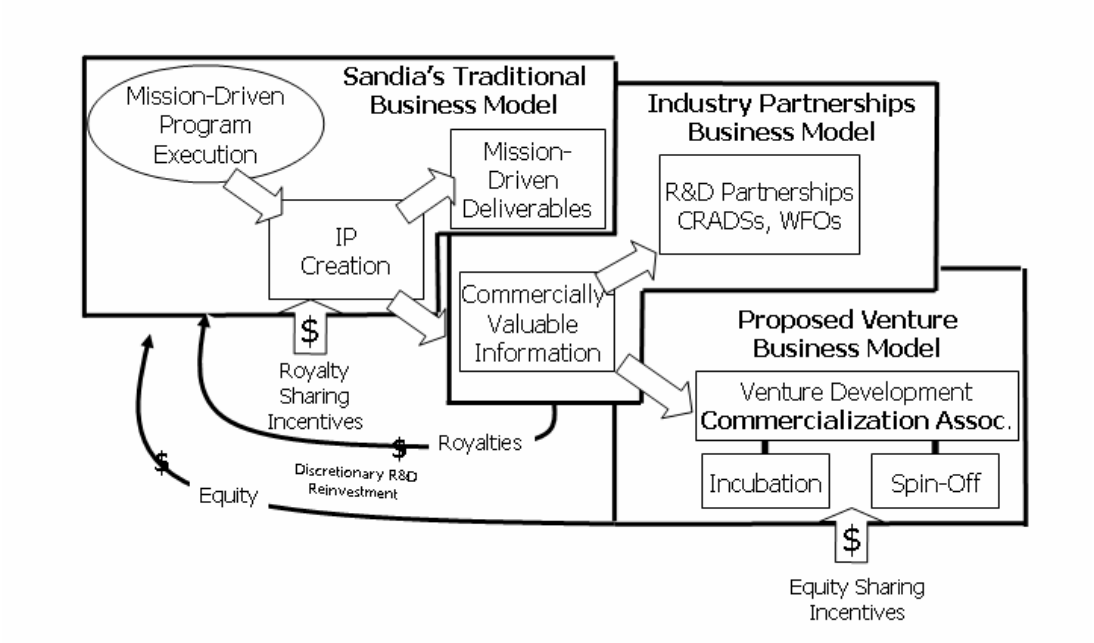

FIGURE 21-1 Three different business models at Sandia National Laboratories. SOURCE: Model developed by Denise Koker, Manager, Business Development, Sandia, Calif.

partnerships with industry. A new business model currently under consideration focuses on the development of incubator-type environments, where technologies can be spun off when appropriate (Figure 21-1). Input from industry will help Sandia make this transition in business models.

Once a market opportunity is identified, several paths can be taken to commercialize a technology: creating a large, multiyear CRADA; evolving from a small business agreement to a strategic partnership with a licensing agreement and CRADA; obtaining a license for a new start-up venture (spin-off); and commercializing stand-alone inventions, from laboratory directed R&D to licensing. These processes have evolved since the Federal Technology Transfer Act was enacted by Congress in 1986 to commercialize government technologies.

Methods of moving ideas into the marketplace have also evolved. Industry generally uses models that are based on customer-driven demand, i.e. filling a market need. Such a model involves the following steps: research and development (R&D); prototyping; pilot production; and volume manufacturing. The model used more frequently at Sandia has the Department of Energy (DOE) as the primary customer. Non-DOE customer needs must be consistent with national security needs. In this model, national security-related products are provided to the government when Sandia's technology is transitioned to industry. Such a model involves the following steps: Sandia R&D; prototyping; pilot production; commercialization partner (private sector); and volume manufacturing. Under this model, discretionary revenue can be fed back to the laboratory through licensing agreements. The main differences between the two models arise from the fact that Sandia is national security-centric, works with nuclear weapons, has restricted outsourcing policies, and is a not-for-profit organization. Similarities include the R&D programs, generation and licensing of intellectual property, and customer-driven product development.

NEW TECHNOLOGY CHALLENGES

Manufacturability is a major challenge for new technologies, such as microelectromechanical systems (MEMS) and nanotechnology. The MEMS industry has leveraged much of the learning and manufacturing rigor of the integrated circuit industry. The integrated circuit industry's existing infrastructure (wafer suppliers, overlapping processing foundries, metrology services, packaging) has facilitated MEMS productization. A culture change is still needed, however, among smaller MEMS companies to implement metrology and achieve stricter process control (i.e., six-sigma). In contrast, there exists little or no infrastructure for nanotechnology to leverage. Nanotechnology start-ups may rely on government laboratories, institutes, and universities to serve as foundries until such an infrastructure is developed. Nanotechnology companies may even use MEMS foundries since they are more closely related to nanotechnology and are more flexible than larger, blue chip industries. Nanotechnology foundries or centers may provide a stopgap solution by offering unique capabilities in key process areas such as metrology.

CONCLUSION

Venture opportunities exist between national laboratories and private companies. National laboratories can, for example, be considered as an R&D nucleus. Most national laboratories have state-of-the-art metrology, analytical techniques, unique processing methods, and modeling capabilities that can be exploited by private companies with little initial investment in capital equipment. Specific venture partnership opportunities with Sandia in national-security technologies include microsystems, nanotechnology, chemical/bioterrorism prevention, water surety (plant and point of use), secure communications, and distributed microsensors.

VII

Presented Papers:
New Manufacturing Paradigm

22

Manufacturing in a Digital Era: Strategic Asset or Vulnerable Commodity?

John Zysman
Berkeley Roundtable on the International Economy

In a digital era, companies and countries must determine whether manufacturing capacity is a strategic asset or a vulnerable commodity. For companies, the relevant issues are, When does production serve to generate and maintain advantage? Under what circumstances is a lack of in-house world-class manufacturing skills a strategic vulnerability? When is it simpler and easier to buy production as a commodity service? For a country or a region, the relevant issue is, What can be done to make this country/region an attractive location for world-class manufacturing, that is, an attractive place for companies to use production in order to create strategic advantage?

This paper develops three arguments. First, the argument about production in a digital age is set in the context of the argument that a service economy will follow on a manufacturing economy. As will be shown, there is in fact an evolution and reorganization of production hidden within the statistics. Second, the emergence of the digital era is put into an historical context. Third, the place of production in value creation and market position is considered for three different types of sectors.

MANUFACTURING MATTERS: THE ORIGINAL ARGUMENT[1]

The sense that we are living through a digital revolution suggests that as a national economy, we can safely exit manufacturing. The implication is that there will be a secure economic life doing software, developing digital applications, and providing services, a whole array of activities that do not involve making things.

This logic is an extension of the argument of 20 years ago about services and manufacturing. Because we were supposedly moving from an industrial society to a post-industrial or service economy, it would be all right for the American economy to lose manufacturing production and jobs. We had moved from agriculture to industry and now would undergo the next transition. But the agriculture into industry metaphor is itself misleading. The agricultural sector didn't disappear. When you fly across the country from California to Washington you fly across the agricultural heartland of America. There is a lot of agriculture between California and the East Coast. Farm production was reorganized, and the process of how you grow things in Nebraska and California evolved. Labor went away from the land into the inputs in the form of fertilizer and machinery. If Nebraska farmers stopped growing grain, the spraying companies in Nebraska would be out of business. They would be unlikely to fly down to Argentina each day to sell their services abroad. Pesticide-free agricultural production in Denmark with limited workforces is possible with the use of GPS systems that allow marking of weed infestations for systematic monitoring.

[1] The original argument was made here: S. Cohen and J. Zysman. 1987. Manufacturing Matters: The Myth of the Post-Industrial Economy. New York: Basic Books.

Hence the original story about agriculture was never about the vanishing of a segment of the economy, farming and food production. Similarly, it turned out that the manufacturing story was not about the exit into services, but about the reorganization of production. It was, rather, a story about its reorganization and the change in the production supply chain and distribution channels.

Categories, Statistics, and the Myth of a Service Economy[2]

Before turning to the digital story, let us consider why there was an enduring confusion about the supposed transition from industry to services. The overall notion is that manufacturing as a portion of the economy had dropped precipitously and the portion included in the services category had risen. The precise numbers depend on what is counted and how. The conventional categories show private goods-producing industries in the United States declining toward 20 percent. Durable goods manufacturing fell below 8 percent. Private service-producing industries have risen over 67 percent. The precise balance of services in the economy as a whole will depend on how government expenditures are categorized (some would argue that no government expenditures are services).[3] As we disassemble the numbers, the notion of the overwhelming importance of a service economy replacing an industrial economy will slowly dissipate. Let us consider the steps in the process.

Services can be separated into two categories: personal and social services, and business services. In the category of personal and social services, we would put professions such as teachers and prison guards. Cynically put, personal and social services include a whole series of caretakers, including valets in the old British days. Business services can be divided into two subcategories: activities upstream from production and activities downstream from production. Downstream activities are those that are not linked to where the good is manufactured. For example, the same auto dealer at the mall where you live will sell you either a Ford or a Lexus. The dealer is downstream from production and neither depends on nor cares where the car was made, whether the Ford was produced in Brazil or Michigan, or the Toyota in Japan or the United States. By contrast, upstream activities are those that occur prior to manufacturing and in support of production activities. The question is how tightly linked the services are to the manufacturing operation and whether they can be separated from production and moved elsewhere. Services that cannot be moved are tightly linked, while those that can be moved are loosely linked. Tightly linked services would include those directly supporting the production line. There are also ancillary activities such as window washing and services that are supportive in terms of back office activities or customer relation phone services.

Two important points must be noted here. First, consider the statistics. If the window washer, or phone service employee, or billing service employee work for General Motors, then those individuals are categorized as manufacturing sector employees. However, if they work for Ace Window Washers, Back Office Temp Services, or Phone Service Outsourcing, then they are categorized as service sector employees. The employees are engaged in the same activities no matter which firm they work for, but they fall into two different statistical categories. The statistical category of service employment therefore is a confused measure that blurs the distinction between what is being done and where it is being done.

Second, the tightness of the linkages between the services and the underlying manufacturing activity must be examined. If General Motors moves to Brazil, the window washers won't go with it. The Detroit window washer cannot wash windows in a Toyota plant in

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[2] Ibid.

[3] R.E. Yuskavage and E.H. Strassner. 2003. Gross domestic product by industry for 2002. Available at http://www.bea.gov/bea/ARTICLES/2003/05May/0503GDPbyIndy.pdf. Accessed November 2003.

Japan. On the other hand, many back office services can now be performed overseas. The back office activities and the customer support services are much more mobile than window washing, which is tied to a particular location. Even before the manufacturing moved to Brazil, the back office might have moved to South Dakota and the phone services to Bangalore.

We can therefore ask, what links these activities together? What strengthens or weakens these linkages? For this discussion, the question is the distinction between strong and weak geographical and organizational linkages: Which activities must geographically or organizationally stay together? And what is the glue that binds them? Indeed, in a digital era with easy communications, including data document transfer, these various back office and customer support services become even more mobile. Is a mastery of English and a sophisticated telecom infrastructure with global links, even if it has limited local ties, all that are needed? Certainly, the ability to communicate fluidly and collaboratively over distances loosens the geographical linkages, alters appropriate organizational structure, and changes control structures among other kinds of activities, as a distributed system of open source software development suggests. In summary, we were never moving in any simple way from manufacturing into services. Not everyone became McDonalds employees or Lazard Freres investment bankers. And now not everyone will begin programming for Microsoft.

The Digital Era in Historical Perspective

How then do we situate production in the emergence of a digital era? Let us try to put the digital era in historical perspective. We will look at the historical evolution of manufacturing in the United States, including the following phases: production and competition, the evolving model; dominance-mass production; challenges—lean production and flexible specialization; comeback—Wintelism; and the digital era.

American Dominance: Fordism and Mass Manufacture

Mass manufacture, Henry Ford and all that, was the first twentieth century production revolution. Mass manufacture in the popular mind comes with the Model T and mass consumption. And that civilian production innovation—mass manufacture—also made possible the volume deployment of the tanks and planes that provided American and Allied forces an advantage.

What is mass production? Mass production is broadly understood to mean the high volume of standard products made with the complete and consistent interchangeability of parts that could simply be connected using machines dedicated to particular tasks that are manned by semiskilled labor.[4] A range of features is hung on to that basic definition. The features include:

- The separation of conception and execution—managers design systems that workers, slotted into rigidly defined roles to match them to machine function, operate;
- The push of product through these systems and onto the market; and
- Large-scale integrated corporations whose size and dominance reflected mass production's economies of scale, dominated the markets.

[4] J.P. Womack, D.T. Jones, and D. Roos. 1991. The Machine That Changed the World. New York: HarperPerennial. See also P. Hirst and J. Zeitlin. 1997. Flexible specialization: Theory and evidence in the analysis of industrial change. In J. Rogers Hollingsworth and Boyer (eds.). Contemporary Capitalism: The Embeddedness of Institutions. Cambridge, U.K.: Cambridge University Press.

Scale implied rigidity, and the economic management counterpart of that corporate rigidity became the policy question of how to avoid business cycles. Booms and busts implied worker dislocations, and the social/political management counterpart of business cycle management became the political debate about how to use a public policy to cushion not only the economic dislocations but also the political dislocations. In any case, Fordist mass production was associated both with American industrial development, military success, and postwar hegemony.

CHALLENGES FROM ABROAD

Producers abroad, often with support of their governments, tried to imitate the American mass production model. Most failed; but some efforts at imitation generated new rounds of production innovation, a second phase in 20th century manufacturing. In the 1960s, the American automobile industry considered itself dominant, and the Cadillac was, due deference to Ford Motor Co., the exemplar of position and prestige. The dramatic Japanese innovations in production in the 1980s gave rise not only to lower-cost, higher-quality production in everyman's cars, but to an entirely new set of luxury cars such as the Lexus. The Lexus was built on the corporate base of the production of cars for everyman, but it also represented a challenge to the luxury market segment of specialty producers such as Mercedes and BMW. Some specialty producers adjusted; others did not. Mercedes and BMW understood that they had to do two things to keep their market position: keep their advantage in driving quality and improve the underlying comfort and amenities in the cars. They did both, aided by marketing that generated considerable pricing discretion. The challenges to American manufacturing came from two different directions: lean production and flexible specialization.

Lean Production

Lean production, or flexible volume production, refers to an interconnected set of Japanese production innovations.[5] Japanese producers created an entirely new approach to volume production that culminated in lean production models.[6] The mechanisms and sources of the Japanese flexible volume manufacturing system attracted intense attention because of the stunning world market success of the Japanese companies in consumer durable industries requiring complex assembly of a large number of component parts. Japan's automobile and electronics firms burst onto world markets in the 1970s and consolidated powerful positions in the 1980s. The innovators were the core auto and electronics firms that in a hierarchical manner dominated tiers of suppliers and subsystem assemblers; the production innovation was the orchestration and reorganization of the assembly and component development process. The core Japanese assembly companies of the lean variety have been less vertically integrated than their American counterparts, but they have been at the center of vertical Keiretsu that have tightly linked the supplier companies to their clients. Characterizations of the Japanese production system emphasize that it provides flexibility of output in existing lines as well as rapid introduction of new products, which permits rapid market response. High quality measured in

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[5] S. Cohen and J. Zysman. 1987. Manufacturing Matters: The Myth of the Post Industrial Economy. New York: Basic Books.
B. Coriat. 1990. The revitalization of mass production in the computer age. Paper presented at the University of California at Los Angeles Lake Arrowhead Conference Center, March 14-18, 1990.
R. Jaikumar. 1988. From filing and fitting to flexible manufacturing: A study in the evolution of process control. Working paper 88-045. Boston: Division of Research, Graduate School of Business Administration, Harvard University.
J.P. Womack, D.T. Jones, and D. Roos. 1991. The Machine That Changed the World. New York: HarperPerennial.

[6] C. Johnson, L. Tyson, and J. Zysman (eds). 1989. Politics and Productivity: The Real Story of How Japan Works. Cambridge, Mass.: Ballinger.

defects has come hand in hand with lower cost.

This distinctive approach to volume manufacturing, however labeled and characterized, emerged in Japan during the years of fast growth and was firmly in place by the time of the first oil shock, in the early 1970s. The developmental strategies of Japan were essential to its production innovation. The distinctive features of the Japanese production system were a logical outcome of the dynamics of Japanese domestic competition in the rapid growth years, making this a nationally distinct innovation.[7] Indeed protected domestic markets and exports were decisive and generally misunderstood or, oddly, understated in the accounts of the emergence of the distinctive system of lean, flexible volume production.[8] Thus while the Fordist story highlights national strategies for demand management, this Japanese story of lean production and developmentalism highlights the interaction among the markets and producers of the advanced countries in international competition. Lean production was the focus of policy and corporate attention because it represented a direct challenge to both mass manufacturing and assumptions of American global economic policy.

Diversified Quality Production and Flexible Specialization

A second alternative to the classical American mass production model had little to do with the volume production strategies emerging in Japan. No single label or instance captured the popular mind. Different versions of the story have variously labeled this collection of innovations as diversified quality production and flexible specialization.[9] The “Third Italy” and the Germany of Baden-Wurttemberg were the first prominently displayed examples of an approach in which craft production, or at least the principles of craft production, survived and prospered in the late twentieth century. The particular political economy of the two countries is shown to have

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[7] J. Zysman and L. Tyson. 1989. The Politics of productivity: Developmental strategy and production innovation in Japan. Chapter in C. Johnson, L. Tyson, and J. Zysman (eds). Politics and Productivity: The Real Story of How Japan Works. Cambridge, Mass.: Ballinger.

[8] J.J. Tate. 1995. Driving Production Innovation Home: Guardian State Capitalism and the Competitiveness of the Japanese Automotive Industry. Berkeley, Calif.: Berkeley Roundtable on the International Economy. The argument is simple. The relationships of production and development in these productions systems are, at best, delicate. Just-in-time delivery, subcontractor cost/quality responsibility, and joint component development push on to the subcontractor considerable risk in the case of demand fluctuations. True, there were techniques to continuously reappraise demand levels and indicate to "client firms" their allocations so that the client firms could in turn plan. This reduced unpredictability throughout the system. But if demand moved up and down abruptly, those techniques would not have mattered. True, government and corporate programs to reduce the capacity break even point in small firms helped. Nonetheless imagine that Japan’s emerging auto sector had to absorb continuously the stops and starts of the business cycle that typified Britain in the 1950 and 1960s. Would the trust relationships that are said to characterize Japan have held up? Could the fabric of small firms have survived to support just-in-time delivery and contractor innovation? Simply a smooth and steady expansion of demand typified the Japanese market in sectors such as autos and facilitated these arrangements and developments. The high growth rates—combined with the need to re-equip Japan in the postwar years—created the basis of the continuous expansion. But domestic growth did fluctuate and the rivalries for market share led consistently to overinvestment, or excess capacity, in the Japanese market. The story about Japan told by Yammamura and Murakami, Tsuru, Zysman, and Tyson, and by Tate in the case of the auto industry, shows that the excess capacity was “dumped” off onto export markets. Seen differently, these exports permitted a steady and smooth expansion without which the production innovations outlined here would not have emerged. The developmental strategies of Japan were essential to its production innovation.

[9] Wolfgang Streeck. 1991. On the institutional conditions of diversified quality production. In Egon Matzner and Wolfgang Streeck (eds.), Beyond Keynesianism. Aldershot: Elgar, pp. 21-61.
Michael Piore and Charles F. Sabel. 1984. The Second Industrial Divide, Possibilities for Prosperity. New York: Basic Books.
Robert Boyer and J. Rogers Hollingsworth. 1999. Contemporary Capitalism: The Embeddedness of Institutions. New York: Cambridge University Press.
Robert Boyer and Yves Saillard. 2002. Regulation Theory: The State of the Art. New York: Routledge Press.

given rise to distinctive patterns of company and community strategies.[10]

This second set of innovations came from firms that had diversified product ranges and that were often competing with regard to quality rather than price. Manufacturing involved smaller runs of higher value-added production. Competitive position rested on skills and flexibility, not low wages. These challenges in the high-valued-added niche markets came from small and middle-sized firms rooted in particular industrial districts. “Craft production or flexible specialization,” argue Hirst and Zeitlin, “can be defined as the manufacture of a wide and changing array of customized products using flexible, general-purpose machinery and skilled, adaptable workers.”[11] Communities consisting of groups of small companies, organized in what are perceived as 20th century versions of industrial districts, are argued to be able, in at least some markets and some circumstances, to adapt, invest, and prosper in the radical uncertainties and discontinuities of global market competition more effectively than larger, more rigidly organized companies. “These districts escape ruinous price competition with low-wage mass producers,” Sabel argues, “by using flexible machinery and skilled workers to make semi-custom goods that command an affordable premium in the market.”[12] The emphases in these discussions are the horizontal connections, the connections within the community or region of peers. This community of peers is certainly distinct from the vertical or hierarchical connections of the dominant Japanese companies.

THE AMERICAN COMEBACK: WINTELISM AND THE EMERGENCE OF A DIGITAL ERA

Wintelism is the transition moment out of an electromechanical era into a digital age. Twenty years ago it seemed that American firms were being beaten in international markets. It seemed that a flood of innovative entertainment products like the Walkman and the VCR were joining traditional electronic products like televisions. The problem was not simply wages, we were discovering, but firms outside the United States also had the capacity to turn ideas into competitive product. As the semiconductor industry joined consumer electronics and autos as a sector under intense competitive pressure in the late 1980s, it seemed that the fabric of advanced electronics was coming unraveled. Then, suddenly, it seemed that American producers were back. But we had not reversed the decline of production in electromechanical products. Rather a new sort of electronics product had emerged, a new segment of the industry.

What is a consumer electronics product?[13] A consumer electronics product is anything you can buy at a store in Berkeley called the Good Guys. They sell consumer electronics. You can walk in and buy a product off the shelf with a 3-year return guarantee. If it doesn’t work, you can bring it back and get a new one. The moment that the consumer electronics sector went from being about television sets to being about digital communication and computing technologies, the world changed. At that same moment, spin-off technologies became spin-on

[10] Charles F. Sabel, Horst Kern, and Gary Herrigel. 1989. Collaborative Manufacturing: New Supplier Relations in the Automobile Industry and the Redefinition of the Industrial Corporation. Cambridge, Mass.: International Motor Vehicle Program, Massachusetts Institute of Technology.
Charles Sabel. 1982. Work and Politics. Cambridge, Mass.: Cambridge University Press.
Suzanne Berger and Michael J. Piore. 1980. Dualism and Discontinuity in Industrial Societies. New York: Cambridge University Press.

[11] Paul Hirst and Jonathan Zeitlin. 1997. Flexible specialization: Theory and evidence in the analysis of industrial change. In Contemporary Capitalism: The Embeddedness of Institutions. J. Rogers Hollingsworth and Robert Boyer (eds). Cambridge, Mass.: Cambridge University Press. p. 228.

[12] Charles F. Sabel. 1994. Flexible Specialization and the Re-Emergence of Regional Economies, in Post-Fordism: A Reader. Oxford: Blackwell Publishers. p. 141.

[13] M. Borrus. 1997. Left for dead: Asian production networks and the revival of U.S. electronics. Working paper no. 100. Berkeley, Calif.: Berkeley Roundtable on the International Economy.

technologies as technical leadership in many of these products moved to the consumer side.[14] What is a new consumer electronics product? The new consumer electronics, as Michael Borrus has argued, are networked, digital, and chip-based. They involve products from personal computers to mobile devices. The nature of manufacturing and the sources of functionality change dramatically. The engineering skills moved to chip-based systems given functionality by software.

The process of creating value and the role of production changed as well. Consider the personal computer: Where in the value chain would you want to be? Do you want to be the producer of the final product, the box, even if, like Gateway or Hewlett-Packard, the box carries your logo? Or would you prefer to be the producer of the constituent elements, the components of the system such as the chip, the screen, and the operating system? The value-added is in the components and the subsystems, and in that sense those are the standards to which they must be built. Much of the value is in the intellectual property, formally in the components, often in partially opened but owned standards that create de facto intellectual property-based monopolies, or dominant positions. You have a big chunk of property in the chip, you have a big chunk of property in the screen. The result was a vertical disintegration of production. Outsourcing, a tactical response usually aimed at cost savings with a decision to procure a particular component or service outside the organization, evolved into cross-national production networks that could produce the entire system or final product. Then that discussion of cross-national production networks (CNPNs), morphed into a broader business discussion of how you manage the supply chain.

Let us state it formally: Wintelism is the code word Michael Borrus and I use to reflect the shift in competition away from final assembly and vertical control of markets by final assemblers.[15] Competition in the Wintelist era, by contrast, is a struggle over setting and evolving de facto product-market standards, with market power lodged anywhere in the value chain, including product architectures, components, and software. Each point in the value chain can involve significant competitions among independent producers of the constituent elements of the system (e.g., components, subsystems)—not just among assemblers—for control over the evolution of technology and final markets. CNPN is a label we apply to the consequent disintegration of the industry's value chain into constituent functions that can be contracted out to independent producers wherever those companies are located in the global economy. This strategic and organizational innovation, what we might now call supply chain management, means that production of even complex products can become a commodity service that can be purchased on the market. The nature of those chains, now often labeled global value chains,

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[14] Wayne Sandholtz, Michael Borrus, John Zysman, Ken Conca, Jay Stowsky, Steven Vogel, and Steve Weber, eds. 1992. The Highest Stakes: The Economic Foundations of the Next Security System. New York: Oxford University Press.
J. Stowsky. 2003. Secrets to shield or share? New dilemmas for dual use technology development and the quest for military and commercial advantage in the digital age. Working paper no. 151. Berkeley, Calif.: Berkeley Roundtable on the International Economy.

[15] By vertical control we mean both vertical integration from inputs through assembly to distribution, as in the case of American auto producers, and the virtual integration of Asian enterprise groups, as when Japanese producers of consumer durables effectively dominate market relations with semi-independent suppliers through the Keiretsu group structure.
Masahiko Aoki. 1993. The Japanese Firm as a System of Attributes: A Survey and Research Agenda. Stanford, Calif.: Center for Economic Policy Research, Stanford University.
Masahiko Aoki and Ronald Dore, eds. 1994. The Japanese Firm: the Sources of Competitive Strength. New York: Oxford University Press.
Masahiko Aoki. 1988. Information, Incentives, and Bargaining in the Japanese Economy. New York: Cambridge University Press.
Michael L. Gerlach. 1992. Alliance Capitalism: The Social Organization of Japanese Business. Berkeley, Calif.: University of California Press.

varies with the complexity of the transactions, the ability to codify the knowledge involved, and the competence of the suppliers.[16] The strategic weapon for companies such as Dell moves from the factory to the management of the supply chain. And the supply chain itself is extended both into the marketplace and back into development. Wintelism, though, was the transition from an electromechanical era into a digital age.

The Digital Age

We have moved into a digital era in which communications and computing are central, and in which many of the products and processes rest on digital technology. The era rests on digital tools for thought. "Information technology builds the most all-purpose tools ever, tools for thought. The capabilities created to process and distribute digital data multiply the scale and speed with which thought and information can be applied. And thought and information can be applied to almost everything, almost everywhere."[17] These tools for thought "amplify brainpower in the way the technologies of the Industrial Revolution amplified muscle power."[18] Certainly these tools permit the reorganization of production as communication and data exchange become easier. But more importantly, how do these tools alter the significance of manufacturing in a firm's strategic choices?

Digital tools affect the core process of creating and sustaining value. They permit the market to be segmented and then attacked with functionally varied product. First, a fundamental feature of the digital era is that analytic tools of data base management permit the consumer community to be segmented into subcomponents, each with distinct needs and wishes. At an extreme, individuals and their particular needs can be targeted. Early on, the insurance industry moved from using computers exclusively for back office operations to using them to create customized products for particular consumers.[19] Thus, collecting that information in a variety of forms (credit cards or grocery store purchases are obvious examples) is a critical matter. The result, of course, is a policy struggle about what information can be gathered, shared, and combined. The wishes of companies and governments to assemble information from diverse sources into consumer profiles or threat assessments is set against individual rights for privacy and community needs for the integrity of the individual. Second, digital tools help respond to these now defined market segments; they help create functional variety in product. Standard product can be given diverse functionality. The coffeemaker that automatically turns on at a particular time in the morning depends on simple digital functionality. The difference between many higher-speed, higher-price printers and their slower, lower-price brethren is in the software that tells the printer how to operate.[20] Let us overstate the conclusion. Electromechanical functionality of the Sony Walkman or a Bang and Olufsen high-end CD system rested on proprietary manufacturing skills. The digital functionality of the coffeemaker and an mp3 player rest largely on commodity chips in products that can be assembled by commodity production services. This package of market segmentation and digitally based functionality turns production into a commodity.

New problems are created. When market advantages rest on proprietary product and market knowledge, protecting that knowledge or intellectual property is a central issue. Digital

[16] Available at http://www.globalvaluechains.org/. Accessed November 2003.
[17] John Zysman, Steve Cohen, and Brad Delong. 2001. Tools for thought: What is new and important about the "E-conomy." Berkeley, Calif.: Berkeley Roundtable on the Industrial Economy.
[18] Ibid. p. 5.
[19] Barbara Baran. 1986. The technological transformation of white collar work: A case study of the insurance industry. Dissertation. Berkeley, Calif.: University of California.
[20] Carl Shapiro and Hal R. Varian. 1999. Information Rules: A Strategic Guide to the Network Economy. Boston: Harvard Business School Press. Page 59 refers to the versioning of IBM printers.

information makes product and process knowledge explicit and permits it to be stored in easily replicable forms. This is the case whether the firm is a media company, a company building routers, or Microsoft. When surgical technique can be formally expressed, the surgeon can be replaced by a robot. The surgical program becomes essential as hip surgery becomes a form of high-end machining. It is plausibly easier to transfer, or lose control of, formalized knowledge than intuitively held know-how. Often what might have previously been embedded in organizational know-how as the accumulation of individual understandings, shrouded from view in final product, is now potentially transferable as a data file. Suddenly intellectual property, a creation of law and social agreement if there ever was one, becomes central to company strategy.

Finally, in our brief review, let us note that the line between service and product, which concerned us at the beginning of this essay, becomes blurred even more deeply in a digital era. Consider accounting. Accounting is a person-based service, a personal service provided by hordes of accountants depending albeit on tools from the original double entry bookkeeping system through computers. But if you create a digital program, put it on a disk or CD, put it in a box, call it Quicken, and allow its unlimited use by the purchaser, then you have a product.[21] If you put the program on the Web for access with support for use on a fee basis, then statistically you are likely to have a service, an application service provider (ASP). Next, consider pharmaceuticals. If NextGenPharma sells a drug to be dispensed by a doctor or hospital or sold in a pharmacy, it is producing a product. With gene mapping and molecular analysis, we are moving toward the possibility of a service not product model of therapies adapted to particular physiologies. If NextGenPharma really is a database company with a store of detailed molecular-level drug information and a store of detailed genome functionality, it could sell an online service to customize drug or therapy. Slowly the distinction between product and service empties of meaning; we are left instead with the question with which we began. If what is being sold is a service, does that imply that sourcing the physical product as a commodity in the marketplace makes sense, that manufacturing skills are no longer critical?

PRODUCTION: STRATEGIC ASSET OR COMMODITY?

When is production a strategic asset and when a commodity that can be purchased in the marketplace? There will not be a single answer, but rather answers that are specific to particular industries. Here we consider three different sectoral groupings, based on the sector's relation to digital tools and to production.[22] At one extreme, some products can at once be digital and exchanged in entirely online marketplaces. At the other extreme, there are products that remain physical, that are usually best evaluated in person (textiles and cars), and must be delivered. In the case of a car or refrigerator the information technology instrumentality creates distinct controls and adds value. Yet, the underlying purpose and the source of functionality, transportation or refrigeration, is something physical and not digital.

Digital Goods and Digital Markets[23]

Let us begin with the most extreme cases, sectors such as finance and media, where both the product can be a digital representation and the marketplace, even delivery of the product, could be online. If production still matters in this extreme case, then we know the

[21] Certainly downloading the program would also be sale of a product, but it confuses the presentation.
[22] François Bar. 2001. The construction of marketplace architecture, from Tracking a Transformation: E-commerce and the Terms of Competition in Industries. BRIE-IGCC Economy Task Force, ed. Washington, D.C.: Brookings Institution Press.
[23] This categorization follows Bar's, ibid.

production questions will endure into the digital era. What does it mean to make or produce an entertainment or financial product for delivery? Evidently, there is the creation of the underlying entertainment content or financial instrument, and then the digital construction, the programming or development of the digital product. Even pure software products, be it a Windows operating system or the Web structure for delivering an accounting service, are built.

Moreover, that digital product is part of a system; it rests on a server and is delivered on a network of digital equipment. More generally, for computers or telecom equipment, the core functionality is the information or data processing. The hardware is a simple instrument for the digital material. Digital processing lives in a hardware house. The digital functionality expressed through the hardware differentiates the products. The issue, which is distinct from our pure software products, is, What hardware knowledge is required to effectively implement the software solutions?[24] Is the semiconductor a commodity, as it is for Dell in a personal computer, or a proprietary chip as it may be for some telecommunications applications, or a specialty chip shared with other producers? That answer, whether it is a commodity or a proprietary house for digital intellectual property, depends on the particular product and the particular hardware environment. And there is no consistency to the answers. Dell outsources its actual manufacturing and assembly, making its supply chain management into a strategic weapon. Dell's market link is the key; it has limited distinct product knowledge. Cisco likewise outsources production, but its distinct product knowledge is in the development of generations of equipment in which functionality is expressed through electronic hardware but determined by software instructions.

While manufacturing implies manipulating things and materials, its definition in my online dictionary more generally talks of "the organized action of making goods and services for sale" and putting something together from components and parts.[25] Certainly our example, Quicken, qualifies as manufacturing by this definition, as does the creation of the Yahoo Web site, and the assembly of the software tools that allow that Web site to function.

But the word "manufacturing" implies smoke and factories. We require a new word, stripped of the grime of nineteenth century manufacturing. It may not be possible to fit the concepts we are developing of a word, manufacturing, already loaded with centuries of accumulated meaning. But why not just talk of production as the general case, and manufacturing as the specific case of physical production? In that case, production—the know-how, skills, and mastery of the tools required—is absolutely central to the products in the digital sector. All the arguments about the linkages and mastery of groups of activities that we developed in the first section of the paper then would simply be revisited.

In sum we must broaden the meaning of a production worker from someone in a factory to an array of other activities. But when we do, the traditional questions—What should be

[24] Clearly, the meaning of manufacturing, or production, changes as software becomes more important. At one point a central office switch cost tens of millions of dollars to develop and several thousand workers to manufacture. Then by the early 1990s, the development costs became a billion dollars, but with semiconductor, board stuffing, and automated assembly the manufacturing could be done with a few hundred people. Early versions of routers and Internet access equipment were really honed when the product was already in the field in the hands of very sophisticated early users, universities, and early Internet service providers. And there were serious mistakes, with stories of early products catching fire because heating problems were not resolved. In any case, if the product must work the first time out for more conventional users such as telecom companies, the lines between development, production, distribution, and support vanish. Consequently, the manufacturing solution may work at the beginning. Is assuring the product will work at the beginning of the cycle a design and development problem which can then be handed over to contract manufacturing folks, or does that design and development expertise require hands-on internal production of the hardware?

[25] It seems appropriate to use the definition from an online dictionary, Wordweb Online Dictionary, at http://wordweb.info/. Accessed November 2003.

produced or built in-house? Which can be outsourced?—do not disappear. What skills are required to produce the digital product? Is the quality influenced by outsourcing? The questions remain. They are just posed in a new context.[26]

And the new context poses entirely new issues. CNPNs were precursors of global value chains, and supply chain management emerged alongside factory management. Data networks permit and facilitate these networked production systems, systems of a variety of different flavors.[27] But the most dramatic evolution comes with distributed product development of software. It is not simply collaboration across distances of traditional software developers. Rather, entirely new production systems have emerged in the open source community.[28]

Indeed, open source software may be the archetype of the digital era, a system of distributed innovation where tasks are self-assigned and where even the management of the innovation is voluntary.[29] It is quite a contrast to the archetype of the industrial era, the division of labor in Adam Smith's pin factory. Here the production of the classic good, the pin that had been made by a craftsman, is now made by an "industrial" process. The capitalist sets the process and the divisions of labor, assigning tasks that subdivide the process. The two systems of political economy—Adam Smith's pin factory and open source—rest, moreover, on quite different notions of property. Perhaps the enclosures were the archetype of property in the great transformation to a market economy that evolved into the industrial era. Property was the right to exclude others from using what had been a commons. By contrast in a distinctive style of the digital age, open source software hinges on a different notion of property. Steve Weber writes:

> Property in open source is configured fundamentally around the right to distribute, not the right to exclude. If that sentence feels awkward on first reading, it is a testimony to just how deeply embedded in our intuitions and institutions the exclusion view of property really is.[30]

Sectors Based on New Processes and Materials

At this other extreme from digital functionality, let us consider as a separate case emerging sectors based on new processes and new materials. An emerging sector such as nanotechnology is all about how you make things. Biotechnology, likewise, is about how you make things. In these sectors the question of production, product innovation, value creation, and market control remain entangled. And, indeed, we would include here the semiconductor industry in which the underlying production process and materials evolve radically as transistor size shrinks. In this sector the question of production, product innovation, value creation, and market control remain entangled.[31] A generation ago the industry was threatened when its ability to develop and source leading-edge production equipment was weakening. The capacity

[26] The critical question, once we acknowledge that software production is a form of manufacturing, is, What are the most effective ways of organizing software production? For this discussion, the list begins with the conventional questions of whether to outsource and of where, geographically, to locate software development. The story becomes interesting when we ask whether to choose conventional hierarchical production structures typified by Microsoft or new alternatives such as the commercialization of Linux products developed in an open source model.

[27] Niko Waesche. 2003. Internet Entrepreneurship in Europe: Venture Failure and the Timing of Telecommunications Reform. Northampton, Mass.: Edward Elgar Publishing.

[28] Steven Weber. 2002. The Success of Open Source. Boston, Mass.: Harvard University Press.

[29] Ibid.

[30] Ibid.

[31] Michael Borrus, Jim Millstein, and John Zysman. 1982. U.S.-Japanese Competition in the Semi-Conductor Industry. Berkeley, Calif., Institute of International Studies.
Michael Borrus, Dieter Ernst, and Stephan Haggard, eds. 2000. International Production Networks in Asia: Rivalry or Riches? New York: Routledge.

to retain an innovative edge in product seemed endangered. Now, the cycle comes full circle and after a generation in which design has often become separated from production, with foundries producing for pure design houses. Once again the question is whether product position can be held if the underlying technologies and their implementation in production systems cannot be maintained.[32]

The strategic place of production is evident if we ask, Who will dominate the new sectors? Will those who generate or even own, in the form of intellectual property rights, the original science-based engineering on which the nanotechnology or biotechnology rests be able to create new and innovative firms that become the significant players in the market? Or will established players in pharmaceuticals and materials absorb the science and science-based engineering knowledge and techniques, by purchase of firms that have spun out from a university or alternately by parallel internal development by employees hired from those same universities?[33]

There is an ongoing, critical interaction among three things: the emerging science-based engineering principles; the reconceived production tasks; and the interplay with lead users that permits product definition and debugging of early production. Arguably, that learning is more critical in the early phases of the technology cycle. Can a firm capture the learning from that interplay if it outsources significant production?

For the firm, the question is whether that interaction is more effective and the learning better captured within the firm, or even possible at all through arm's-length marketplaces? As new processes or materials emerge, it is harder to find the requisite manufacturing skills as a commodity. Certainly, with new processes and materials, new kinds of production skills become essential. Will outsourcing risk transferring core product/process knowledge and developing in others strategically critical assets? For the nation or region, the question is whether ongoing production activity is needed to sustain the knowledge required to implement the new science and science-based engineering. In other words, a regional or national government may not care if the learning goes on within a specific firm, as long as the learning is captured in technology development within its domain. Those intimate interplays have traditionally required face-to-face, and hence local and regional, groupings. With the new tools of communication, what happens to the geography of the innovation node is an open question.

In this second big category, it is evident that if a firm or a national sector loses the ability to know how to make things, to use production as a strategic capacity, then it will lose the ability to capture value. Whatever goes on in the laboratories at Berkeley, if you can’t capture it in a product you can make and defend, then the science is not going to translate into a defensible position in terms of jobs and production.

Conventional Products with Digital Functionality and a Physical Function

Certainly traditional markets will be altered by market segmentation addressed with digital functionality, as we noted above. Digital tools permit new answers to the fundamental question of how much people are willing to pay for which products. Firms have new ways to identify who will pay how much for what and create products that people are willing to pay more

[32] National Research Council. 2003. Charles W. Wessner, ed. Securing the Future: Regional and National Programs to Support the Semiconductor Industry. Washington, D.C.: National Academies Press.

[33] What happened in semi-conductors development was that at a moment of new technology development, when the two major dominant established players—IBM and ATT—were restricted by antitrust competition concerns from producing semiconductor products for sale in the merchant markets. But the antitrust ruling was critical to that outcome, and to the emergence of the merchant semiconductor firms. That merchant sector changed the course of information technology evolution worldwide.

for. But the story goes beyond that.

Digitally rooted online sales/marketing and supply chain management alters the links between a firm and its customers, as well as suppliers. The Dell story shows how innovative uses of the net that ties customers from sales through to product build can create a dramatic advantage.[34] And, as development and production processes are woven together to speed time to market and improve design choices, the lines between production, design, and development blur even more thoroughly. Then, because the firm is constructing and evolving a complex evolutionary system, not just procuring a set of defined components, more of the system—a larger portion of the value-added—must be kept in-house and not outsourced. More generally, if production becomes characterized by rapid turnaround and custom activity, is the decision about where to locate production within the firm changed? Do diversified quality production and flexible specialization teach us that custom production and rapid turnaround imply tighter geographical and organizational links between production and development?

The range of products in this category is in fact too great to be put into a single set. Questions that must be answered in each case, though, are these:

- What is required to implement the digital functionality?
- Is a proprietary position required, and can a proprietary position be developed with outsourced digital development of hardware and software?
- How much knowledge is now derived from production? Is it possible for rivals to enter the market based on their learning from producing?
- Without production, how is innovation in the core product affected? How much production knowledge is required for next-generation efforts?

But even these questions are conventional. We might ask an altogether different set of questions: When do the new tools alter fundamentally the underlying business models on which firms operate? When do market knowledge and new communication tools transform a product business into a service business?

CONCLUSION

The digital era is defined by a set of tools for thought—that is, data communication and data processing technologies that manipulate, organize, transmit, and store information in digital form, with information defined as a data set from which conclusions can be drawn or control exercised. The emerging digital tool set and networks mean that information in a digital form becomes critical to a firm's strategies to capture value and market position.

Business strategies and organization, the business models that define the links between objectives and implementation, have all evolved in response to and in implementation of these tools. And with that evolution, the meaning, not just the role, of manufacturing has evolved as well. The term "production," as the act or processes of producing something, can encompass a range of products, digital as well as physical, and also delivery platforms that provide services. One implication clearly is that both matters of software and supply chain management must be

[34] Gary Fields. 2003. From communications and innovation, to business organization and territory. In The Production Networks of Swift Meat Packing and Dell Computer, BRIE Working paper no. 149. Berkeley, Calif.: Berkeley Roundtable on the Industrial Economy.
Martin Kenney and David Mayer. 2002. Economic Action Does Not Take Place in a Vacuum: Understanding Cisco's Acquisition and Development Strategy. BRIE Working paper no. 148. Berkeley, Calif.: Berkeley Roundtable on the Industrial Economy.

understood as questions of production as much as of service.

For a company, the question is how to use production as a strategic weapon. For a country, the question is how to be the most attractive location for strategic production. When production changes very rapidly, jobs can be dislocated or altered. However, if production doesn't change, then those jobs become commodities and are vulnerable to innovation abroad or to moving abroad. For both company and country the question, differently framed for each, is how to adapt to the changing logics of production.

Does production matter? Absolutely, but production can either be a commodity that is vulnerable to relocation or closure or it can become a strategic asset. As corporate strategists and national policy makers, we must help make sure that production capability is a strategic asset that we control, not one that is used against us.

23

Manufacturing Knowledge and the Arrow of Time

Eugene S. Meieran
Intel Corporation

Although it is difficult to understand the increasingly complex and ever-expanding manufacturing arena, it is essential for a company's success. The manufacturing process has many facets, and, with the added complexity of globalization of this capability, a company must have a clear and concise path to follow in order to ensure that it remains competitive. One approach to managing this complex environment is to relate things to the different timelines that are important to different stakeholders. For example, university research on future manufacturing needs may have a 3- to 6-year window of opportunity, whereas a factory manager may have a 0- to 1-year window of opportunity for improving day-to-day operations. To put it another way, researchers into manufacturing technology search for the perfect answers whenever. Because time-to-money is increasingly important in manufacturing, however, things need to happen quickly, and manufacturing managers typically search for good enough solutions to their problems now. Time is relative to these two perspectives and the question in this specific situation is how we close the gap between what is perfect and what is good enough.

MANUFACTURING PROCESSES AND TIME

Another way to think about timelines in manufacturing is to consider manufacturing as a process where people operate processing equipment, with the results of this process being the manufactured products. This process has a direct flow, from beginning to end, and the product increases in complexity as the process is carried out. This process is also irreversible, as in the case of entropy, where, for example, if you drop a glass and it breaks, the flow cannot be reversed. Time flows in one direction, from the start of the process to its completion.

The link between the fact that time is relative to different people involved in manufacturing, and the flow of time from the beginning of the process to the end, lies in the expansion of the information universe in which much of the manufacturing processes occur. As in the expanding physical universe, where galaxies and other stellar entities are moving apart at a high rate, the virtual universe is expanding and the manufacturing entities in the virtual universe are moving apart. While the force that holds the physical universe together, gravity and the exchange of gravitons, is not well understood and the future of the physical universe is not known, the "force" in the virtual universe can be thought of as knowledge. Because the exchange of data, or information knowledge, is possible, it is possible to control the complexity and expansion in manufacturing.

New technologies being continuously developed can help us to control our manufacturing destiny. This is important because in our expanding virtual universe, interdependency and interaction between knowledge objects is increasing. The volume of data, information, and knowledge inhabiting this space is also increasing. These interdependencies result in an increasing impact on manufacturers and customers in terms of cost, quality,

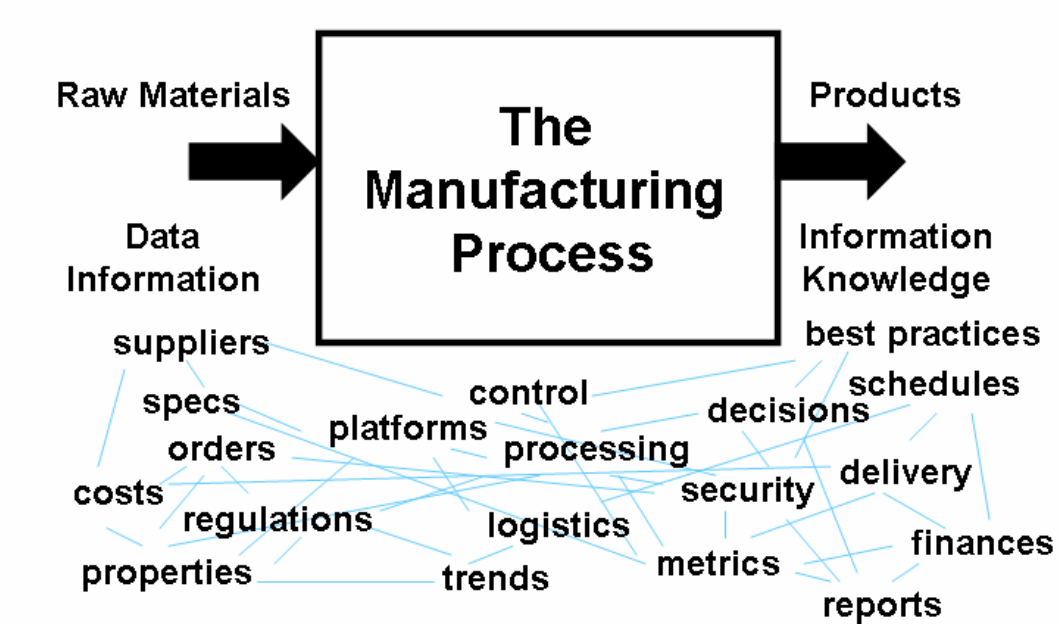

FIGURE 23-1 Illustration of real and virtual manufacturing transformations.

performance, and time.

DATA, INFORMATION, KNOWLEDGE, AND WISDOM

The distinction between data, information, knowledge, and wisdom is important. For example, raw data in a table do not appear to be very useful. We do not know what the numbers mean. Additional reference material can turn data into useful information, for instance, by arranging it spatially into a map.

In the same way, additional information can lead to knowledge, for example, directions from one place to another on the map. The last application to this process is wisdom, which we define as expertise applied to knowledge. For example, a “wise” person could inform us that at rush hour we should use Ray Road rather than Chandler, or that there is a speed trap at Rural and Chandler. This adds richness to the travel guide.

With these definitions in mind, we can now look at the manufacturing process. Figure 23-1 illustrates manufacturing as a transformation: in real space, a transformation of raw materials into products, and, in virtual space, a transformation of data into knowledge or wisdom. The data, information, and knowledge involved in the manufacturing process increase in volume and are interrelated. There are no boundaries between what were once considered to be independent “buckets.” As a result we must continuously create, develop, deploy, categorize, store, apply, and recreate the systems to handle the voluminous data, information, knowledge, and wisdom that apply to and relate these activities to one another. Fortunately, new information and knowledge management technology enables us to do this.

PROBLEMS AND OPPORTUNITIES FACING MANUFACTURERS

With the ever-growing complexities presented in the manufacturing process it is critical to understand both the problems and the opportunities facing manufacturers today. Significant

problems facing manufacturers include decreasing time-to-money, with a resulting need for speedy responses to manufacturing issues; increasing susceptibility to attack and/or security breaches, making swift responses absolutely necessary; a more volatile workforce as a result of globalization and expansion; the exponentially increasing volume of data, information, and knowledge noted above that must be formatted, controlled, and distributed properly and effectively; obsolete and legacy systems that make it difficult to expand, evolve, or grow in an efficient manner; an absence of a well-thought-out architecture or plan, resulting in new pieces of functionality simply being attached to the existing structure; and strong, agile, and globally distributed competition.

At the same time, opportunities in manufacturing are constantly emerging. Lower-cost processes and faster technologies to cope with legacy environments are becoming readily available. Interoperability and testbed standards allow us to figure out how to make all the systems work together. New approaches in learning technologies and teaching bring people into manufacturing and train them or take people already in manufacturing and retrain them with the new technology. New collaboration capabilities exist, both virtual and real. This new type of collaboration creates a whole new environment. New materials are continuously being developed, and faster computers and better communication capabilities make it easier to design complex products.

Globalization can be defined as the physical separation of people, e.g., by distance and time zones, and the virtual separation of people due to culture, values, and languages. Collaboration technology can be applied to issues arising from globalization, but this begs the question of how people collaborate in the first place. How does electronic/virtual collaboration differ from face-to-face meetings or audio conferences? New types of collaboration will generate new norms and new societies. These exciting issues must be addressed in order to continue on the path of successful manufacturing.

Fortunately, there are many resources available to the manufacturing community, including:

- Academia (universities, community colleges);
- National labs;
- Consortia (partnerships between industry, national labs, academia);
- Suppliers;
- Internal expertise; and
- Professional societies.

The difficulty arises in linking these collective sources of expertise together rather than just summing up each individual's knowledge. The establishment of a resource for sharing expertise would enable projects to be undertaken more productively and efficiently.

IMPORTANCE OF ARCHITECTURE AND PLANS

In order to achieve the desired outcome of efficient manufacturing processes, a defined architecture/plan must be developed. An example is the Winchester Mystery House, built by the wife of the inventor of the Winchester Repeating Rifle. Additions to this house were haphazard and were made without any specific plan (it was believed that as long as the house was under construction, Ms. Winchester would not pass away). The house is a maze of different shapes and functions, with redundancy, poor connectivity, random and useless stairways, doors leading

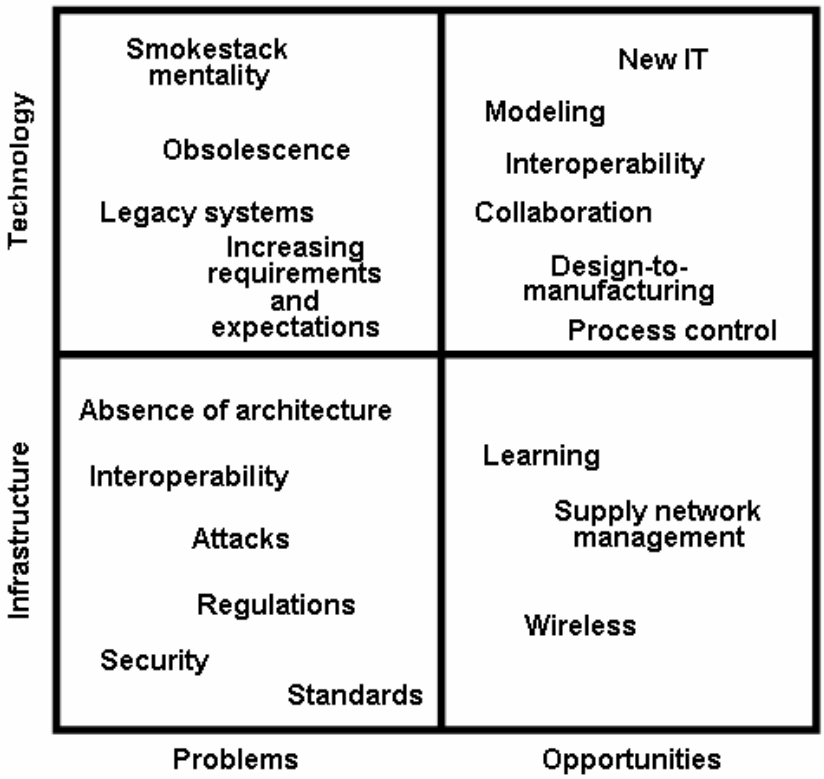

FIGURE 23-2 Information management issues related to creating an integrated architecture for improving manufacturing performance.

nowhere, and windows opening onto blank walls. It is possible to live in this house, but it is not a very functional or efficient design. Westminster Abbey, on the other hand, is a well-known and beautifully designed structure. Construction of Westminster Abbey took years of preparation and planning with a clear focus on architecture and function. It is considered to be an efficient use of space and an inspiring building. Too often, our approach in manufacturing is to build suites of applications reminiscent of the Winchester Mystery House, with patchy and inefficient interfaces. Our effort should be to develop a Westminster Abbey-type approach, with a truly integrated and well-thought-out architecture.

Figure 23-2 illustrates some of the information management issues related to the creation of an integrated architecture. The elements in the matrix represent knowledge objects that should be addressed in order to improve manufacturing performance. This matrix points to the following manufacturing issues (not prioritized) that must be addressed in order to improve performance:

- Interoperability/interoperability standards;
- Pervasive and adaptive process control;
- Advanced learning technology;
- Global collaborative capabilities;
- Enterprise-wide supply network management;
- Knowledge management and navigation tools;

- Security and other protection systems;
- Modeling and simulation technology;
- Wireless and remote communication;
- Software to enhance moving from ideas to products; and
- Incorporating intelligence into processes and products.

CONCLUSIONS

Manufacturers are facing significant issues such as equipment and process obsolescence; sophisticated competition; globalization of customers, facilities, and suppliers; rapid change; increasingly complex human factors; and increasingly complex products, logistics, and processes. These issues must be addressed and resolved by a company if it is to remain competitive. Fortunately, emerging manufacturing technologies and capabilities can help address these issues and open the door for new opportunities. In particular, data, information, and knowledge management capabilities will enable leveraging of these opportunities to handle ever more complex manufacturing processes. Indeed, such capabilities provide the foundation for a new manufacturing paradigm. Previously, manufacturers depended heavily on the creation and distribution of energy and power, as well as on product movement. Today, manufacturers exist in an era of knowledge, wisdom, and information creation and distribution.

Manufacturing operations use as much information as they do raw materials and create at least as much knowledge as they do products. Our expanding use of data, information, and knowledge appears to be the only way to cope with the exploding complexity and interdependencies within the physical manufacturing environment. Emerging information technologies appear able to satisfy most foreseeable manufacturing needs. To be successful, however, requires collaboration between laboratories, suppliers, universities, competitors, manufacturers, and funding agencies. Highly competitive manufacturing must also be highly cooperative manufacturing. Even modest investments in crosscutting technologies, infrastructure development, research and development, and collaboration can have a significant impact on our leadership position and economy.

Appendixes

Appendix A

Biographical Sketches of Committee Members

Robert J. Hermann is a senior partner at Global Technology Partners, LLC, a firm that specializes in investments in technology, defense, aerospace, and related businesses worldwide. Previously, Dr. Hermann spent 16 years at United Technologies Corporation (UTC), where he retired as senior vice president for science and technology in 1998. Prior to joining UTC, Hermann served 20 years with the National Security Agency, with assignments in research and development, operations, and the North Atlantic Treaty Organization (NATO). In 1977, he was appointed Principal Deputy Assistant Secretary of Defense for Communications, Command, Control, and Intelligence; and in 1979, he was appointed Assistant Secretary of the Air Force for Research, Development, and Logistics. He held a parallel position as director of the National Reconnaissance Office. Dr. Hermann has held a number of positions on advisory boards, including member of the President's Foreign Intelligence Advisory Board (1993-2001); chair of the board of directors of the American National Standards Institute (1998-2000); chair of the board of directors of Draper Laboratory; member of the board of directors of Condor Systems and Orbital Sciences Corporation; and member of the Defense Science Board. Dr. Hermann is a member of the National Academy of Engineering.

William Baeslack is dean of the School of Engineering at Rensselaer Polytechnic Institute, leading and administering a college of approximately 150 faculty, 2,500 undergraduates, and 750 graduate students. Concurrently, he is a senior materials scientist in the metals and ceramics division of the U.S. Air Force Reserves. Prior to joining Rensselaer, Dr. Baeslack served as interim vice president for research and development at Ohio State University and as president of the Ohio State University Research Foundation. In addition, he served as chair of the Department of Welding Engineering and professor in the Department of Industrial, Welding, and Systems Engineering. Dr. Baeslack is the author of over 150 journal articles and 7 book chapters. He is active in professional associations, including the American Association for the Advancement of Science, the American Society for Engineering Education, and ASM International. Dr. Baeslack has served as an industry consultant to GE Aircraft Engines, Lockheed, McDonnell Douglas, and Rocketdyne.

Edward C. Dowling is executive vice president for operations at Cleveland Cliffs, Inc., the largest iron producer in North America. His responsibilities include profit and loss responsibility for five large-scale iron ore mining, processing, and manufacturing operations; an international reduced iron facility; purchasing, research and development, engineering, safety, and environmental functions; and overall company-wide improvement efforts. The total production value of these businesses exceeds $1.3 billion, and there are over 4,000 employees. Prior to joining Cleveland Cliffs, Dr. Dowling served as senior vice president and director of process management and engineering at Cyprus Amax Minerals Company. In that position, he was responsible for leading a subsidiary of Climax Molybdenum Company, Climax Specialty Metals and Performance Chemicals, and the downstream copper smelting and refining operations. He is recognized as an expert in process engineering, integrating engineering

theory and practice to obtain real solutions to important industrial problems. Dr. Dowling has published more than 35 articles focusing on processing engineering and technical approaches to operations and business optimization. In addition, he has received a number of industry awards, including, most recently, an award from the Extractive Processing Division of the Metallurgical Society (2000) and the Robert H. Richards Award from AIME (2001). He is a member of the Metallurgical Society, Sigma Xi, the Mining and Metallurgical Society of America, and the American Iron and Steel Institute.

Thomas W. Eagar is the Thomas Lord Professor of Materials Engineering and Engineering Systems at the Massachusetts Institute of Technology (MIT). Previously, he served as head of the Department of Materials Science and Engineering, director of the Materials Processing Center, and codirector of the Leaders for Manufacturing Program. Dr. Eagar is the author or coauthor of over 175 publications in national and international journals and the coinventor of 13 U.S. patents, with 3 additional U.S. patents pending. He is active as a member of technical committees for U.S. governmental departments and agencies and is active in professional associations. Dr. Eagar has received numerous awards, including Nelson W. Taylor Lecturer, Pennsylvania State University (1995); William Irrgang Award, American Welding Society (1993); Henry Marion Howe Medal, ASM International (1992); and Comfort A. Adams Lecturer, American Welding Society. Dr. Eagar is a fellow of the American Welding Society, the American Society for Metals International, and the American Academy of Arts and Sciences. He has served on many National Research Council panels and committees and is a member of the National Academy of Engineering.

Joseph A. Heim is part of the corporate materials engineering group at Genie Industries, Inc., where he: evaluates opportunities to develop vertical business units; resolves supply chain issues; and improves the organization’s engineering-science fundamentals. Prior to working with Genie Industries, Dr. Heim was a member of the industrial engineering faculty at the University of Washington, where his research focused on the coordination of complex collaborative tasks and computer-based anthropological tools to support product development. He also served as a senior program officer at the National Research Council, directing studies to determine if there were opportunities at the federal level to improve the performance of smaller American manufacturing firms. He is a member of the American Society of Engineering Education and the Society of Manufacturing Engineering and was the J. Herbert Hollomon Fellow at the National Academy of Engineering.

Karl Kempf is a senior fellow and director of decision technologies in the technology and manufacturing group of Intel Corporation. He also serves as adjunct professor at Arizona State University. As a member of Intel’s technology manufacturing engineering group, Dr. Kempf directs the continuous improvement of decision-making processes in Intel's capacity supply chain (i.e., designing, building, ramping, and running manufacturing facilities). As a member of the supply network group, he directs the continuous improvement of decision-making processes in Intel's product supply chain (i.e., planning worldwide production and logistics across multiple product lines). Since joining Intel in 1987, Dr. Kempf has been involved in designing and implementing decision policies for production scheduling, staffing, and cross-training; equipment maintenance; ramp management; equipment selection and layout; strategic and tactical production planning; and logistics operations. He has also been involved with a wide variety of modeling and simulation projects. Prior to joining Intel, Dr. Kempf worked at McDonnell Douglas Corporation, where he was a member of the team that won the contract for automating the initial NASA space station. Dr. Kempf is the author of over 75 research papers on heuristic and mathematical decision science and over 50 internal publications. He has delivered keynote addresses at national and international conferences. Dr. Kempf cofounded and cochaired the American Association for Artificial Intelligence's Manufacturing Special

Interest Group and has served on the editorial board of IEEE's expert journal focusing on artificial intelligence applications in manufacturing. He is a member of the National Academy of Engineering.

Max Lagally is the Erwin W. Mueller Professor of Materials Science and Physics at the University of Wisconsin-Madison. He is a member of the Department of Materials Science and Engineering, with a joint appointment in the Department of Physics. His research focuses on synthesis and characterization of materials at reduced dimensionality, i.e., surfaces, interfaces, thin films, and clusters, with primary emphasis on semiconductor and magnetic materials and on instrumentation development. In 1997, Dr. Lagally formed PIEZOMAX Technologies, now nPoint, Inc., a company dedicated to developing precision positioning and motion tools for nanotechnology. Dr. Lagally has authored approximately 300 publications, edited 4 books, and is the holder of 2 patents, with 5 additional patents pending. He is the recipient of a number of research honors, including the Welch Award of the American Vacuum Society; the MRS Medal; and the David Adler Lectureship Award. He has been a Humboldt Senior Research Fellow in Germany and the Gordon Godfrey Visiting Professor of Physics at the University of New South Wales. He is a member of the German National Academy of Science (Leopoldina) and the National Academy of Engineering.

James Mattice is director of management and organizational development at Universal Technologies Corporation (UTC). In this position, he provides corporate leadership in the areas of strategic planning and new business development. He also supports ongoing government and commercial activities in the areas of research, development, technology advocacy, technology transition, executive development, and training. Mr. Mattice has 38 years of experience in conducting in-house laboratory research and in leading all aspects of basic research, exploratory research, advanced development, manufacturing technology, and executive development programs and organizations. Prior to joining UTC, Mr. Mattice served as Air Force Executive-in-Residence at the Federal Executive Institute; Deputy Assistant Secretary of the U.S. Air Force for Research and Engineering in the Office of the Secretary of the U.S. Air Force; Executive Director in the office of the Commander, Director of Development Planning; and in a variety of senior management positions in the Air Force Laboratories at the Aeronautical Systems Center of Wright-Patterson Air Force Base. Mr. Mattice is internationally recognized for his accomplishments as a research and development organization leader, corporate strategic planner, international cooperative program architect, and interservice, interagency collaborative policy/program agent. He has served on numerous boards, special study panels, and advisory committees in government and with industry and academia.

Anthony C. Mulligan is founder, president, and chief executive officer of Advanced Ceramics Research, Inc. Mr. Mulligan focuses on applications for and marketing of the advanced composite materials developed by the company's research personnel. He has also been extensively involved in the production startup and volume ramp-up of several new product production lines, including a volume production of precision composite carrier products. Mr. Mulligan is also the founder and principal of a successful medical products manufacturing company (Revdyne, Inc.) and a successful pet products manufacturing company that supplied major U.S. department stores such as Kmart, Walgreen's, Albertson's, Fry's, PetsMart, and Ames. Mr. Mulligan serves in a number of advisory positions, including member of the Industrial Advisory Council to the Aerospace and Mechanical Engineering Department at the University of Arizona; member of the board of the Arizona Manufacturing Extension Partnership, a National Institute of Standards and Technology program; member of the board of directors of the Small Business Technology Coalition; and, previously, chair of the Small Manufacturing Executives of Tucson. Mr. Mulligan is a member of ASM, the American Ceramics Society, and the Society of Manufacturing Engineers and serves on the Structural Mechanics Committee for the

Metallurgical Society.

Jack Solomon is director of technology planning at Praxair, Inc. In this position, he directs a group charged with prioritizing research and development programs, negotiating agreements for outside technology, commercializing research and development programs, and identifying new business opportunities. Dr. Solomon served as chair of the Vision 2020 Chemical Industry project, which examined the technical disciplines of new chemical science and engineering technology; supply chain technology; information systems; and manufacturing and operations. The goal of the project was to create a technology roadmap for the chemical industry to follow.

Joel Yudken is sectoral economist and technical policy analyst in the public policy department of the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO). The focus of his work is the evaluation and development of labor-based industrial policies in response to technological and economic change. His primary areas of emphasis include energy/electricity and environmental policy, manufacturing policy, and media/telecommunications and Internet policy. In this capacity, he works with staff and officers from a wide range of union affiliates and with officers and staff from several AFL-CIO state labor federations. Previously, Dr. Yudken held the following positions: senior advisor on modernization and workforce development at the National Institute of Standards and Technology's Manufacturing Extension Partnership; senior fellow at the Work & Technology Institute; professional staff at the U.S. House of Representatives' Committee on Banking, Housing, and Urban Development; and legislative fellow in the office of U.S. Senator Barbara Boxer (D-CA). He has written, spoken, and consulted extensively on science, technology, and industrial policy; Internet policy; technology and workplace change; energy policy; economic development; and defense conversion. He is a member of the National Research Council's Board on Manufacturing and Engineering Design.

Appendix B

Workshop Agenda

MARCH 27, 2003

Welcome and Remarks
Robert Hermann, Chair, Forum Planning Committee

Keynote Address
Samuel W. Bodman, Deputy Secretary, U.S. Department of Commerce

Setting the Scene: The Value of Manufacturing
Session Moderator: Gary Fischman, Biomedical Materials and Applications Consultant

Thomas Eagar
Thomas Lord Professor of Materials Engineering and Engineering Systems
Massachusetts Institute of Technology

John Tracy
Vice President, Structural Technologies, Prototyping, and Quality
The Boeing Company

Michael Baroody
Executive Vice President, National Association of Manufacturers

Economic Perspectives on Manufacturing
Session Moderator: James B. Rice, Jr., Massachusetts Institute of Technology

John Zysman
Co-director
Berkley Roundtable on the International Economy

Chad Wilkerson
Research Economist
Federal Reserve Bank of Kansas City

Ron Blackwell
Director, Corporate Affairs
AFL-CIO

The Human Element in Manufacturing
Session Moderator: Leo Reddy, CEO, NACFAM

Phyllis Eisen
Vice President, Manufacturing Institute
National Association of Manufacturers

Mark Troppe
Director of Economic and Workforce Development
National Center on Education and the Economy

Challenges and Opportunities in New Technologies
Session Moderator: Marvin DeVries, University of Wisconsin at Madison

Rebecca Taylor
Vice President, Government Relations
National Center for Manufacturing Sciences

Gregory Cardinale
Sandia National Laboratories

Arden Bement, Jr.
Director
National Institute of Standards and Technology

Implications of Globalization on Manufacturing
Session Moderator: James J. Thompson, Office of the Secretary of Defense

John F. Cassidy, Jr.
Senior Vice President, Science and Technology
United Technologies Corporation

Charles Wade
Senior Consultant
Technology Forecasters

Margaret Eastwood
Vice President, Solutions
Motorola, Inc. (retired)

MARCH 28, 2002

View from the Hill
Session Moderator: Gary Fischman, Biomedical Materials and Applications Consultant

Olwen Huxley, Professional Staff Member
House Science Committee, Subcommittee on Environment, Technology, and Standards

Kristen Sarri, Legislative Director
Northeast-Midwest Coalition, Office of Senator Jack Reed

Major Drivers for Manufacturers
Session Moderator: Carol Gardinier, Chair, Joint Defense Manufacturing Technology Panel

Barbara Sotirin and Robert Rohde
Office of the Assistant Secretary of the Army (Acquisition, Logistics, and Technology)

Robert W. “Buddy” Garland
U.S. Department of Energy Office of Industrial Technologies

Eugene Meieran
Intel Corporation

Important Dilemmas for Manufacturers
Session Moderator: Delcie Durham, National Science Foundation

Anthony C. Mulligan
President and CEO
Advanced Ceramics Research, Inc.

Stephen Sleigh
Director of Strategic Resources
International Association of Machinists and Aerospace Workers

Summary session, with comments by the committee chair

Appendix C

Acronyms and Abbreviations

ACTD	advanced concept technology demonstration
AIA	Airline Industries Association
ASP	application service provider
ATD	advanced technology demonstration
ATP	Advanced Technology Program
BEA	Bureau of Economic Analysis
BMED	Board on Manufacturing and Engineering Design
CAGR	compound annual growth rate
CAIV	cost as an independent variable
CNPN	cross-national production network
CQI	continuous quality improvement
CRADA	cooperative research and development agreement
CTMA	Commercial Technologies for Maintenance Activities
DARPA	Defense Advanced Research Projects Agency
DASA(R&T)	Deputy Assistant Secretary of the Army for Research and Technology
DoD	Department of Defense
DOE	Department of Energy
EMS	electronic manufacturing services
EPA	Environmental Protection Agency
EUVL	extreme ultraviolet lithography
FCS	Future Combat Systems
FDI	foreign direct investment

FLAG	Fair Litigation Action Group
GDP	gross domestic product
IAM	International Association of Machinists and Aerospace Workers
ILO	International Labor Organization
IMS	Intelligent Manufacturing Systems
IT	information technology
ITP	Industrial Technologies Program
JTRS	Joint Tactical Radio System
MANTECH	Manufacturing Technology
MEMS	microelectromechanical systems
MEP	Manufacturing Extension Partnership
MSA	metropolitan statistical area
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NAM	National Association of Manufacturers
NCAT	National Center for Advanced Technologies
NCMS	National Center for Manufacturing Sciences
NIST	National Institute of Standards and Technology
NRC	National Research Council
OECD	Organization for Economic Co-operation and Development
OEM	original equipment manufacturer
OIT	Office of Industrial Technologies
PM	program manager
R&D	research and development
RF-NEMS	radio frequency nanoelectromechanical system
SBIR	Small Business Innovation Research
SME	small or medium-sized enterprise
SMT	surface mount technology
STEP	Standard for The Exchange of Product Model Data

STTR	Small Business Technology Transfer
TFI	Technology Forecasters, Inc.
TPA	Trade Promotion Authority
UTC	United Technologies Corporation
WFO	work for others
WIA	Workforce Investment Act
WTO	World Trade Organization