MANUFACTURING

A Report on the Industry

June 2004

Industrial College of the Armed Forces
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Fort McNair, Washington, D.C. 20319-5062

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
2004 Manufacturing A Report on the Industry	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Industrial College of the Armed Forces National Defense University Fort McNair Washington, DC 20319-5062**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**46**	

MANUFACTURING

ABSTRACT:

Manufacturing has been the heart and soul of the U.S. economic engine for over a hundred years. It may be asserted that manufacturing has propelled the nation to victory in multiple world wars and fueled America's leadership role in developing a global economy in the 20th century. However, many fear that something is desperately wrong with the current state of U.S. manufacturing citing recent job losses as a sign of sickness. The debate quickly turns to blaming the "globalization" of the economy which allegedly lured manufacturing jobs overseas along with the heart of the U.S. economy. Globalization has arguably challenged the U.S. manufacturing industry and therefore poses a significant threat to U.S. national security. But is this really so?

During January to June 2004, the Manufacturing Industry Study seminar looked broadly at the manufacturing sector, both in the U.S. and abroad. The group listened to advocates for the manufacturing industry, academia and government, and then visited various industry, academic and research institutions to assess the state of manufacturing. While intensive at times, these visits enabled the study group to peel back the façade of theory and rhetoric, and get to the heart of the manufacturing sector. The final product of this study will outline why manufacturing needs to be studied, define the manufacturing sector, and assess the current state of manufacturing in the United States, examine challenges and opportunities for the industry, examine the role of government in fostering the industry, and examine the implications of globalization from both a U.S. and international perspective

This study identified several strategies that must be accomplished by the government, industry and government/industry partnerships to overcome manufacturing challenges and capitalize on the opportunities offered by the global economy. The government must work to level the "globalization" playing field, fund basic research to grow technology, and establish education initiatives to maintain a qualified and capable workforce. The manufacturing industry needs to embrace globalization, capitalize on customer satisfaction expectations and improve productivity by "moving up the value chain" from Industrial Age production levels and concepts. Government, academia and industry partnerships need to increase workforce training/retraining programs and conduct effective technology transfer activities. Finally, manufacturing must remain healthy because it provides U.S. economic prosperity, which in turn enhances U.S. national security.

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DATA COLLECTION

Seminar Presentations:
National Association of Manufacturers (NAM)
National Institute of Science and Technology (NIST)
Federation Incorporated, Product Data Management
University of Maryland, Micro-Electronic Mechanical Systems
Tompkins Manufacturing Consultants
National Defense Industrial Association (NDIA)
House Committee on Small Business, U.S. Congress
National Center for Defense Manufacturing and Machining (NCDMM)

Domestic Site Visits:
Northrop Grumman Electronic Systems, Baltimore, MD
General Dynamics Ordnance and Tactical Systems, Red Lion, PA
Harley-Davidson Motorcycles, York, PA
Boeing Aircraft, Vertical Lift Division, Philadelphia, PA
USMC Expeditionary Fighting Vehicle, Woodbridge, VA
Ford Motor Company, Norfolk, VA
Northrop Grumman Newport News Shipbuilding, Newport News, VA
Johns Hopkins University Applied Physics Laboratory, Laurel, MD
East Penn Manufacturing Company, Lyon Station, PA
Caterpillar, Clayton, NC
Wilmington Machine, Wilmington, NC
General Electric Aircraft Engines, Wilmington, NC
Biolex, Pittsboro, NC
University of Kentucky, Lexington, KY
Toyota Motor Manufacturing, Georgetown, KY
Mazak Machine Tools, Florence, KY

International Site Visits:
ABB Robotics, Vasteras, Sweden
Sapa, Vetlanda, Sweden
Saab Aircraft, Linkoping, Sweden
Ericsson Electronics, Stockholm, Sweden
Republic of Ireland Department of Defense, Dublin, Ireland
Dublin City University, Dublin, Ireland
Benchmark Electronics, Dublin, Ireland

'Manufacturing is a cornerstone of the American Economy. The United States is the world's largest producer of manufactured goods and leads the world in innovation. Simply put, manufacturing matters—to jobs, rising productivity and higher standards of living. Manufacturers improve our quality of life.'[i]

INTRODUCTION

In 2004, an election year in the United States, the television bombards us with political advertising and news reports hoping to inform the public of critical policies and differences between the election platforms of the major parties. One critical issue is conspicuous amongst all others: the economy, and the drive for employment and productivity. In spite of an economic recession and the constant battering of information and commentary on the loss of jobs in the manufacturing industry, the manufacturing industry itself seems healthy, producing manufactured goods for the population and for export.

Manufacturing has been the heart and soul of the U.S. economic engine for over a hundred years. It may be asserted that manufacturing has propelled the nation to victory in multiple world wars and fueled America's leadership role in developing a global economy in the 20th century. However, many fear that something is desperately wrong with the current state of U.S. manufacturing citing recent job losses as a sign of sickness. The debate quickly turns to blaming the "globalization" of the economy, which has allegedly lured manufacturing jobs overseas along with the heart of the U.S. economy. Globalization has arguably challenged the U.S. manufacturing industry, and therefore poses a significant threat to U.S. national security. But is this really so?

During 2004, the manufacturing industry study seminar looked broadly at the manufacturing sector, both in the U.S. and abroad. The group listened to advocates for the manufacturing industry, academia and Government, and then visited various industry, academic and research institutions to assess the state of manufacturing. While intensive at times, these visits enabled the study group to peel back the façade of theory and rhetoric, and get to the heart of the manufacturing sector. The final product of this study will outline why manufacturing needs to be studied, define the manufacturing sector, outline and assess the current state of manufacturing in the United States, examine challenges and opportunities for the industry, examine the role of government in fostering the industry, examine the implications of globalization from both a U.S. and international perspective, and provide recommendations to enhance and sustain the manufacturing industry.

WHY MANUFACTURING?

Manufacturing is important to the U.S. because of the significant contributions it makes to our economy. America's manufacturers provide the nation and its people with good jobs, a better quality of life, and inventions that have established the national identity. Manufacturing is the backbone of the economy and the muscle behind national security.[ii] Why is this so?

Firstly, manufacturing acts as a job and revenue multiplier. There are approximately 15 million people in the U.S. manufacturing sector; however, there are about 8 million more people whose jobs directly depend on manufacturers.[iii] Ultimately, each U.S. manufacturing job directly or indirectly creates about another 4 jobs in the U.S.[iv] For example, an automotive company directly employs 31,000 American manufacturers, but once you account for the related

sales/services, research and development, suppliers, design, financial services, and dealers located in all 50 states, it actually employs 180,000 people. Additionally, for each dollar spent in manufacturing, $1.43 is made in other sectors.[v]

Secondly, manufacturing leads in productivity and Gross Domestic Product (GDP) growth. In terms of orders, exports, and capital investments, U.S. manufacturing currently accounts for about 11% of the GDP[vi], and manufacturing productivity increased 4.8 % in the fourth quarter of 2003.[vii] Over the last decade, manufacturing has contributed more than one fifth of the overall economic growth of 22%.[viii] Additionally, manufacturing accounts for most of the $700B we sell abroad — about 62% of U.S. exports ($50B/month) as compared to the agriculture sector which accounts for about 6% of U.S. exports ($50B/year).[ix]

Thirdly, innovation and research and development are other major reasons why manufacturing is important to the U.S. Accounting for two thirds of private sector research and development, and 90% of patents, manufacturing is a leading customer and driver of Information Technology (IT), an enabler of scientific research and funding, and is the driver of tech-based productivity growth.[x] The U.S. is the global technology leader, and technology is a direct result of investment. As manufacturing technology and jobs move offshore investment within those sectors go as well.

Lastly, while the price of manufactured goods has remained relatively steady over the last 20-30 years, albeit with recent downward pressure, the structural costs to produce these goods have increased.[xi] Structural costs such as healthcare, litigation, taxes, energy prices, and regulatory requirements add about 22% to the cost of doing business in the U.S.[xii] Without these costs, the total cost of manufacturing in the U.S. would be less than the cost of manufacturing in Canada, the UK, Germany, France, and would be close to South Korea.[xiii] These are domestic costs that manufacturers must overcome; if they pass them on to the customer by raising prices, they won't be competitive internationally.

THE INDUSTRY DEFINED

The Committee on Visionary Manufacturing Challenges broadly defines manufacturing as "the processes and entities required to create, develop, support, and deliver products."[xiv] An alternate definition limits manufacturing to the capital intensive, technically sophisticated production of components and materials, excluding final product assembly from the definition as labor intensive and unsophisticated.[xv] However, this is not representative of what the study group saw on its industry travels. The U.S. Census Bureau defines U.S. manufacturing as:

> *"The manufacturing sector comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products. The assembling of component parts of manufactured products is considered manufacturing…"* [xvi]

While each of these definitions is arguably correct, for the purposes of this paper, the study group defines manufacturing simply as the production, assembly and integration of durable goods, components and materials for sale to a consumer. For the purposes of the study, this definition does not include manufacture of non-durable goods, but does recognize the unique subset of the defense manufacturing industry.

U.S. Manufacturing

For U.S. manufacturing, an extended period of global dominance in manufacturing innovation, process engineering, productivity, and market share ended in the late 1980s. The managerial practices, strategies, and organizational designs applied by U.S. manufacturers had not adapted sufficiently to the changing global competitive environment, and thus the U.S. manufacturing industry was not performing as well as many foreign competitors.[xvii] A strategic scan undertaken at the time would have revealed that manufacturing had entered the early stages of a period dominated by the convergence of three powerful trends:

a. Global competition caused by the rapid advancement of manufacturing capabilities worldwide.

b. The improvement of modern manufacturing products and processes through the emergence of advanced manufacturing technologies.

c. Changes in traditional management, organizational structures, and labor practices representing new strategic opportunities and new sources of competitiveness.[xviii]

These trends provided powerful incentives for the U.S. manufacturing industry to change. To regain and retain any level of competitiveness, or indeed to ensure survival, the overseers of U.S. manufacturing industry recognized the following factors:

a. The competitive manufacturing climate, enhanced by superior communication and knowledge sharing, requires the ability to respond rapidly to market forces.

b. Sophisticated customers will demand customized products manufactured to the highest levels of quality.

c. Creativity and innovation will become the basis of manufacturing competition, and ensure that the U.S. remains a dominant force in this sector.

d. The development of innovative process technologies will alter the scope and scale of manufacturing.

e. Information and knowledge on all aspects of manufacturing and the marketplace will be instantly available in a form that can be used for decision-making.[xix]

CHALLENGES AND OPPORTUNITIES

The strategic manufacturing environment provides the U.S. with many challenges and opportunities. These factors include productivity and employment, competitiveness, outsourcing, and the influences of the global marketplace.

Productivity and Employment

With the upturn of the global economy, manufacturing output and profits have been steadily improving over the previous 12 months. Domestic manufacturing sales have increased, with the Institute of Supply Management (ISM) index of manufacturing new orders rising 28.5% since September 2003, and overall production and capacity utilization exhibited pronounced upward movement. During the corresponding period, the Bureau of Economic Analysis reported

that manufacturing profits rose to $97.7 billion.[xx] Overall manufacturing productivity growth appears very positive at this time.

Employment in the manufacturing sector, however, continues to be problematic. Over 2.8 million domestic manufacturing jobs have been lost since July 2000, with 516,000 lost in 2003.[xxi] Despite U.S. Government predictions to the contrary, substantial employment growth in the manufacturing industry remains elusive. However, this should not be surprising. The introduction of technology has enabled industries to increase output while reducing costs, without the need to employ additional personnel. This contrast is clearly evident in the figures at Appendix 1 (Figures 1 and 2).

While entire plants and industry segments have closed or moved offshore, those that remain are extremely competitive. Increases in demand are being met through increased productivity, expanded workweeks, and contracted or temporary workers. Manufacturing firms we visited universally stated that they were very reluctant to add any additional permanent employees to their payroll and would continue to use alternative means of meeting increased output requirements unless a permanent increase in demand was demonstrated. A marked improvement in manufacturing employment is unlikely unless economic conditions improve to such an extent that construction of entirely new plants becomes required. This is most likely to occur only in high-tech manufacturing, although niche markets such as American made automobiles and motorcycles continue to provide expansion and limited job growth.

Competitiveness

Manufacturing is a highly competitive industry that approaches the market characteristics of perfect competition, at least within the commercial sector — there are a large number of firms and customers; products are relatively homogeneous; limited barriers to entry or exit exist; and near perfect information exists regarding availability, pricing and quality of products. As such, no one firm can set the prices for the industry; markets set the price for products and firms are price takers. A major source of differentiation for manufacturing firms is customer satisfaction; defined by quality, responsiveness, flexibility and value.[xxii]

Companies understand, and the government recognizes, that innovation and technology are the keys to competitiveness. The National Coalition for Advanced Manufacturing (NACFAM) supports government initiatives in this area.[xxiii] The National Institute of Standards and Technology (NIST) also assist industry in the advancement of manufacturing, including such programs as the Automated Robotics Manufacturing Facility that develops computer controlled manufacturing technology.[xxiv] However, the level of commercialization of federally funded research and development remains low, at around 10%. Reasons for this vary, including the development of technologies that have no market application (due to excessive production costs or lack of practical use), to an industry reticence to utilize developments from other sources.[xxv] While the government must continue to fund basic research to ensure continued innovation, industry must take the lead in applied research where the focus must always be on commercial viability.

However, contrast this with companies within the U.S. defense industry. While many of the defense firms in the U.S. manufacture high quality components that are competitive within the global marketplace, the U.S. Government as the sole customer supports many firms. Primarily large consolidated companies manufacture many of the major weapon systems only for the U.S.

military. Firms engaged exclusively in defense manufacturing appear to maintain inefficient processes and operate at higher costs, while barriers to entry are so high that competitors are unlikely to appear. However, this is not the sole responsibility of industry, as the defense business is cyclic and is a high-risk industry for both product quality and financial stability.

Outsourcing

While it was not politically well received, Gregory Mankiw accurately commented that outsourcing jobs is probably a good thing in the long run.[xxvi] Critics are quick to see outsourcing internationally as the hemorrhaging of jobs to low wage countries; however, this argument ignores the benefits that accrue to the firm by allowing it to focus on its core competencies. Making decisions about outsourcing, even if the decision is ultimately made to retain a function in-house, forces a firm to focus on its core competencies, make decisions about the firm's strategy for positioning for the future, and assess what will lead to a sustainable competitive advantage.

There are several factors driving U.S. firms to consider outsourcing as a means of remaining competitive for the future. Firstly, outsourcing represents an opportunity to take advantage of lower cost input. Global competition from foreign and domestic firms is driving prices lower while improving quality. Since 1994 prices for manufactured goods have declined 6% (Appendix 1, Figure 3).[xxvii]

Secondly, outsourcing forces firms to focus on core competencies and position themselves more effectively to deal with future trends, including increased customer service. As Traci Purdum aptly stated in her article "Survival of the Fittest", "Manufacturing is no longer about making things, it's about customer satisfaction."[xxviii] A key to future competitiveness for U.S. manufacturing firms is a better understanding of customer needs through customer familiarization and proximity to market.[xxix] Several experts consider the most important competitive advantage to be customer intimacy. The ability to customize products to suit end customer needs will take on even greater significance in the future.[xxx] According to Chuck Stockinger, the Executive Director of the Industrial Supply Manufacturers Association, U.S. firms need to respond to the loss of manufacturing jobs by differentiating their products through "intimate knowledge of customers".[xxxi] Product proliferation necessitates collaboration; however these relationships with suppliers need to be flexible enough to accommodate rapid change in response to emerging and disappearing market opportunities. Evidence of North American firms exploiting this source of competitive advantage are planned expansions of facilities to China, where 47% of those firms surveyed by Deloitte already sell products in China.[xxxii] A desire, and in some cases a need due to political factors, to expand a global presence to have proximity to target markets is very positive for the future health of the industry.

Finally, outsourcing allows firms to exploit and share innovations and advances along the entire supply chain to the advantage of all participants. While firms have a lot to gain through outsourcing (in terms of reducing costs, accelerating innovation and focusing on core competency/improving insight into customer needs) it would be imprudent to ignore the associated risks. Outsourcing either domestically or internationally results in longer supply chains, difficulty in monitoring supplier networks, increased coordination efforts to foster good relationships, the threat that suppliers will enter your market and become competitors, increased travel cost, and the risk of quality erosion. Additionally, increased complexity in the supply

chain can limit responsiveness to opportunities if a firm allows itself to get bogged down in inflexible bureaucratic organization.

Global Marketplace

Buying goods made in America is not a high priority for U.S. consumers. The U.S. imported $1.2 trillion of products in 2002, an amount equivalent to 11% of the GDP.[xxxiii] U.S. consumers make purchases based on price, quality, durability, and style, and often the country of origin is irrelevant to consumers. Therefore, U.S. firms cannot dictate pricing for high volume, low quality goods, but must take what the market will bear.

Given the extreme advantage low-cost labor countries enjoy, it is unrealistic to believe that U.S. firms can be competitive in the production of all parts and assemblies. U.S. firms need to strengthen their competitive position by focusing on core competencies and outsourcing (domestically or internationally) those components, services, or parts that make strategic sense. U.S. manufacturers can overcome the wage differential through increased productivity and the use of automation, but they can't raise prices without losing market share. Therefore, U.S. firms need to assess their bill of materials and make realistic strategic decisions as to what it can and should produce internally. Outsourcing alone may not result in lower costs, although Jim Hemerling of BCG estimated that cost savings attributable to outsourcing internationally could be as high as 50%.[xxxiv] Included within that estimate are not only lower wages, but also lower costs for equipment, tooling, raw materials, and real estate. Ireland provides an interesting example. Ireland is now the largest exporter of computer software in the world, largely from U.S. companies. In addition, Ireland provides 40% of the total U.S. computer hardware investment.[xxxv]

However, for the use of outsourcing to be effective, additional coordination needs to occur. Passing inefficiencies along the supply chain is not a sustainable long-term strategy. Increasing the use of outsourcing and adopting Just-in-Time (JIT) practices without sharing forecast data results in subcontractors having to carry buffer stock and can create large swings in capacity utilization.[xxxvi] This is particularly relevant for specific raw materials which may become scarce or where access is difficult to secure. This topic is explored further in Appendix 3.

Another threat or opportunity, depending on one's perspective, created by the global impact of the emergence of China on world markets is the re-positioning of the historically low cost labor market countries China has displaced. Countries such as Mexico that have traditionally filled the demand for low skilled labor are responding to the threats to their traditional niche markets by seeking more complex, more highly skilled work.[xxxvii] Faced with the dual threat of China's cheap labor, and lower labor cost countries seeking higher value work, it is more critical then ever for U.S. firms to focus on areas where value is added and the labor cost differential can be overcome through productivity advantages. The U.S. should exploit outsourcing in products and services where no advantage or strategic necessity for internal production exists. Conversely, there is great opportunity for U.S. companies to expand into the potentially huge Chinese market, particularly in sectors such as construction equipment and electronics.

Increased Speed of Innovation

The ever accelerating pace of new product introduction, and high expectations that new products will account for increasing percentages of manufacturing firms' sales, place a heavy burden on firms to continue innovating. Innovating is expensive; however, outsourcing can

reduce the burden on an individual firm through "innovation spillover" from either upstream or downstream manufacturers and through shared research and development.

Firms that outsource can profit from and exploit "innovation spillover" from related industries and products. Research and development and knowledge "spillovers" allow firms to benefit from advances and knowledge without having to make the full investment directly. This allows firms within a value chain to benefit from knowledge of emerging trends, transmission of technology, and innovations of one member and find new ways to exploit them in its own segment. While technology is an important factor in the manufacturing industry, industry alone cannot carry the burden for development and introduction of innovation, so important to national security and economic prosperity.

MANUFACTURING TOOLS, TECHNOLOGY AND AUTOMATION

To adapt to the competitive global market, the integration of human and technological resources must continue to allow manufacturing to be planned, operated, maintained, coordinated and enhanced. Technology must be exploited to respond rapidly with products and processes. Manufacturing is also dependent on information technology; however, the future is dependent on the rapid transformation of that information into useful knowledge and effective decisions. Finally, the development of innovative manufacturing processes and products with a focus on decreasing dimensional scale is required to ensure dramatic changes in production capabilities.[xxxviii]

Sustaining And Disruptive Technologies

Clayton M. Christensen, author of The Innovator's Dilemma, and a Harvard Business School Professor, divides the advancement of technology into two primary terms, sustained and disruptive. Mr. Christensen describes sustained technology as the industry's rate of improvement in product performance that mainstream customers in major markets have historically valued. His definition of disruptive technology is described as a new technology that unexpectedly displaces an established technology. Additionally, he states that disruptive technology lacks refinement, often has performance problems because it is new, appeals to a limited audience, and may not yet have a proven practical application.[xxxix] Disruptive technology brings many positive changes to our daily lives, but can harbor a negative impact on industry.

Disruptive technologies can be detrimental to many manufacturing industries in many ways. One of the most recent disruptions was the introduction of assembly line automation. "If a company foresees a disruption, and marshals resources within a separate entity to capitalize on it, picking the wrong customer will lead to failure. Aggressive revenue expectations can keep venture managers from choosing to target emerging markets, places where disruptive technologies are likely to find their initial success".[xl] Disruptive innovations bring failure long before success is realized. Industries experiencing such technology must remain supple and look to the future in order to survive the implementation of such technology. The technology must continuously be analyzed for design enhancement and higher volume and profitability output.

Christensen states that large corporations are designed to work with sustaining technologies; they excel at knowing their market, staying close to their customers, and having a mechanism in place to develop existing technology. Sustaining technology, as defined by Christensen, is often just a mere bump in the road if industry is prepared for the financial burden it may create. In time, the benefits will outweigh the costs.

Since the end of the Second World War, technology has enabled increased productivity, reduced manufacturing costs, and the production of better quality goods. This has been more so since the recent introduction of computer-based technologies. This section describes some of those technologies, how they are utilized in industrial applications, and the benefits that technology brings to the manufacturing sector.

Robotics

An industrial robot is a programmable, multi-functional entity designed to perform tasks through various programmed motions. Unlike the 'humanoid' robots envisioned in the 1960s, modern production robots perform set tasks from a fixed position. They are adaptable, reliable, easy to program, safe to operate, and are capable of working in hazardous places. The main areas of use for robots are in materiel handling, production processing, assembly, and sealing and painting.[xli]

Robots are used extensively on automotive assembly lines. Used primarily for chassis welding and component painting, which are repetitive and hazardous tasks, robots enable companies to employ fewer people. Robots are also used for precision tasks, such as the placement and sealing of windscreens on the main production line. However, although the work is repetitive, robots are still not used for general assembly of automobiles, as a fixed robot still does not have the freedom of movement of a person.

The introduction of robots into U.S. manufacturing has been controversial. While robots have certainly increased productivity and the quality of products, this has been at odds with the socio-economic implications of manufacturing employment and quality of living.[xlii] While the introduction of robots has removed people from dangerous work places, it has also removed many people from the workforce altogether. This has been more prevalent in the 'low tech' manufacturing sector, which has always relied upon mass labor to provide output. Robots therefore, have increased the productivity and quality of American products, but at the expense of a certain portion of the workforce. In contrast, the use of robots in the 'high tech' manufacturing sector (such as computer chip production) has enabled production not previously achievable, without the shedding of jobs.

Computerized Manufacturing

The advent of the computer has transformed the manufacturing industry from the 'industrial' to the 'post-industrial' age, revolutionizing manufacturing processes and procedures, and providing the flexibility and agility required for the industry to compete in the modern world. Computer-based technologies provide faster production and higher quality, at reduced cost, primarily from the introduction of Computer Numeric Control (CNC) systems.[xliii]

CNC systems provide computer control of machine tools, bringing speed and repeatability to the production of components, and the ability to rapidly reprogram machines to do a variety of tasks. They also have the benefit of providing oversight to the manufacturing task, allowing experienced personnel to simultaneously monitor a number of machines. CNC machines are further enhanced by the introduction of 'autonomation' (the combination of autonomy and automation); the concept of adding an element of human judgment to automated equipment so that the equipment becomes capable of discriminating against unacceptable quality. Thus the automated process becomes more reliable—a system whereby a machine automatically shuts down, either after completing a cycle or when a defective part is produced.[xliv]

U.S. Defense contractors have remained competitive in the global ordnance market by introducing a variety of CNC systems that have increased production and cut costs, through reductions in both manpower and waste. Furthermore, they have been able to reduce the floor space of existing tasks, and then introduce new product lines into their facility to boost productivity and profits. Some companies have also adopted autonomation technology, by introducing sensors into their ammunition manufacturing equipment to detect the presence of imperfections during drilling operations. Sensors detect travel of the tapping arm and will automatically shut the machine down if the arm does not travel within the specified range. Shutdown prevents machines from producing defective parts, further reducing waste at the facility, and increasing critical customer satisfaction and confidence. However, CNC equipment produced in the U.S. for the manufacturing industry not only increases output, but does so using fewer machinist personnel, leading to the argument of productivity versus employment.

Computerized Management Systems

While technology has made improvements to manufacturing techniques, the industry remains labor intensive, particularly in assembly lines such as in the automotive and aircraft industries. However, that is not to say that technology cannot improve the efficiency and effectiveness of the workers employed within the assembly line. Computer technology provides workers with essential information for their jobs, and provides oversight of their tasks. It also provides management with critical data that is utilized to assess production efficiency.

Both commercial and defense companies use information management systems to record production errors, which halt the assembly line before multiple errors are made. They also utilize data management systems to identify faults on their hand tools as they occur. Complete Data Management Systems are also used to allow workers access to real-time information necessary to complete their assembly tasks. Line personnel can order parts, check work records, and view assembly instructions without leaving their station, or waiting for management intervention.

Nanotechnology

Nanotechnology is the precision placement, measurement, manipulation, and modeling of sub-100 nanometer scale matter; that is, the technology of controlling the structure of materials down to a few atoms or molecules.[xlv] While nanotechnology has the capacity to make current manufacturing processes and methods virtually obsolete, the useful application within today's manufacturing industry is limited, primarily due to current entry cost barriers. However, the rapid development of Micro-Electro-Mechanical Systems (MEMS) manufacturing has great potential within defense applications.

MEMS is based on a manufacturing technology that has roots in microelectronics, but MEMS has gone beyond this initial set of processes as it became more intimately integrated into macro devices and systems. MEMS will be successful in applications where size, weight and power must decrease simultaneously with functionality increases, conducted under extreme cost pressure.[xlvi] For instance, a typical missile accelerometer and gyroscope cost $1,000, but an equivalent micro-device may cost only $20, which can then be fitted into smaller warheads such as howitzer and mortar shells to provide in-flight guidance.[xlvii] While potential production costs are very low, the high development costs required to initiate production currently inhibits the transition of this technology to general industry. Both academic researchers in this field and the firms visited considered this technology to be promising but years from the degree of maturity

where it could be considered commercially viable and scalable. The future of global manufacturing success lies in the high-tech world of nanotechnology, where quality products can be produced quickly and cheaply. However, while miniaturization is possible, it generally remains the domain of universities and research institutions due to the high cost of research and development.

MANUFACTURING PROCESSES AND NEEDS

In today's competitive, global economy, many business organizations are striving to be the best in their industries. Benchmarking the best manufacturing practices of leading edge companies and educating our workers on these processes allows the manufacturing industry to continually improve and strengthen. While a majority of the firms we visited used this tool, most limited benchmarking to other facilities within the same company or close competitors. Few firms looked beyond their particular industry segment to benchmark their performance relative to state of the art firms. Specifically, the best manufacturing practices that are proven to tackle efficiency and effectiveness problems must be mastered by the entire U.S. manufacturing industry for it to stay competitive. For these reasons, it is in everyone's best interest for U.S. companies to maximize efficiencies through such practices as Lean Manufacturing and Six-Sigma (an explanation of Six-Sigma, and examples of reported benefits, is detailed at Appendix 2).

The most successful manufacturers have adopted best practice solutions such as Just In Time (JIT), Lean Production, Supply Chain Management (SCM), and Agile Manufacturing. After analyzing the similarities and differences in these various processes, these and other manufacturing-related best practices can be logically grouped into the categories of efficiency, effectiveness, and both efficient and effective. Many times the lines between these best practices blur, and some of the pieces of each concept are identical.

Efficiency. JIT and Lean Manufacturing are two Manufacturing Industry best practices that can be categorized under the efficiency category. JIT is a term that is familiar to most people. In this context it is aimed at organizing manufacturing processes so that parts are supplied to the shop floor only when they are needed – not too soon and not too late. In other words, the right parts are delivered, manufactured, purchased, etc. at the right place and at the right time. The idea is to keep inventory of pieces, parts, end items, etc. at the lowest levels possible, thus keeping costs down. JIT requires limiting the number of suppliers used and development of long-term, trusted suppliers. Lean Manufacturing (also known as Lean Production) is a production philosophy that conceptualizes the entire production process and attempts to eliminate non-value added steps throughout the process from product design and raw materials input to product output and customer service. All suppliers in a Lean Manufacturing process are treated as partners.

Effectiveness. Continuous Improvement and Agile Manufacturing are two best management practices used by leading edge manufacturers to improve effectiveness. Continuous Improvement or Kaizen is a Japanese term for gradual, unending improvement. This concept may be familiar to those who have studied Total Quality Management concepts. It is essentially ongoing improvement involving everyone: top management, supervisors, and workers inside the company and throughout the supply chain. It is applicable to almost any established process and is used by most leading edge manufacturers. Agile Manufacturing is often mistaken for Lean Manufacturing, but it is not the same. Agile Manufacturing includes all of the Lean Manufacturing concepts in addition to forming virtual partnerships to combine state-of-the-art

production methodologies to custom make products to suit each customer's taste, specifications, and budget.[xlviii] Simply put, it includes all the principles of lean manufacturing plus the agility necessary for an unpredictable (changing demand) business environment. Sometimes agile processes are not the most efficient but always strive to be the most effective for the manufacturer and the customer.

Efficient and Effective. Supply Chain Management and E-manufacturing are two processes used by the Manufacturing Industry to strive for both efficiency and effectiveness. SCM is "…the integration of key business processes from end users through original suppliers, and it provides products, services, and information that add value for customers and other stakeholders".[xlix] The goal of SCM is to optimize each link in the supply chain, while integrating each part of the chain into one overall process. Trust between supply partners, up and down the value stream, is the key to its success. E-Manufacturing leverages technology and interconnects customers, manufacturing operations (even machine to machine), and supply chain partners. This process allows information transfer via the Internet from the customer to manufacturing operations and supply partners.

LABOR FORCE

The U.S. manufacturing industry depends on a highly trained, intelligent workforce to maintain its global competitiveness. The struggle to acquire, educate, train and retain quality salaried professional and hourly touch employees is a recurring theme among all manufacturers visited. Labor force changes resulting from demographic shifts and the increasing technological complexity of manufacturing processes are contributing to projected shortfalls in qualified manufacturing workers. To meet the demands for a workforce of the future, training and education programs must generate the skilled workers and engineers critical for U.S. manufacturing competitiveness.

Skilled Labor Shortage. Several reasons are cited for the apparent shortage of skilled labor. Demographic shifts in the population indicate that a majority of skilled manufacturing workers are approaching retirement age. The increasing skill level required of manufacturing workers is also cited as contributing to the expected shortfall. Maintaining a skilled workforce is the greatest challenge facing manufacturers today.

Approaching demographic changes will have a major impact on U.S. manufacturers. Of the firms visited during the course of this study, the average age of the workers on the manufacturing floor was consistently in the range of 47 to 52 years of age. In the auto industry alone, it is reported that 250,000 workers will reach retirement age by 2005. Simple replacement of retiring employees does not bridge the skill gap presented by retirements. Given the limitations of the available labor pool, the increasing complexity of manufacturing processes and the extensive training period required to train new employees, a potential labor shortage is projected.

The rapid introduction of technology has forced a shift from a majority of unskilled labor jobs in the 20th Century to a greater requirement for skilled labor today. Productivity changes, uses of technology and the requirement for agile and flexible manufacturing processes have reshaped the skills required in both professional and hourly workers in today's manufacturers. Only 30% of manufacturing jobs today are considered unskilled. This represents a 50% decrease over the last fifty years. Advances in manufacturing will necessitate skilled employees in over 85% of positions in U.S. firms by 2005.[l]

A Workforce For the Future. Several manufacturing advocacy and research organizations report that a talent shortage threatens the future U.S. manufacturing workforce. An increasingly high-tech workplace underscores the need for the next generation of manufacturing workers to be adequately prepared. Similar to the educational leap required to train workers for the Industrial Age, manufacturing workers of the Information Age will be required to integrate a new set of technological, interpersonal, and problem-solving capabilities. The physical skills of the Industrial Age worker are being replaced by cognitive requirements of the Information Age for both production and engineering personnel in the manufacturing sector.

Such a major shift in capabilities will require fundamentally different education and training. Assisting manufacturers in the identification and assessment of these critical capabilities is the charter of the Manufacturing Skill Standards Council (MSSC). This Council, comprised of leaders from the education community, manufacturing firms and workers' groups, proved invaluable in the creation of "A Blueprint for Workforce Excellence."[li] This sector-specific assessment tool established skill standards and captured the best practices for a flexible and adaptive industrial workforce. These skill standards can serve as the foundation of a complete system that includes assessment and certification programs. From digital journeyman programs to diversity education and team skill development, state of the art manufacturers recognize the criticality of worker skill development for future competitiveness.

Advanced labor skills are fundamental to the U.S. innovation infrastructure and a vital factor to compete in an uncertain global economy. It is imperative for the U.S. to produce and retain an ample quantity of scientists, engineers and high skilled workers. The core technical skills provided by engineering degree programs remain critical. According to the National Science Foundation, American students enrolling in engineering degrees declined more than 20% the past two decades. Less than 50% of those enrolled complete a science or engineering degree within five years.

Engineers of the future must become more equipped with multi-disciplinary skills critical to Information Age manufacturing. Today's manufacturing engineers embrace the challenges of virtual corporations, dynamic and integrated supply chains, and empowered production teams within the context of decreased product lifecycles and increased global competition. Achieving success for a manufacturing professional today requires as much understanding of effective teamwork as it does mastery of agile/lean manufacturing processes. They also need a basic understanding of global economies and cultures to exploit the opportunities presented in outsourcing and global balancing. Some companies proactively support comprehensive engineering curricula to assure an ample supply of well-rounded, talented graduates. Strong partnerships between industry and academia result in more expanded interdisciplinary curricula required to meet future workforce requirements.

Effectively responding to the projected manufacturing labor force shortage, and focusing on creation of the workforce of the future, is essential to ensure the continued competitiveness of U.S. firms in this sector. Without cooperation among industry, academia and government it is unlikely that the U.S. manufacturing industry will successfully face this challenge.

Each of these challenges is important to the manufacturing industry, and the government should take the lead in helping to adapt our citizens and our defense industries to meet these

challenges proactively before they become threats to the survivability of this industry. This citation from our current National Security Strategy recaps why we need to focus government policy and allocate resources to overcome these challenges:

> *'Ultimately, the foundation of American strength is at home. It is in the skills of our people, the dynamism of our economy, and the resilience of our institutions. A diverse, modern society has inherent, ambitious, entrepreneurial energy. Our strength comes from what we do with that energy. That is where our national security begins.'*[lii]

GOVERNMENT ROLES

Manufacturing is inherently important to the United States and its long-term security. Accordingly, the Government has published a number of strategies relating to the U.S. manufacturing sector. On 24 February 2004, President Bush reaffirmed this belief when he released 'Executive Order Encouraging Innovation in Manufacturing' to ensure that Federal agencies provided effective assistance to the private sector in its manufacturing innovation efforts, particularly through the Small Business Technology Transfer (STTR) program. Through the United States Code,[liii] the Department of Defense manages the Manufacturing Technology Program to ensure that the U.S. maintains a vigorous manufacturing capability and a robust defense industry. This approach is critical in realizing a responsive, world-class manufacturing capability that will affordably produce the nation's defense needs.[liv]

More generally, in January 2004, the Department of Commerce released their report, '*Manufacturing in America: A Comprehensive Strategy to Address the Challenges to U.S. Manufacturers*'. In conjunction with the National Association of Manufacturers, the government has committed to a six-point plan to foster conditions for a robust manufacturing industry. The objective of the plan is:

a. make healthcare costs more affordable,

b. reduce the lawsuit burden on the U.S. economy,

c. ensure a reliable and affordable energy supply,

d. streamline regulations and reporting requirements,

e. open markets for American products, and

f. enable families and businesses to plan for the future with confidence.[lv]

Review of Government Intervention. The period where a 'laissez-faire' approach could be advocated as government policy towards the manufacturing sector is long gone. The level of global integration and competition and the societal expectations of industry demand a level of government involvement far beyond that of the early Industrial (manufacturing) Age. Government policy in this era should focus on the imperative to 'do no harm' to the comparative advantages of U.S. manufacturing sector. While fostering a balanced international marketplace and a foresighted domestic environment, the government must provide the raw resources to an industry sector that underpins both the overall strength of the U.S. economy, and that funds the tools to meet the U.S. National Security Strategy.

Specific areas where government roles and goals must be focused to prevent erosion of manufacturing comparative advantage include: 1) rationalization of U.S. healthcare expectations, 2) preventing the abuse of laws and regulations [specifically: tort reform and application of environmental and workplace regulations], 3) maintaining uninhibited access to capital markets through rational regulation and regulation enforcement while preventing 'crowding out' of private investment by excessive government borrowing and, finally, 4) creating a homeland security environment that balances the need for security with the needs of industry that ultimately provides the resources that fund those security measures. Notably, the U.S. Department of Commerce plan addresses most of these areas.

Areas where government roles and goals must foster a balanced international marketplace and a domestic resource base that contributes to manufacturing robustness include: 1) continuing the press for free trade, 2) maintaining the world-class American post secondary education structure while achieving a significant increase in engineering and science graduates, and 3) assisting the legacy manufacturing sectors in overcoming structural mistakes and impediments [specifically the defined benefit pension and health burdens that threaten such critical manufacturing sectors as transportation and steel] through market oriented policies while avoiding outright government bailouts of these sectors.

There are several areas that should specifically NOT be addressed by government policies or goals, where interference is likely to stifle the growth of the manufacturing sector. Examples of areas the government should refrain from interference include: 1) knowledge management structures and IT integration/innovation, 2) international outsourcing, and 3) specific R&D direction. Why? Because the ability of government to choose world class and cutting edge ideas or applications has been proven to result in a dismal allocation of resources. Instead of government intervention to implement such ideas or applications, the international competitive market place, fostered by a government that presses for an ever-expanding free trade regimen with the rest of the world, will press the U.S. manufacturing sector to adopt the most profitable ones — witness the significant turnaround in U.S. auto manufacturers with the introduction of Japanese competition.

Homeland Security. Given the post-September 11, 2001 environment, the generally held assumption is that the manufacturing industry would be "battening down the hatches" and clamoring for federal aid to improve their homeland security posture. But review of industry specific literature and the response of industry representatives to the question; "What has been the impact of 9/11 on your company and are there any security measures that you have implemented as a result of our current War on Terror?" indicated a surprisingly limited impact.

There have been some active efforts to improve security in the national manufacturing environment. The efforts have been to improve physical security measures by adding: access controls, badges, guards, and camera systems; and improve basic information/cyber security by adding anti-virus software, firewalls, and passwords. Cyber security efforts have generally been limited to the protection of proprietary information, while system improvements needed to assure continuity of operations in the event of a catastrophic incident have received little emphasis. The terrorist attacks on 9/11 did change the world. The U. S. manufacturing industry is aware of new threats and vulnerabilities in our society and economy, but must balance its homeland security response with the need to remain viable and globally competitive.

Communication is the common theme among issues reviewed. There is still a discernable gap between the government's message on security and what the manufacturing industry is able to accept in terms of risk and the costs that can be endured with regard to competitive advantage. Manufacturing as an industry must be addressed in the critical infrastructure protection strategy and included in the national information sharing forums. Increasing government focus in this area will improve industry's recognition of homeland security threats and vulnerabilities. Improved situational awareness and communication will enable industry and government to develop a better partnership to best protect our nation and its citizens.

INTERNATIONAL ASPECTS

From an overall economic perspective, the U.S. and the EU are both major world players. They represent 32.4% and 26.95% of the world's GDP respectively (2002 figures).[lvi] As "regions", they both have democratically run governments and believe in free enterprise. They have historical ties that go back more than two hundred years and have many of the same likes and dislikes. As such, it is no surprise that the manufacturing industry in the EU is very similar in many ways to that in the U.S. They both have a vast number of businesses in the "manufacturing industry" of varying sizes producing a wide range of goods. For example, the major European companies produce many of the same goods that would be found in the U.S. — ranging from automotive, steel, aerospace, defense, office machinery and computers, electronics and communications, chemicals, pharmaceutical, medical supplies, pulp and paper, textiles and sporting goods. Both regions are also undergoing change in the manufacturing sectors and are looking at maintaining a competitive edge through similar innovation, i.e., lean manufacturing, supply chain management, research and development, etc.

It must also be appreciated that the creation of the EU itself, the use of a single currency throughout much of the EU (except Denmark, Sweden and the UK) and the "Single Market Program" are relatively new changes. While some of the advantages of operating as a region, versus a collection of national economies, have been realized, there should be little doubt that continued efficiencies and increased competitiveness can and will be achieved across the entire region once more of the policy issues are solidified.[lvii] The EU recently expanded to 25 countries, further affecting the way business is conducted in the EU.

Although it is not as strong as the U.S., the EU manufacturing sector is relatively strong compared to the rest of the world. The EU recognizes that globalization is pushing companies to be more creative and more productive or some business and jobs will not survive. While they appreciate that there will be growth in the EU manufacturing sector over the short term, the projections are that this growth will be lower than the world average, and immediate attention is required to improve this situation. Companies in Ireland and Sweden are well on their way to achieving these improvements.

In the 1990s, the Irish Government introduced the National Development Plan, a €2.5b program of national investment to ensure that Ireland 'moves up the global value chain'. Of this amount, €700m was provided for university research facilities, and another €650m was provided to the Science Foundation of Ireland. This coordinated approach to research between government, academia, and industry has fostered a rapid growth in high-technology manufacturing within Ireland. For instance, 40% of U.S. information technology investment resides in Ireland, and Ireland is the largest exporter of software in the world. To further encourage innovation within the Irish manufacturing sector, the government provides company

tax incentives for each dollar spent on research and development. All of these initiatives position Ireland to remain globally competitive and relevant, but more importantly, ensures that Ireland remains at the forefront of 'value' manufacturing, educating and employing highly skilled people. Notable, however, was the lack of emphasis on defense manufacturing within Ireland, with all efforts directed towards commercial applications. However, this is not surprising given that the Irish Defense Force consists of only 13,000 personnel.

Sweden also maintains a robust high-technology manufacturing industry, in both the commercial and defense sectors. However, much of the defense industry has grown from government control, and remains focused on domestic and regional sales. In contrast, the commercial manufacturing sector is highly competitive and globally focused, successfully selling to the entire world market. Much of the efficiency gained in Swedish manufacturing is gained by the use of innovative manufacturing processes (such as JIT), and a focus on customer needs. In terms of the Swedish workforce, the Swedish Government maintains a very strong education stance, and a much larger percentage of the manufacturing workforce has tertiary education than normally found in the U.S. This becomes very important, not just because of the productivity benefits that education brings, but because Swedish labor laws do not allow manufacturers to easily dismiss workers. While this brings the benefit of a secure workforce, it also produces reluctance in some employers to hire permanent staff, particularly in times of economic downturn. Notwithstanding this situation, the employers and workers visited portrayed a harmonious and focused team.

In comparing the EU and U.S. manufacturing sectors, there are two primary differences in approach. While the U.S. concentrates on employment to the exclusion of research, innovation and 'value' manufacturing, Europe is fast becoming the high technology manufacturing market, and in doing so is attracting the very best and brightest people from around the globe. Secondly, while the U.S. manufacturing industry is overtly espousing lean manufacturing concepts (without always employing them), European manufacturers that were visited in Sweden and Ireland are getting the job done without the fanfare or overhead often associated with such concepts.

CONCLUSION

The U.S. manufacturing industry is highly productive, but additional steps would foster growth in the sector. While the U.S. Government has identified a strategy to enable the industry to meet its future potential in supporting national security, practical measures have not yet been implemented that will produce sustainable improvement. This study identified several strategies that, if implemented by government, academic and industry partnerships, would counter manufacturing challenges and capitalize on the opportunities offered by the global economy. Harnessing the collective capabilities of this triad of government, academia and industry is critical to the future of the manufacturing sector.

RECOMMENDATIONS

Government, academia, and industry to enhance and maintain a healthy U.S. manufacturing industry should adopt the following strategies:

a. U.S. manufacturers must embrace globalization by using a balanced approach to become the global solution provider, and utilize advanced technologies to modernize manufacturing processes to enhance competitive advantage in the global market. This strategy includes improving processes and making operational and organizational changes to become more efficient and effective.

b. U.S. manufacturers should capitalize on increased customer satisfaction expectations by providing tailored products better and faster than competitors. This includes locating facilities near key customers/customer bases in "match-up zones" and developing concurrent manufacturing approaches to achieve agility and speed time-to-market.

c. U.S. manufacturers should continue to cut costs by modernizing and implementing process improvements to offset high labor, raw material, energy, and tax costs; and by utilizing U.S. technology and best practices, e.g., lean manufacturing and supply chain management, to increase productivity.

Academia, in conjunction with industry, should initiate public and private partnerships to encourage increased workforce training and retraining programs.

a. The academic community needs to focus on "upskilling" the general population through education initiatives to meet minimum levels of technical competence.

b. The public-private partnerships, led by academia, should capitalize on growing technology, through research and development, and encouraging technology transfer from R & D to production to help U.S. manufacturers improve their production processes and efficiency while protecting intellectual property and sensitive technologies.

The role of government is to assist in the development of a healthy, qualified, and capable workforce and to promote globally fair trade practices. To meet these objectives the U.S. Government should pursue the following:

a. Reform of healthcare is an urgent priority for industry. Expanding treatment options, increasing drug prices, and significant health problems coupled with increased demand from both employees and retirees make healthcare expense a significant burden on industry. The U.S. government must define minimum standards for healthcare and establish minimum citizen obligations to help reduce healthcare costs. Today, the citizen is free to ignore personal health obligations and industry bears the incurred medical costs.

b. Tort and worker compensation reform is needed in the U.S. High and unpredictable costs associated with the nearly unregulated tort awards and much-maligned workers' compensation programs are a disincentive to industry operating in the U.S. Government must move to rationalize the penalties associated with bona-fide

transgressions and plaintiffs must bear some risk (such as court costs when the plaintiff fails to win their case) when bringing a lawsuit.

c. Science and technology programs in primary and high schools should be initiated. Incentives should be offered to students and educational institutions, at the secondary level, to expand proficiency and breadth of science curricula. The U.S. Government should also encourage "life-long learning", beginning at the primary school level, to overcome the resistance to re-training throughout life. Changing the U.S. culture to value continuous learning will create and maintain a workforce that is technically competent and skilled.

d. Immigration and border control policies, regulations, and procedures should be updated to: 1) ensure domestic organizations remain U.S.-based vice moving overseas to obtain foreign personnel with necessary talents; 2) to revise U.S. visa programs for foreign graduates of U.S. universities that benefit from public and private U.S. education and research funding to stay and work in the U.S.; and 3) enable U.S.-based activities to continue to utilize cross-border Just In Time (JIT) supply chains essential for making industry competitive.

e. Fair global trade should be encouraged by expanding broad-based and bilateral free trade agreements, improving protection of intellectual property rights, increasing World Trade Organization (WTO) coverage, and enforcing fair trading practices through the International Monetary Fund (IMF) and WTO.

f. Corporate tax must be reformed to embrace globalization. The objective is to harmonize U.S. tax policies with international taxation regimes to eliminate disincentives to U.S.-based economic activity or reduce the competitiveness of U.S. companies.

g. Communication between government and industry must be improved. Manufacturing as an industry must be addressed in the critical infrastructure protection strategy and included in the national information sharing forums. Increasing government focus in this area will improve industry's recognition of homeland security threats and vulnerabilities and develop a better partnership to best protect our nation and its citizens.

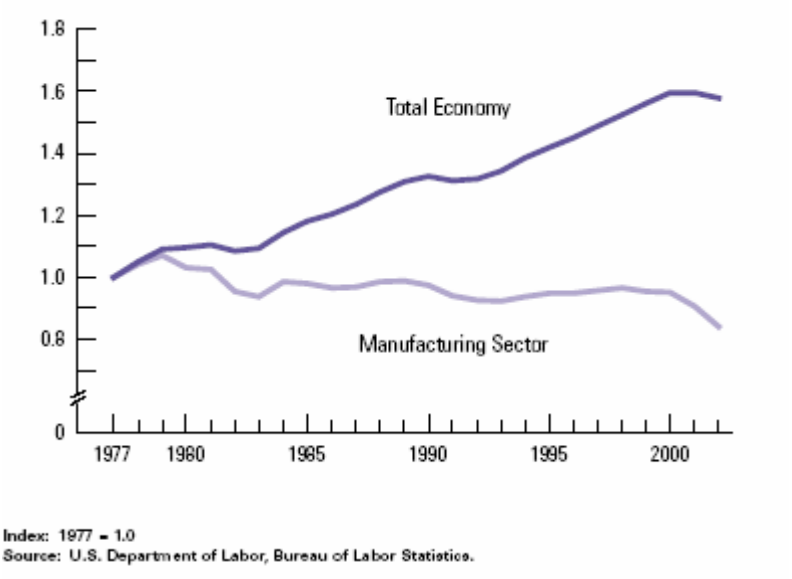

Figure 1: Total Employment Growth and Manufacturing Employment Decline, 1977 – 2002.

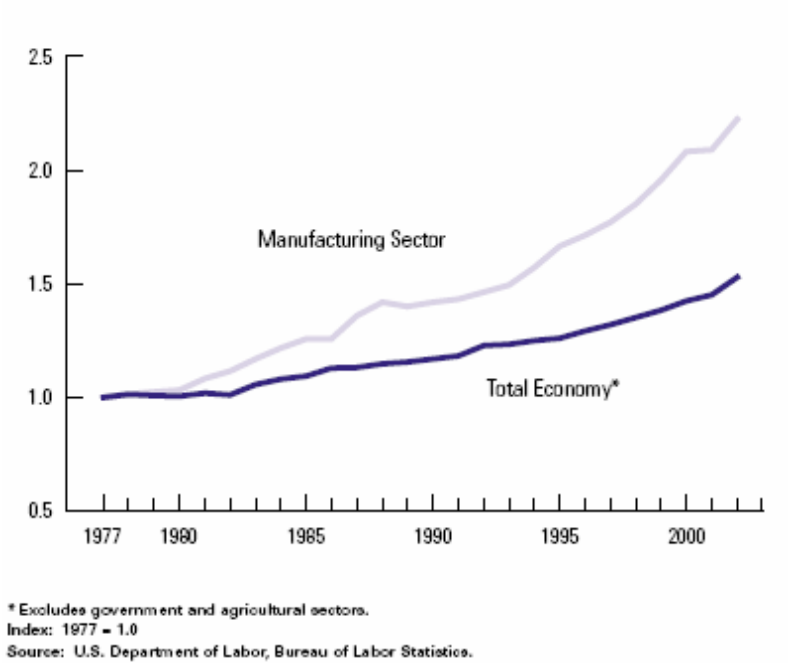

Figure 2: Productivity in Manufacturing and the Total U.S. Economy, 1977 – 2002.

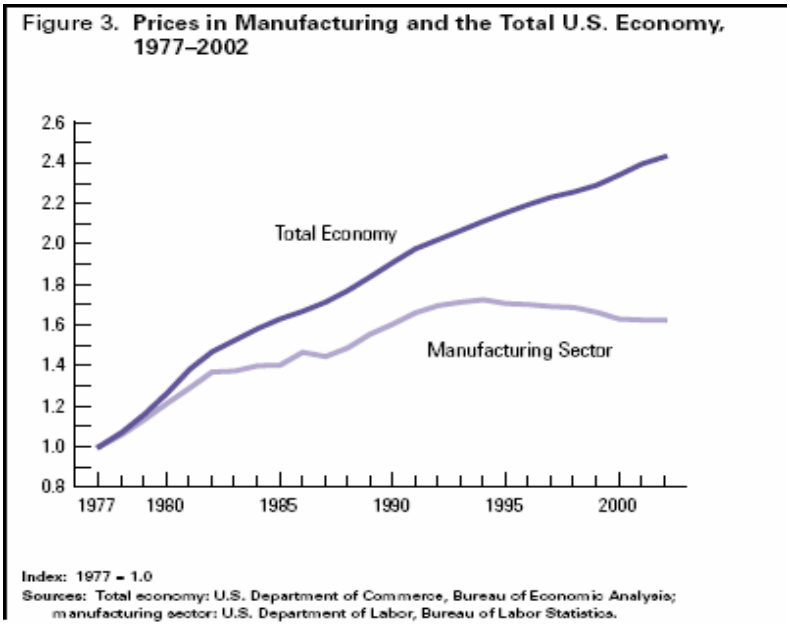

Figure 3: Prices in Manufacturing and the Total U.S. Economy, 1977-2002.

SIX SIGMA

INTRODUCTION

Oliver Wendell Holmes, Jr. said, “A man’s mind stretched by a new idea, can never go back to its original dimension.” In today’s environment, U.S. manufacturers are forced to develop new and innovative ways to stay competitive — that often means going “Lean” and employing tools such as Six Sigma. In fact some believe the clever money is going on combinations of Lean and Six Sigma, which some companies have begun to call Lean Sigma.[lviii]

WHAT IS SIX SIGMA?

“Six Sigma complements Lean nicely. It is a disciplined process that focuses on decreasing Defects Per Million Opportunities (DPMO) which supports the lean goal to reduce waste. Six Sigma's goal is to accomplish less than 3.4 defects per million opportunities or 99.999966% of good product produced," says Jeff Stotts (field engineer in Mid-America Manufacturing Tech Center’s (MAMTC) Pittsburg office.)[lix] According to Mark Minter, regional director of MAMTC's Overland Park office, consistency is the name of the game: "Lean is an umbrella program to eliminate waste. Six Sigma, on the other hand, looks at variation in processes. If we get rid of waste and variation, we can get a more consistent process".[lx]

To understand the huge and tremendously valuable degree of improvement between one and Six Sigma, consider this: If you're talking about distance, one sigma is from here to the moon, and Six Sigma is four steps. Or, if you're talking about misspelled words per page in a book, one sigma is 17 and Six Sigma is one misspelled word in all the books in a small library.[lxi]

Traditionally companies accepted three or four sigma performance levels as the norm – or 6,200 to 67,000 problems per million. But products we do not tolerate defects in, such as airline safety, surgical operations or drug prescription, are at or above Six Sigma range. In other areas, the Six Sigma standard of 3.4 problems per million opportunities is a response to the increasing expectations of customers and the increased complexity of modern products. [lxii]

Companies operating at three or four sigma typically spend as much as 25% of their revenues fixing problems.[lxiii] This is known as cost of quality, or more accurately the cost of poor quality. Companies operating at Six Sigma typically spend less than 5% of their revenues fixing problems.[lxiv] General Electric estimates that the gap between three or four sigma and Six Sigma was costing them between $8 billion and $12 billion per year in inefficiencies and lost productivity.[lxv]

The goal of any organization is to be competitive – be it a profit or not-for-profit company, or be it a provider of a service or a product. The single most important factor in being successful is to meet the expectations of the customer; that begins with having a good understanding of the customer’s expectations. Those considering applying Six Sigma should consider the answers to the following questions:

1. Who are your customers?

2. What are their requirements?

3. What are the correct metrics?

4. How do you measure these requirements?

5. How do you improve your processes?[lxvi]

"Six Sigma works best for business problems where you are held within a rigid process / product framework and the application of DMAIC can be applied," Stotts said. In fact, many companies visited have adopted the DMAIC (define, measure, analyze, improve, control) model or some variation for their Six Sigma projects. "DMAIC is the traditional approach we use with clients to solve problems and implement Six Sigma," Mike Niedenthal (MAMTC's vice president of operations) said. [lxvii] The Six Sigma DMADV process (define, measure, analyze, design, verify) is an improvement system used to develop new processes or products at Six Sigma quality levels.[lxviii]

EXAMPLE OF SIX SIGMA

Boeing and Lockheed Martin each manufacture Evolved Expendable Launch Vehicles (EELVs) to launch government and commercial satellites. A goal of the EELV program was to replace current launch vehicles with evolved systems at a 25 to 50 percent cost reduction. As part of the EELV program, Rocketdyne (which became part of Boeing in 1996) developed the RS-68 engine for Boeing's Delta IV. It's the first American-developed new rocket engine since the Space Shuttle main engine (SSME) in 1981. The company employed Lean Manufacturing, to include Six Sigma, techniques while developing the RS-68. The RS-68 has 95% fewer parts than the SSME; touch labor has been reduced from 171,000/hour to 8,000/hour; and employed advanced manufacturing benefits such as casting instead of welding.[lxix] Although the odds are that about 80% of first-time launches will experience some sort of anomaly, the RS-68 (and the rest of the Delta IV launch vehicle) was responsible for the successful delivery of the W5 communications satellite for Eutelsat S.A. to orbit on 20 Nov 02.[lxx] Since then, Delta IV has successfully launched two DoD communication satellites.[lxxi]

Lockheed Martin has also employed Lean Manufacturing and Six Sigma in their EELV efforts, the Atlas V. Nineteen heritage suppliers provide 88% of the Atlas V, so Lockheed Martin is managing with Lean principles for controlled and reliable supplier processes.[lxxii] They've established a non-conformance reduction program and offer supplier assistance in Lean / Six Sigma training. They have a goal of reducing Atlas V non-conformances 75% by the 10th production vehicle.[lxxiii] The Atlas V's inaugural launch was 21 Aug 02, when it successfully placed a HOT BIRD^{TM} 6 for Eutelsat in the correct orbit. Since then, it has successfully flown 3 times in just 11 months.[lxxiv]

CONCLUSION

The need to remain globally competitive, forces all manufacturers to produce the highest quality goods at the lowest cost.[lxxv] The more efficient and responsive the industry can be, the better our economic viability, productivity, and ultimately our standard of living. For these reasons, it is in everyone's best interest for U.S. companies to maximize efficiencies through such practices as Six-Sigma.

STRATEGIC MATERIALS FOR THE MANUFACTURING INDUSTRY

INTRODUCTION

There is continued debate over the past decade as to the level of decline within the U.S. industrial base. This concern has intensified with the continuing losses of manufacturing jobs within the U.S. and outsourcing of jobs outside its borders. Faced with overall job losses and outsourcing, there is an equal concern on what corollary affect these issues have on the U.S. defense industrial base. One of the underlying issues that affect all of these concerns is the requirement to have available raw materials and other components necessary to meet the needs of the U.S. industrial base. The U.S vision is to manage these strategic materials for both commercial and national defense reasons. Is there still a requirement to manage these materials in the era of globalization, and how well is the U.S. doing to meet these requirements?

BACKGROUND AND CURRENT STATUS

Planning for the use of strategic materials for our nation is not a recent phenomenon. The requirement to manage strategic materials was first introduced in 1916 during the European war and has been developed and refined into our current requirement.[lxxvi] The development of mobilization plans incorporated the management and utilization of strategic materials. To provide for a more robust and systematic study of industrial mobilization planning, the War Department established the Army Industrial College in 1923.[lxxvii]

Natural resources are the basic ingredients of all raw materials, which in turn become the end item products such as military hardware, commercial equipment, and supplies. For the past century, and in particular since World War II, the United States has been viewed as a leader in manufactured goods. Although the U.S. does not physically control all the natural resources and raw materials outside its borders, they are able to obtain the necessary materials through relationships with foreign suppliers, maintaining alternative providers, and providing the security of long-haul transportation lanes between sources and consumers.

More than 90 minerals, metals, and materials are critically useful for military purposes. Relative importance depends on present and projected needs, but iron plus the dozen items listed in Table 1 possess properties that are globally in demand.[lxxviii] Although these materials relate to military applications, it is easy to see how these same representative properties are useful in the commercial market. Foreign markets also view these minerals and metals as the lifeline to their manufacturing success and are consuming them at a higher rate than ever before. An example is China who has come to the forefront as a direct threat to both commercial and defense industries for the competition of raw and natural resources mainly in steel and electronic chips.

Current evidence illustrates a continued need for management of strategic and critical materials for economic and national defense purposes. This is accomplished through the Strategic and Critical Materials Stockpiling Act. The Act states: “a stockpile of strategic and critical materials be maintained to decrease and preclude, where possible, dependence upon foreign sources of supply in times of national emergency”.[lxxix] The Defense National Stockpile Center (DNSC) under the Defense Logistics Agency (DLA) manages the stockpile.[lxxx]

Annually, the Secretary of Defense must submit to Congress a report for stockpile requirements. There are currently 36 on-line materials and 19 advanced materials identified for

the stockpile.[lxxxi] What is interesting to note, an e-mail from the Office of the Secretary of Defense (OSD) discussed the concern from some members of Congress on certain materials requiring review for possible inclusion, or additional research, for the 2005 stockpile list.[lxxxii] For example, Neodymium, used in the production of neodymium-iron-boron magnets is currently produced in China with U.S. manufacturing sector heavily reliant on this product. Although used in the commercial market, it is found in solid-state lasers as well. China is the world's primary source for Neodymium. Samarium, Rhenium, Scandium and Yttrium are also on the OSD list for review.

ROAD AHEAD AND CONCLUSION

Although the U.S. has a viable Strategic and Critical Stockpile program, the overall vision is shortsighted. The U.S. continues to manage the program based on material requirement versus commodities/systems requirements. The National Research Council, through the National Materials Advisory Board, conducted a study at the request of DoD to identify and prioritize critical materials and processing research and development. Their recommendations include:

1. Accelerate the transition of materials from concept to service

2. DoD invest into research of the design of materials, devices, and systems assisted by computation and phenomenological models of materials and materials behavior

3. DoD invest in research that promote convergence, combination, and integration of biological, organic, semiconductor, photonic, and structural materials

4. DoD invest in research that promote discovery and characterization of new materials with unique or substantially improved properties (by 50 % over current properties)

5. DoD invests in research leading to new strategies for the processing, manufacturing, inspection, and maintenance of materials and systems. [lxxxiii]

The above recommendations are viewed as long term recommendations taking the U.S. to continued dominance in the manufacturing sector for the next 10-20 years. Innovation is the key to this success and it will occur only through investment in research. However, in the short term there is much debate as to safeguarding the industry through "Buy American" initiatives or the use of tariffs. The majority of the readings on this subject along with discussion with industry leaders indicate the best approach is for government to stay out of the competitive nature of business except where countries use unfair business practices (devalued dollar, counterfeiting, copyright infringements, just to name a few).

One key for continued success is the sustained management of the strategic and critical materials stockpile. Is there still a requirement to manage these materials in the era of globalization? Yes! Access and the acquiring of natural and raw resources will continue to play a role in determining the health of a country's economic power. It is evident through real-world industry concerns regarding requirements for scrap steel and semiconductors, that these materials must continue to be managed to allow U.S. companies to access these materials for both commercial and defense related production. In the era of globalization, where the world has reduced in size for the market economy, it is even more critical that the U.S. government continues to monitor, and then manage, those critical materials necessary for the industrial base.

The process in place to manage these materials is adequate. Congress, with its oversight responsibilities in place, is asking the tough questions of DoD to ensure our industrial base has the needed materials to compete with other countries. However, the U.S. vision must change. DoD is the driver behind the stockpile requirement and they must move away from managing individual materials and focus on the industrial base as a system. By focusing on the industrial base as a system, the U.S. government can encourage innovation in manufacturing processes allowing industries to move away from certain materials as they find new and improved means for production.

Table 1: ***Twelve Militarily Useful Minerals and Metals***

Minerals and Metals	*Representative Properties*	*Typical Military Products*
Bauxite (Aluminum)	Light Weight Castability	Aircraft Frames Hydraulic Cylinders
Chromium	Corrosion Resistance Oxidation Resistance	Gun tubes Landing Gear
Cobalt	Heat Resistance Abrasion Resistance	Jet Engine Alloys Cutting Tools
Columbium	Malleability Acid Resistance	Petroleum Tankers Jet Engines
Copper	Malleability Ductility	Electric Wiring Cartridge Brass
Manganese	Hardness Toughness	Ship Propellers Torpedoes
Nickel	Corrosion Resistance Hardness	Electroplated Aircraft Parts Axles, Gears, Valves, Rods
Platinum	Catalytic Abilities High Melting Point	High Octane Fuels Electronics
Tantalum	Corrosion Resistance Acid Resistance	Armor Penetrators Electronics
Titanium	High Strength Light Weight	Armor Plate Space Capsules
Tungsten	Heat Resistance Hardness	Spark Plugs Electrical Contacts
Uranium	Radioactivity	Nuclear-Powered Naval Ships Nuclear Weapons

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