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ROLE OF TECHNOLOGY IN
MANUFACTURING COMPETITIVENESS

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“To live well, a nation must produce well”¹

A manufacturing revolution has emerged in the past 50 years that is as significant as the industrial revolution of the 19th century. From 1950 to 2000, the average productivity growth in manufacturing in the United States was 2.8% per year, and this figure has been accelerating for the past two decades as manufacturing productivity growth has exceeded the average of other sectors by more than one percent per year (please see table below). Stated more simply, a US manufacturing worker can produce four times as much per hour today as compared with fifty years ago. This gain has resulted from competitive pressures, the advent of new technologies, and a series of product and process innovations. It has also resulted in a much higher standard of living for Americans, as products become more useful and more affordable. In order to utilize this new manufacturing capacity, U.S. firms (and others) have expanded their marketing abroad, creating rapid increase in global trade.

U.S. Average Annual Productivity Gains						
	1950-1960	1961-1970	1971-1980	1981-1990	1991-2002	1977-2002
All US 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%

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, which, create high value for their markets. The sustainability of growth in the U.S. manufacturing sector is based on the ability of America to continue to innovate. Innovation is 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 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 result in a declining ability to provide for the wants and needs of our people.

The Importance of Manufacturing in the US Economy

It is difficult to underestimate the importance of manufacturing in the US economy. According to the 1997 U.S. Economic census, the payroll of the American manufacturing sector is 14% larger than the next two largest sectors (finance and insurance, retail trade) combined, despite having 15% fewer employees²! Some have said that other industries, such as financial services and trade will replace manufacturing in the future. An examination of the economic sectors refutes this argument. There are only four economic sectors that generate material wealth: agriculture, mining, manufacturing, and construction. Other sectors, such as services and trade, redistribute this wealth, and are 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. As a result, manufacturing is and will continue to be the fundamental base for the economic health and security of the United States.

The economic impact of the manufacturing sector is not limited to direct employment of manufacturing employees. A recent University of Michigan study concluded that more than 6.5 “spin off” jobs (including trade, service, and indirect manufacturing) were created in 1998 for every direct automotive manufacturing job³. This illustrates the importance of measuring 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!

The Most Serious Challenge to U.S. Manufacturing: Lack of New Innovation

It was mentioned earlier that 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 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 American manufacturing.

The United States is the most prolific innovator in the history of nations. This success is clearly not explained by abundant natural resources or geographic location alone. 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. It is the skills of the people that drive us forward, so there should be no illiteracy or illnumeration 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 America more competitive in the global market.

Stimulating Innovation by Investing in Development

The path to commercialization of 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 into 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 NSF and NIH, 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 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 10-20 years⁴. For a company requiring a 17% return on investment, a 15 year development period means that the potential must exist to earn more than 10 dollars *per dollar invested*. This is unreasonable for most industries. Furthermore, entire industries can disappear in 15 years, so businesses 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 10-15 year development periods.

Development is considered to be the “Valley of Death”. It has earned this name for two reasons. First, many scientific results go unused because they are unable to attract development funding, and many development projects die early because companies are unable to see the returns necessitated by long development timeframes. Second, academia, where a large portion of Federal research is performed, does not respect or reward development: following a path of development can kill careers. 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 has an excellent track record of technology development, in part because it has the right ratio of research to exploratory development—roughly equal shares. The DOD avoids squandering its research by

maintaining this ratio. The Federal Government can improve innovation by encouraging other research funding agencies to meet the same R:D funding ratio as the DOD.

Because the 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 Federal Government Can Help Manufacturing

The manufacturing sector is crucial to the U.S. economy. It is the sector with the largest 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 of 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 American 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 of 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 development channels. Industry cannot afford the risk of 5 to 20 year development projects. Small businesses, which have been 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 that will improve the ability of industry and academia to create industry-creating innovations. Most of these changes deal with two major problems: the limitations of our people in dealing with technology, and the lack of technology development structure. These changes 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 of manufacturing workers**, to help improve direct product and process innovation, and to prepare workers for future industries. Every worker should be numerate and literate.
- **Balancing Federal research budgets between research and development**, so that research expenditures aren't squandered by failure to fully develop the new knowledge.
- **Requiring researchers to include potential applications and cost/benefit justification**, to ensure a favorable return on taxpayer investment.

¹ Dertouzos, Michael, Lester, Richard, Solow, Robert (1989), *Made In America*, The MIT Press, Cambridge, MA page 1.

² 1997 Economic Census: Summary Statistics for United States 1997 NAICS Basis.

³ Fulton, Grimes, Schmidt, McAlinden, Richardson, et al (1998), "Contribution of the Automotive Industry to the U.S. Economy in 1998: The Nation and Its Fifty States" page 28.

⁴ Eagar, Thomas, "Bringing New Materials to Market", *Technology Review*, February/March 1995.