

National Innovation Initiative

The Extended Production Enterprise and Innovation

November 2004

Version 3.0

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The Extended Production Enterprise and Innovation v.3.0

SUMMARY

The 21st Century Innovation Working Group recognizes manufacturing as an important driver of present and future prosperity. The manufacturing sector plays a large role in investing in R&D, introducing new products and generating economic output, productivity, employment and exports. Structural shifts in the global manufacturing environment now require a change in perspective and strategy if we are to maintain a strong and competitive US manufacturing base.

The change in strategic perspective is focused on expanding innovation opportunities at the intersection of manufacturing and services. Business processes that comprise the manufacturing process do not need to take place in a single firm or location. In fact they are increasingly a part of a distributed and **extended production enterprise**. The creation of value by US manufacturers now requires complementary innovations in non-factory processes and novel integration of supply chains, small manufacturers, services, logistics systems and customer support functions. The value being provided by manufacturing is shifting from a **production to a solutions model**.

The 21st Century Innovation Working Group recommends:

- 1. Establish world class centers for production excellence to accelerate knowledge sharing, the speed of innovation and jumpstart commercialization of new technology based products.**
- 2. Refocus DOD research and procurement technology programs to support breakthrough technologies and speed up the deployment process.**
- 3. Encourage and support the development of voluntary, open and interoperable software standards to drive innovative applications for the extended production enterprise.**
- 4. Expand use of industry led technology roadmapping projects to define the next generation of innovation opportunities for the extended production enterprise and advise on federal R&D priorities.**
- 5. Establish prototype Innovation Extension Centers for Small Manufacturers**
- 6. Consider strategies for reducing the burden of external overhead costs on innovation and productivity improvement.**

The Extended Production Enterprise and Innovation v.3.0

Prepared by: Egils Milbergs with major contributions from William Bonvillian, Rick Jarman, Anthony Warren, Ned Ellington, Rebecca Taylor, Chad Evans and Taffy Kingscott

Although the dominate feature of the US economy is the service sector, the 21st Century Innovation Working Group recognizes manufacturing as an important driver of present and future prosperity. The manufacturing sector plays a large role in investing in R&D, introducing new products and generating economic output, productivity, employment and exports. However, the recent economic recession has surfaced new challenges and problems:

- Employment declines in manufacturing
- Loss of export competitiveness
- Change in the pattern of foreign investment trends toward developing economies
- Shortages of critical skills
- Rise in non-controllable costs such as health care and regulatory compliance

We must put aside the growing perception that manufacturing is in decline and instead begin designing and implementing a new foundation for high performance production. With the right innovation strategies, investments and changes in policy the US has an opportunity to accelerate the deployment of new production processes and strengthen the contribution of manufacturing *and* the service sector. In fact, the integration of services with manufacturing is central to the evolution of the extended production enterprise. The value being provided by manufacturing is shifting from a *production* to a *solutions* model.¹

Structural Changes in Manufacturing

We have met challenges to the US manufacturing base before. Manufacturers showed amazing resilience when they faced up to the mid-80s competitiveness challenge, primarily from Japan. Manufacturers responded and fought back impressively by giving extraordinary attention to the fundamentals of cost, quality control and productivity improvement. By the late 1990s the US emerged as the manufacturing productivity leader of the world.

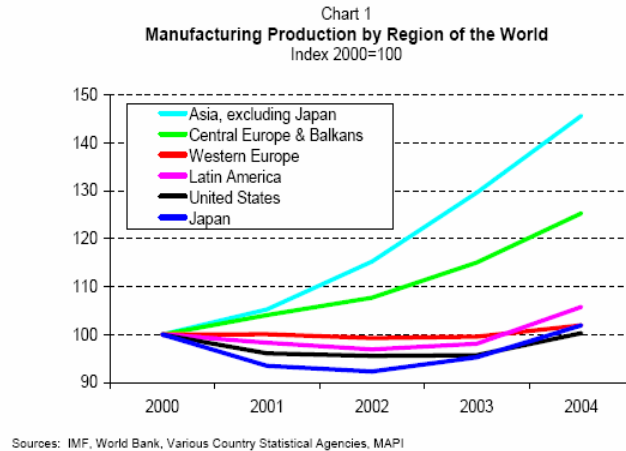
Today the situation is different and more complex. The challenge is more than waiting for a business cycle recovery; the challenge is profoundly structural.

Driving this structural shift are the transformation of formerly centrally planned economies toward market oriented economies, less reliance by developing economies on import substitution toward export oriented development, increased adoption of global business strategies, reduction of global trade barriers that accelerate the transnational flow of goods, services, personnel and capital, and, worldwide diffusion of IT and communication applications. Manufacturers also must deal with terrorist and political risks that can cause major disruption of just-in-time supply networks. These factors are having a particularly large impact on US based high technology manufacturing industries. The traditional manufacturing strategies of cost control, lean, six sigma, continuous productivity improvement and quality are the minimum requirements to compete in today's global marketplace. **In the future, the winning strategy will depend on innovation, adaptiveness, collaboration and speed within the extended production enterprise.**

¹ Duesterbuerg, T. and Preeg, E. (editors). *US Manufacturing: The Engine for Growth in a Global Economy*. Praeger. 2003.

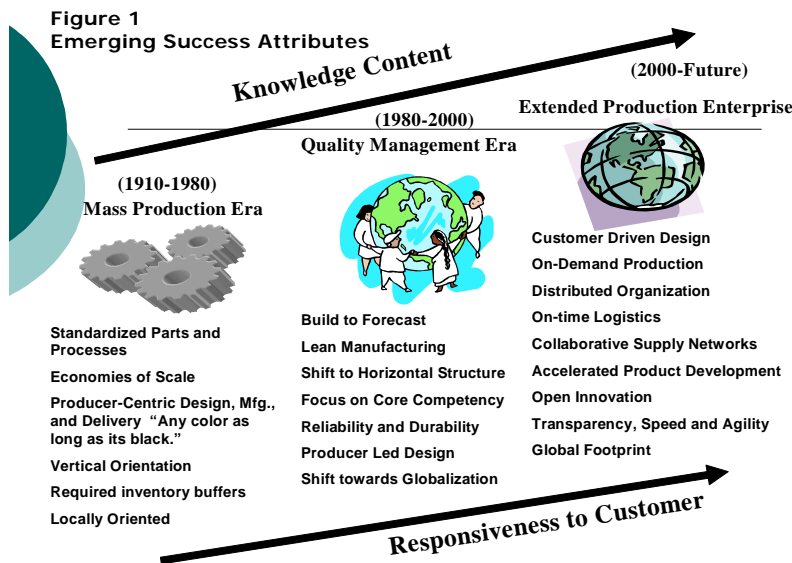
Global Position of US Manufacturing

Although the United States remains the world's leading producer of manufactured goods, it now trails among major regions of the world in manufacturing growth. Chart 1 shows that the United States is last among the six major geographic regions of the world in terms of manufacturing growth since the beginning of the decade.² Not only did manufacturing in the United States decline more than other regions in the global recession in 2001, it has been slower to recover from the industrial downturn. The fastest regions for manufacturing growth in the world have been in Asia (outside of Japan) and in Central Europe and the Balkans. These areas are low-cost manufacturing centers that are now well positioned to export manufactured goods to developed countries like the United States, Japan, and Western Europe.



Requirements for Success

To overcome our cost and wage disadvantages, we need to lead the world in deploying new production technologies and integrate the manufacturing function into the larger innovation ecosystem with a focus on creating value. We must maximize the growing intersection of manufacturing and services and find innovative ways to manage supply networks, small manufacturers, services, logistics, and customer relationship functions. *“Dazzling prototypes are not sources of profit. Reliable and cost-competitive products must be manufactured to reap the final reward of innovation.”*³ Innovation across the extended production enterprise will create a strong productivity and value creation



advantage for U.S. based industry. The fundamental requirement for success is how to incorporate higher levels of knowledge content and customer responsiveness into manufacturing operations. Figure 1 shows some of the emerging attributes of the successful 21st century enterprise. Those manufacturers that make innovation the centerpiece of their competitive strategy will be the global winners.

² Meckstroth, D., *The United States Trails the Global Manufacturing Expansion of the Early 2000s*. e-Alert. Manufacturers Alliance/MAPI. November 4, 2004. p. 1

³ Bonvillian, W. *Meeting the New Challenge to U.S. Economic Competitiveness*. Issues in Science and Technology. Fall 2004. p. 80

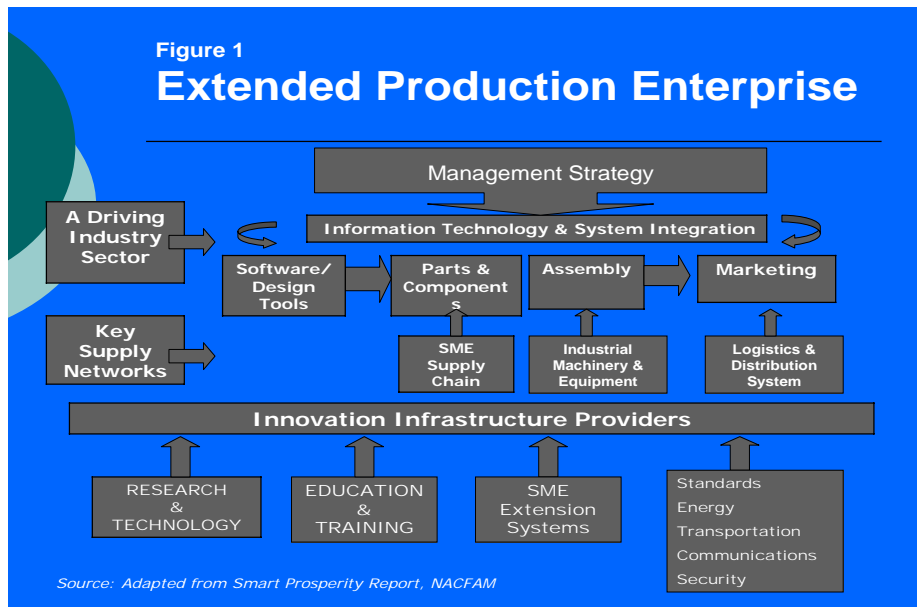
From Factory-Centric View to the Extended Production Enterprise

A new strategic perspective on manufacturing is needed to focus innovation on these new requirements. Business processes do not need to take place in a single enterprise or location. In fact they are increasingly a part of a distributed and *extended production enterprise*. The successful 21st century manufacturer will be more like a system integrator, managing a supply chain or virtual network that consists of various combinations of business process suppliers whether or not provided by the manufacturer itself.

Consequently, the creation of value by manufacturers now requires complementary innovations in non-factory processes and novel integration of supply chains, services, logistics systems and customer support functions.

“Globalization is causing a shift in the source of competitive pressure, and of competitive advantage, from excellence at the point of production— now more or less assumed— toward excellence in governing spatially dispersed networks of plants, affiliates, and suppliers.” (Electronic Industry Alliance, 2004).

Figure 1 illustrates the emerging 21st Century production enterprise as an extended, networked and distributed system. As the figure makes clear, component fabrication and assembly are only a part of value chain from raw material to the customer and include software and design tools, supply chains, advanced industrial machinery and equipment, distribution and logistics systems and the overall management strategy that integrates the whole system toward customer value.



These components in turn rest on a common infrastructure of research, technology development, standards, education and training and technical assistance organizations to small and medium sized suppliers. If we want to ensure that successive waves of innovation begin in the US and that US workers are the first to benefit from the next big things we have to optimize collaboration, innovation, efficiency, dynamism and effectiveness of the entire extended production enterprise. **Industry must lead, but government can be a critical partner, enabler and facilitator.**

Trends and Challenges for the Extended Production Enterprise

Technology Opportunities. A number of significant trends in manufacturing technologies hold potential for creating a US competitive advantage. We see it in the elements of flexible automation progress, complex numerically controlled tooling and advanced CAD/CAM, precision engineering and design, dual use systems for commercial and military products and in contract distributed manufacturing to gain the advantages of volume, e-commerce that connects supply chains, materials databases and shared use facilities for R&D and prototyping. These technologies if leveraged appropriately offer major productivity improvements to help offset the wage and cost advantages of foreign competitors.

Collaborative Approach is Key. A key ingredient for success will be collaboration between industry, customers, suppliers, research and government to share the risk, cost and time of development of new technologies. This means integrating new designs, processes and materials in a modular fashion. We will need to invest in new human, organizational, and financial models. The U.S. could dominate nano-technology if we are the first to build nanofabrication capabilities to make cost competitive products for the global market.

DOD has a Critical Stake. If US production capabilities continue to shift to overseas locations, and our innovative design and R&D stages follow it offshore, the Department of Defense will face a major national security problem with maintaining a technology edge and its transformation strategy. DOD is a huge beneficiary of productivity gains in manufacturing which helps DOD afford its vast acquisition and procurement program as it transforms its infrastructure to deal with the changing threat environment. The DOD can play a vital role by collaborating with industry on breakthrough manufacturing processes such as distributed and desktop manufacturing, quality inspection that is built into the production process, use of revolutionary materials and methods of fabrication, and devices and machines built at the nano-scale.

New Business Models. The next generation of manufacturing will entail new business models that integrate services, design, and manufacturing stages throughout the *extended production enterprise* creating value “on-demand.” Business processes increasingly rely on software, communication technologies and an expanding array of computing devices and sensors to work effectively. Open computing platforms—both hardware and software—are an essential feature of a more networked world. Software research and standards for interoperability enable enterprises to have the freedom to share information, collaborate and upgrade applications without tremendous legacy costs or time delays. The lack of software interoperability adds to production inefficiencies and poses a major barrier to shortening the design to manufacturing execution cycle. More interoperability will enable a “network effect” and more efficient manufacturing/service integration. The pervasive and exponential economic impact of the Internet owes its success to the application of open computing principles and standards.

Adaptive Capacity of Small and Mid-size Manufacturers. There is perhaps no greater need for innovation than in the small and mid-size manufacturing sector (SMEs). The 350,000 SMEs that employ over 7 million people and comprise nearly half the US manufacturing base are confronting enormous challenges to remain viable in today's global economy. Issues facing small manufacturers include disproportionate regulatory burdens; unfamiliarity with changing technology, production techniques and business management practices; lack of interaction with other companies in similar situations; difficulty in finding high quality assistance; access to qualified workers; high health insurance costs; and, the problems in obtaining capital to modernize. These trends in combination raise serious economic survival issues for small manufacturers.

Technology Roadmapping and Federal Research Priorities. Technology roadmaps represent a consensus regarding industry direction and research needs, innovation trajectories, alternative scenarios and the possibility of disruptive technologies and surprises. Industry associations and sector based collaborations are making greater use of technology roadmapping methodologies as an input to the federal R&D priority setting process as well as inputs to their own innovation planning. Roadmapping exercises can provide the basis for public and private investments in radically new production systems.

RECOMMENDATIONS

1. Establish world class centers for production excellence to accelerate knowledge sharing, the speed of innovation and jumpstart commercialization of new technology based products.

Industry led collaborations focused on innovation, knowledge and flexibility in production will help accelerate deployment of new technologies as fast as they become available. Shared R&D and production facilities, knowledge exchanges, and on-demand training and education in high tech sectors of manufacturing can be leveraged across many industries in both the commercial and government sectors. World class centers of production excellence provide an infrastructure that attracts, develops and retains top technical talent, reduces costs through shared facilities, accelerates new product development and time to market, educates students from the technician to the PHD level and potentially generates start-up companies in new high growth markets.

For example the creation of SEMATECH in the 1980s played a vital technology development role for maintaining the global market position of the US semiconductor industry. The National Center for Manufacturing Sciences (NCMS) is another large scale industry collaboration devoted exclusively to manufacturing technologies, process, and practices. The Infotonics Technology Center is showing promise as a partnership of industry, universities, New York State and the federal government aimed at creating a state-of-the-art prototype and pilot fabrication facility to accelerate the commercialization of new products in the field of photonics and micro-systems.⁴

Federal funding for centers for production excellence should be catalytic. Long term sustainability requires leadership from industry and a combination of private sector and state and local government financing.

2. Refocus DOD research and procurement technology programs to support breakthrough technologies and speed up the deployment process.

DOD should work collaboratively with industry to reestablish its historic role as a sponsor of breakthrough technologies in 21st century manufacturing processes. These could include distributed and desktop manufacturing, quality inspection that is built into the production process, use of revolutionary materials and methods of fabrication, supply chain collaboration and devices and machines built at the nano scale.⁵ A particular need is in breakthroughs in small-lot manufacturing, with the goal of becoming as efficient and cost competitive as mass production. DOD could help transition those manufacturing technology and process advances into the prototype and testing phases at DOD contractors. This would enable new approaches to be evaluated and later transitioned into a broad base of U.S. industry.

⁴ Allen, G. and Jarman R. *Collaborative R&D: Manufacturing's New Tool*. Wiley. 1999

⁵ NACFAM Reports. *Defense Supply Chain Policy: Roundtable Discussion, September 2002* and *Contributions of and Issues Concerning Small and Medium Sized Manufacturers in the Defense Industrial Base*. June 2002

3. Encourage and support the development of voluntary, open and interoperable software standards to drive innovative applications for the extended production enterprise.

Greater interoperability of computing devices and software through open standards will benefit US trade, competitiveness, GDP growth and employment. Interoperability is no longer just a technical issue. Its real value is in meeting rising user expectations regarding the exchange and use of information and applications.⁶ For example within the supply chain process, businesses are attempting to apply advanced software systems and algorithms to manage interactions transparently with information to reduce the “bull-whip” effect on inventory due to changes in supply and demand. The software industry which supports the extended production enterprises is moving from packaged software products to software as a service on the network. This transformation will profoundly affect the software industry itself and the industries which use such software to manage their business processes. Substantial productivity improvements can be gained as computing becomes more pervasive and interoperable in the extended production enterprise.

“It is estimated that the adoption of computing into everyday objects such as consumer and industrial products will create a total savings of \$70 billion in the United States and \$155 billion internationally. The cost savings will come from areas such as improved visibility into the supply chain, theft reduction, and improved operations... The next phase of the software and Internet evolution will start to merge bits with atoms... The physical world and the virtual world will become increasingly connected as computing devices and physical objects of all kinds gain intelligence and the ability to communicate with the network via wired and wireless technologies and intelligent identification techniques.” Nicolas Evans, Business Innovation and Disruptive Technology: Harnessing the Power of Breakthrough Technology for Competitive Advantage

Enterprise Integration Act of 2002

In 2002 Congress took an important step in passing legislation authorizing the National Institute of Standards and Technology (NIST) to work with major manufacturing industries on standards development for electronic enterprise integration. The legislation was based on the finding that over 90 percent of United States companies engaged in manufacturing are small- and medium-sized businesses. Most of these manufacturers produce goods for assembly into products of large companies. The emergence of the Internet and the promulgation of international standards for product data exchange have greatly accelerated the movement toward electronically integrated supply chains. European and Asian countries are investing heavily in electronic enterprise standards development, and in preparing their smaller manufacturers to do business in new environment. Their efforts are well advanced in the aerospace, automotive, and shipbuilding industries and are beginning in other industries including home building, furniture manufacturing, textiles, and apparel.

Open standards are specifications that are openly documented and available, evolved collaboratively through standards organizations or by consensus in the commercial marketplace. The characteristics of openness when applied to standards are:

- ***Published without restriction***
- ***Made freely available for adoption by industry***
- ***Controlled by an open industry organizations with a well-defined inclusive process for evolution of the standard***
- ***Implemented by offerings in the marketplace***

⁶ Milbergs E., Kueter J. *Exploiting E-Manufacturing: Interoperability of Software Systems Used by US Manufacturers*. Prepared by National Coalition for Advanced Manufacturing. February 2001.

The 21st Century Innovation Working Group strongly endorses the objective of developing a common reporting format for sharing usability data with consumer organizations; determining software quality using automated and knowledge-based methods with industry partners; planning a shared manufacturing business to business interoperability test bed; improving software engineering processes and cooperating internationally in this field of knowledge.

No one set of standards will meet all legitimate needs. At the same time, a proliferation of incompatible software programs and on-line services is also a possibility with damaging consequences to the freedom to collaborate, productivity and competitiveness of small manufacturing enterprises. This would create severe operational problems for small to medium sized suppliers who do business with multiple customers. Lacking systems that are interoperable they frequently find themselves having to support several different proprietary software and hardware platforms. The lack of software interoperability adds substantial costs, operational inefficiencies and lengthens the design to manufacturing development cycle.

The excess carrying cost of the lack of software interoperability in the auto supply chain is more than \$1 billion. ⁷The annual cost to U.S. industry of weakness in software testing is in the range of \$60 billion per year. ⁸ Industry-led commitment and solutions are needed, but government can play an essential facilitating role in producing those solutions.

This issue needs to be addressed with some urgency to take advantage of a huge innovation opportunity. It is recommended that industry and government collaborate to:

- Create a neutral test-bed for open standards software and web based services designed for interoperability.
- Allocate increased R&D support for design of next generation interoperable computing and software platforms.
- Incorporate software interoperability standards into government and corporate procurement and e-commerce activities
- Promote adoption of open standards software through such mechanisms as the NIST Manufacturing Extension Partnership program and proposed pilot Innovation Extension Centers. (*See Recommendation below*)

4. Establish Prototype Innovation Extension Centers for Small Manufacturers

Innovation is a strategic imperative for small manufacturers if they are to avoid major disruption of their business as foreign competitors enter their market space and their larger business customers consider shifting production activity to overseas locations.

The time is right for establishing innovation as a new mission and focus for the NIST Manufacturing Extension Partnership network of 350 centers that has traditionally focused on providing technical assistance services in manufacturing operational efficiency and

⁷ Brunnermeier, S., Martin, S. *Interoperability Cost Analysis of the US Automotive Supply Chain*. Prepared by Research Triangle Institute for National Institute of Standards and Technology. March 1999. p. ES-6.

⁸ Research Triangle Institute report prepared for NIST. *The Economic Impacts of Inadequate Infrastructure for Software Testing*. May 2002

quality.⁹ SMEs must become “adaptive” and capable of finding new competitive advantages by looking ahead for market changes, dominating niche markets and rapidly exploiting new technologies and service advantages.¹⁰ Many resources available to SMEs are in regional colleges and universities, federal labs, small business development programs and financial communities. However, there is no common framework or process for integrating these resources at the right time and in the right quantity.

Department of Commerce should consider pilot testing the creation of prototype innovation extension centers to assist small manufacturers develop new innovation capabilities including how to identify emerging innovation opportunities working jointly with customers, new product design processes and tools, collaboration with larger enterprises on optimizing supply chains and logistics, application of advanced information technology tools and services, and financing of innovation strategies. Such innovation centers could assist small manufacturers navigate and integrate the resources of the federal government such as the SBIR programs and facilitate small business partnerships with federal laboratories, universities and venture capital community. If the prototype centers prove successful they could be scaled up to a nation wide network funded by federal, state, local and private sector. Such centers will enhance regional innovation clusters and expand opportunities for investments in R&D and commercial innovation.

5. Expand use of industry led technology roadmapping projects to define the next generation of innovation opportunities for the extended production enterprise and advise on federal R&D priorities.

Another section of the NII report makes the case for bolstering federal basic research support, encouraging high risk multidisciplinary research and providing more balanced investment across various disciplines including the physical sciences, engineering, mathematics, computer science, non-medical life sciences, environment sciences and the social sciences.

This shift is critically important to the future vitality of the extended production enterprise. We recommend that industry associations and sector based collaborations make greater use of **technology roadmapping methodologies** as an input to the federal R&D priority setting process. Technology roadmaps represent a consensus on where industries are likely to be heading and help identify the innovation trajectories, research needs, alternative scenarios and the possibility of disruptive technologies and surprises.

An exemplary roadmapping project, the biannual National Electronics Manufacturing Initiative (NEMI), identifies the 10 year outlook for key technology developments impacting the global electronics industry. This widely utilized roadmap helps OEMs, EMS providers and suppliers prioritize R&D and technology deployment investments, influence the focus university-based research and provide guidance for government R&D investment in emerging technologies.¹¹

⁹ Reeder, F., et.al. *The Manufacturing Extension Partnership Program*. National Academy of Public Administration. May 2004. p. viii.-x

¹⁰ Warren, A., Susman G. *Review of Innovation Practices in Small Manufacturing Companies*. Prepared by The Pennsylvania State University. 2004. See also: *Competing Against Manufacturing in Low Cost Regions: Focus on China*. Prepared by Stone & Associates, Inc. for NIST-MEP, Final Report. March 2004.

¹¹ <http://www.nemi.org/roadmapping/index.html>

In the case of the nation's defense infrastructure such roadmaps can have a significant influence on the development and speed by which we deploy new intelligence gathering systems, weapons and technologies for homeland security. For manufacturers in the commercial marketplace properly focused federal research investment can provide the foundation for entirely new kinds of production processes, products and market opportunities. Research areas of high potential for manufacturers include nanotechnology, meson-scale manufacturing, engineered materials, pervasive computing, knowledge management, alternative energy systems and web based enterprise integration.

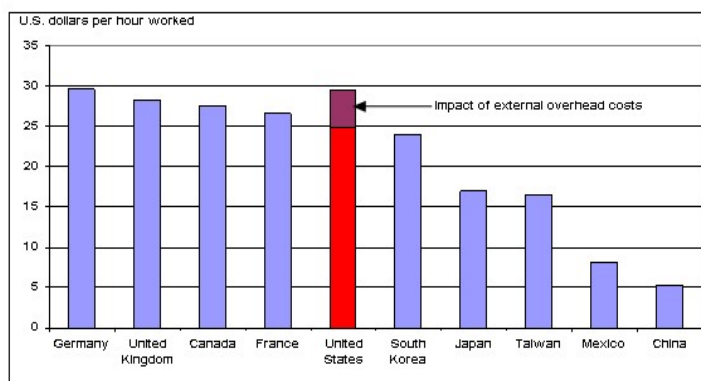
Collaborative road mapping exercises have significant advantages over individual company efforts. Companies can collaborate with customers and potential customers as well as suppliers and potential suppliers. It leverages the collective capabilities and expertise of industry without compromising confidential competitive information. By identifying where industry is going and what technologies, business practices and products it needs to get there, businesses can more effectively focus their investments in innovation toward customer needs and avoid costly mistakes. Through collaboration industry can better surface the range of strategic uncertainty and formulate innovation investments with less risk. Technology road mapping which is not narrowly formulistic can also reveal important intersections with complementary service sector technologies and provide forward looking insights on societal, environmental and public policy issues needing attention in the innovation and deployment process.

6. Consider strategies for reducing the burden of external overhead costs on manufacturing innovation and productivity improvement.

Rising external costs, not directly controllable by manufacturing firms, largely offset the US manufacturing advantage in innovation and productivity. External overhead costs from taxes, health and pension benefits, tort litigation, regulation and rising energy prices add approximately 22 percent to U.S. manufacturers' unit labor costs (nearly \$5 per hour worked) relative to their major foreign competitors. The absolute value of the excess cost burden on U.S. manufacturers (nearly \$5 per hour) is almost as large as the total cost index for China.¹² Taken

together, external overhead costs offset a large part of the 54 percent increase in productivity realized since 1990. The study goes on to point out that all four of the top U.S. developing country trading partners (China, Mexico, South Korea and Taiwan) have dramatically increased their U.S. trade share since 1990 and are orienting themselves toward high-end manufactured goods such as industrial machinery, telecom equipment and office machines, and transportation equipment. A reduction in these external costs

Raw Cost Position of the United States
And Its Nine Largest Trading Partners, 2002



Source: Organization for Economic Cooperation and Development, U.S. Bureau of Labor Statistics, National Statistics of Taiwan, UN Industrial Development Organization, and author's calculations.

¹² Leonard, J. *How Structural Costs Imposed on US Manufacturers Harm Workers and Threaten Competitiveness*. Prepared for the Manufacturing Institute of the National Association of Manufacturers. December 2003. p. 11.

would enhance US manufacturing global competitiveness and reduce the costs and future risks of innovation.

NAM makes the following recommendations:

- Reduce the corporate tax burden and reform the treatment of foreign-source income.
- Reduce the burden of rising health coverage costs and encourage greater consumer responsibility for health status and coverage costs.
- Reform rules for funding pension plans to avoid devastating cyclical swings in funding requirements.
- Undertake serious legal reform by curtailing frivolous lawsuits, placing large, nationwide class-action lawsuits in federal court, and negotiating fair and equitable compensation to legitimate asbestos claims.
- Establish a more objective cost-benefit review process for proposed and existing regulations that takes full account of adverse business impacts.
- Adopt changes in land-use regulations to allow access to undeveloped domestic natural gas reserves.