EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

January 30, 2004

President George W. Bush
The White House
Washington, D.C. 20502

Dear Mr. President:

We are pleased to transmit to you a copy of the Report, *Sustaining the Nation's Innovation Ecosystems, Information Technology Manufacturing and Competitiveness*, prepared by your Council of Advisors on Science and Technology (PCAST).

In early 2003, the PCAST undertook a two-pronged effort to explore the standing of U.S. innovation leadership, as well as the challenges confronting the Nation's "innovation ecosystems." This first report examines the current state of manufacturing -- particularly information technology manufacturing -- and its relationship to research and development. The second report, expected to be issued later this Spring, will examine the status of the Nation's science and engineering workforce and the education pipeline that supports it.

The Information Technology Manufacturing and Competitiveness Report's recommendations are geared toward sustaining U.S. high technology leadership, in order to maintain the Nation's rising standards of living through further productivity gains and the creation of new industries and new jobs. As you will recall, PCAST discussed this Report with you during your meeting with PCAST on December 3, 2003.

The full PCAST discussed and approved this Report at its December 2, 2003, public meeting. Please let us know if you have any questions concerning the enclosed Report.

Sincerely,

John H. Marburger, III
Co-Chair

E. Floyd Kvamme
Co-Chair

Enclosure

EXECUTIVE OFFICE OF THE PRESIDENT
PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20502

January 16, 2004

The Honorable John H. Marburger, III
Director, Office of Science and Technology Policy
Executive Office of the President
Washington, DC 20502

Mr. E. Floyd Kvamme
Co-Chair
President's Council of Advisors on Science and Technology (PCAST)
Washington, DC 20502

Dear Jack and Floyd:

It is my pleasure to transmit to you the finalized version of the Report, ***Sustaining the Nation's Innovation Ecosystems, Information Technology Manufacturing and Competitiveness,*** which originated in PCAST's Subcommittee on Information Technology Manufacturing and Competitiveness.

In March 2003, the PCAST established this Subcommittee, and asked it to examine the facts, trends and issues surrounding information technology (IT) manufacturing and competitiveness. The panel held over 20 sessions and teleconferences with corporate executives, government officials, academics, and other industry professionals to explore the topic in detail. Our study allowed us to gain new perspectives and learn of new concerns. This Report summarizes our work and recommendations, as well as the discussions that occurred at two PCAST meetings. The Report was approved by the full PCAST at its December 2, 2003, meeting and, as you know, we also discussed the Report with the President personally on December 3, 2003.

While undertaken as the country emerged from the recent recession, our study emphasizes long term trends, concerns and opportunities. The Report finds that the Nation's overall manufacturing output remains strong, largely due to productivity gains driven by IT and advances in manufacturing technology. Manufacturing employment is declining, however, and may be on a course historically analogous to the agriculture sector. IT manufacturing was particularly hard hit by the recession, and several global trends will maintain pressure on this sector.

The study finds IT outsourcing to be of significant concern within the high tech community, but ultimately focuses on a different primary concern. We learned of the increasing ability of foreign nations not just to manufacture products that have become essentially commoditized, but to develop the fundamental capacities to compete with the U.S. on its leadership level – that of innovating new products and new industries. U.S. high tech leadership

is not automatically assured, and the country must do the right things in order to preserve its continued technological preeminence.

The Report therefore focuses on the components of our Nation's "innovation ecosystems," and recommends courses of action to buttress the health of these ecosystems. We do not recommend IT-industry or even manufacturing sector subsidies, but rather find most critical the need to continue to undertake broad-based efforts that help maintain our high tech advantages. As the Report explains, these steps principally include maintaining a strong base of university R&D, keeping our workforce, education and economic climate competitive, and undertaking steps to respond, as may be appropriate, to foreign tax and subsidy programs.

In addition to the Report, I am enclosing a discussion piece from the leadership of the National Science Foundation, whom I asked to consider the current state of affairs and relate their thoughts back to me. Their outline of issues important to the Nation's continued economic success coalesces with our Report and articulates well the areas of leadership that must be targeted.

I believe the President policies have been highly consistent with our findings and recommendations – particularly including his support for increased R&D and his desire to buttress our education system and entrepreneurial climate. This Report will hopefully serve to maintain the pressure to act on these goals, as well as to highlight some new areas to pursue.

Sincerely,

George Scalise
Chairman
Subcommittee on Information Technology
Manufacturing and Competitiveness

Enclosures

National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

December 24, 2003

Ensuring Manufacturing Strength through Bold Vision

- **Anticipating the Future.** Civilization is on the brink of a new industrial world order. The big winners in the increasingly fierce global scramble for supremacy will not be those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques and tools so advanced that *there is no competition*. That means securing unquestioned superiority in nanotechnology, biotechnology, and information science and engineering. And it means upgrading and protecting the investments that have given us our present national stature and unsurpassed standard of living.

- **What It Will Take**. If the United States is to dominate the next, critically decisive stage of industrial progress, it must be the first to create the technologies and workforce skills of the nano era. American science and engineering have shown us that assembly on the molecular scale – or smaller! – is essential to achieve breakthroughs in communications, information processing, transportation, materials, sensors and pharmaceuticals, among others. What we have lacked is the will and determined vision to catapult ourselves beyond 20th-century thinking by applying our best research results to revolutionary manufacturing techniques that will make today's products better and build tomorrow's products first.

- **The Age of Molecular Manufacturing.** In order to meet that challenge, we will need designs, fabrication tools, and manufacturing systems that come not from mere incremental improvements, but directly from the frontiers of discovery, both recent discoveries in hand and those yet to come.

  Existing facilities can be renovated, retrofitted and reinvented to take advantage of the latest research – and to protect and prolong the multi-billion-dollar investments that America's high-tech industries have already made. Meanwhile, we can begin designing the factories of the future. Both will house "bottom-up" nanomanufacturing that constructs new organic and inorganic structures atom by atom. The resulting materials and products will display heretofore unimagined combinations of strength, flexibility, lightness, energy efficiency and environmental sustainability. They will be the goods in intense worldwide demand, and they will not be made by the cheapest labor of hands. The scaling down and miniaturization of components will enable us to make factories the size of silicon chips for sensors, computers, and medical treatments.

  At the same time, many of our most productive plants will literally be plants. Crops such as corn and tobacco will become "factories" to make pharmaceuticals to fight cancer and other diseases, and the source of novel compounds with new and valuable properties – all with a minimal impact on the environment.

- **Educating the 21st Century Workforce.** Assuring our economic security and jobs for our citizenry requires a workforce so well trained and capable, so agile and up to date, that it thrives on the continuous technological change and fast-paced progress that are an absolute certainty in coming years.

John A. Brighton
Assistant Director
For Engineering

Joseph Bordogna
Deputy Director

Rita R. Colwell
Director

THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

Sustaining the Nation's Innovation Ecosystems

Report on

Information Technology Manufacturing and Competitiveness

January 2004

Executive Summary

Overview

This Report contains PCAST's recommendations to the President on sustaining the nation's innovation ecosystems. PCAST submits the Report to help maintain the United States' global high technology preeminence, and our associated economic prosperity and high standards of living, for years to come.

Almost sixty years ago, Vannevar Bush's letter to President Truman helped set the United States on a course that not only launched the National Science Foundation, but also established the basic underpinnings of the Nation's modern research and development (R&D) enterprise. His words were prescient and still ring true today:

> "The pioneer spirit is still vigorous within this Nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards for such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress" (July 5, 1945)

The Nation's scientific and pioneering spirits remain strong, but we confront new challenges from new economic realities and tough-minded foreign competitors. PCAST undertook a review of these trends in order to understand them better, and to assess their potential threat to our innovation leadership and continued economic prosperity. We found that U.S. innovative strengths remain sound, but that certain pressures are very real. We also found, disconcertingly, that considerable anxiety exists within the S&T community over the Nation's future prospects for continued high tech preeminence. Accordingly, PCAST submits this Report to the President as a means to help strengthen our considerable national assets, and also to reinvigorate the basic sense of optimism and confidence, and mission, as captured by Vannevar Bush.

One comment received by PCAST while conducting this study, from the leadership of the National Science Foundation, crystallizes well the current state of affairs and carries the Vannever Bush vision forward to today's competitive global environment:

> Civilization is on the brink of a new industrial world order. The big winners in the increasingly fierce global scramble for supremacy will not be those who simply make commodities faster and cheaper than the competition. They will be those who develop talent, techniques and tools so advanced that *there is no competition.* That means securing unquestioned superiority in nanotechnology, biotechnology, and information science and engineering. And it means upgrading and protecting the investments that have given us our present national stature and unsurpassed standard of living.

Through this Report, PCAST notes that the Nation's technological and innovation leadership depends upon dynamic "innovation ecosystems," rather than mechanical end-to-end processes. We believe that basic R&D and manufacturing constitute the ecosystems' primary pillars, but that other components support the health of the overall system as well. Accordingly, while key aspects can and should be strengthened, it would be a mistake to view individual pieces separately, as if operating in a vacuum.

In that regard, in today's global environment, a highly successful innovation and technological leader will have the following attributes:

1. A strong basic R&D investment;
2. A large body of skilled scientists and engineers;
3. A flexible and skilled work force;
4. Reliable utilities and other infrastructure;
5. Federal and state laws and regulations that do not inhibit high tech manufacturers from locating facilities at home;
6. A competitive investor and tax environment; and
7. A level playing field, with enforcement of trade agreements and intellectual property (IP) rights.

This Report notes that other nations are catching up to our leadership in these areas. They are increasingly replicating our basic innovation platforms, rather than merely manufacturing commoditized products on an outsourced basis. These trends mean the United States has begun confronting a new level of global competition. The Report is therefore intended to provide information to strengthen the United States' own "innovation ecosystems" in order to

buttress our technological leadership, continue our economic prosperity, and maintain rising standards of living for the Nation's people.

Recommendations

In light of these trends and considerations, the Report recommends two fundamental courses of action: (1) maximizing our advantages, and (2) assessing foreign competition and responding appropriately with policies for the future.

1. Maximizing Our Advantages

The United States has considerable economic and innovative advantages, including the world's leading market. The Nation also leads the world in the attributes discussed above – on an overall basis if no longer on each individually. To maintain these strengths, and improve them where needed, PCAST recommends:

- The Nation's R&D base should continue to be strengthened;
    - This recommendation includes Federal funding for basic research in promising areas (such as nanotechnology, information technology, and manufacturing R&D), and the creation of a task force to study Federal-state R&D cooperation.
- Our S&T education and related workforce skills should be improved;
- Our entrepreneurial climate should be enhanced; and
- Our underlying infrastructures should be rejuvenated.

2. Assessing Foreign Competition and Establishing Policies for the Future

Foreign governments are pursuing policies not only to build their own innovation ecosystems, but also to attract U.S. companies and individuals to locate their plants and skills outside of U.S. borders. These programs are largely tax oriented, and are having real impacts upon corporate and individual decision-making. In light of these trends, PCAST recommends:

- The U.S. R&D tax credit should be made permanent;

- The President should form a task force to assess foreign tax programs and their impact on investment practices, and report back on how the United States should appropriately respond; and
- Given the swift nature of technological obsolescence, the Administration should pursue an expedited WTO process to resolve IP and market access violations.

With these recommendations, PCAST believes the United States will be well-positioned to sustain its innovation ecosystems, maintain its technological preeminence, and lead "the next, critically decisive stage of industrial development."[*]

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[*] Letter to PCAST panel from the NSF Leadership. The full paragraph is as follows:

> If the United States is to dominate the next, critically decisive stage of industrial progress, it must be the first to create the technologies and workforce skills of the nano era. American science and engineering have shown us that assembly on the molecular scale – or smaller! – is essential to achieve breakthroughs in communications, information processing, transportation, materials, sensors and pharmaceuticals, among others. What we have lacked is the will and determined vision to catapult ourselves beyond 20th-century thinking by applying our best research results to revolutionary manufacturing techniques that will make today's products better and build tomorrow's products first.

The President's Council of Advisors on Science and Technology

Report on Information Technology Manufacturing and Competitiveness

Overview

In March 2003, the President's Council of Advisors on Science and Technology (PCAST) formed a subcommittee on Information Technology Manufacturing and Competitiveness to examine issues surrounding the migration of information technology manufacturing from the U.S. to foreign countries. The subcommittee's task was to gather the facts, explore potential ramifications, and provide draft recommendations to address the issues found to exist.

To assist in its deliberations, the panel commissioned a study by the Science and Technology Policy Institute (STPI) at RAND,[1] and concurrently held numerous meetings to survey the perspectives of industry and related experts. The panel held over 20 meetings with leading academics, corporate executives and other industry representatives, as well as federal government officials, and state and local officials.

The PCAST primarily focused its work on the information technology (IT) sectors of the economy, not manufacturing generally. Data were gathered and examined to develop an overall and historical manufacturing perspective, with the IT focus allowing for more in-depth analysis of the key technology sector. This focus was motivated by the significant value added that the IT sector provides to the U.S. economy -- as a distinct manufacturing sector, as a business market that serves as the basis for much innovation and economic growth, and also as a technological enabler for increased productivity that provides an additional avenue of economic

[1] Science and Technology Policy Institute, Prepublication Draft (December 2003) (The "STPI Report").

benefit to the Nation across a wide range of sectors.[2] Studies have found that technology improvements accounted for up to one-half of GDP growth, and at least two-thirds of productivity growth, in the post-war period.[3] The panel also focused its efforts on assessing how current trends may affect the Nation's science and technology (S&T) enterprise -- and thus its long-term economic security -- remaining mindful of the vital role IT plays in contributing to our national security as well.

The United States enjoys global technological preeminence, but its continued leadership is not automatically assured. This Report presents PCAST's Findings and Observations, and associated Recommendations, intended to help the Nation maintain its innovative leadership.

The Timing of this Report

In preparing this Report, PCAST remained mindful of the state of the U.S. economy. Many of the concerns addressed here crystallized in the wake of a brief recession, from which the economy appears to be rebounding well. At this writing, the last two quarters recorded economic growth of 3.3 % and 8.2 % respectively (2003 Q2 and Q3), and job growth now appears to be following. Nonetheless, these recommendations are based upon certain trends we explored in the S&T sector, such as Internet-based abilities to better manage a global enterprise, foreign outsourcing of not just manufacturing but services and design, and the increasing tendency of foreign science, technology, engineering and mathematics graduates to return to their native countries to work. Whether the U.S. is in the midst of an economic boom or the depths of a recession, the recommendations here are meant to foster our shared desire to maintain U.S. high tech leadership as a driver of continued economic growth and high standards of living for the Nation's people.

[2] National Institute of Standards and Technology, *99-2 Planning Report, R&D Trends in the U.S. Economy: Strategies and Policy Implications* (April 1999) (The "NIST 99-2 Study").
[3] NIST 99-2 Study 5-6.

Findings and Observations

1. Manufacturing Trends

A. Overall Manufacturing and Productivity

Strong productivity gains have allowed the overall volume of U.S. manufacturing output to remain very strong over the past 50 years, despite manufacturing's decline as a share of GDP and the decreasing number of manufacturing jobs.

The accompanying STPI analysis examined numerous studies which assert that a U.S. manufacturing "crisis" exists, and compiled the latest economic data available. This analysis demonstrates that while U.S. manufacturing industries once accounted for 27 percent of U.S. GDP in 1947, by 2001 manufacturing's share of GDP had shrunk to 14 percent.[4] Moreover, manufacturing jobs have declined from 30 percent of full-time equivalent workers to under 15 percent over the same time frame.[5] Between 1995 and 2003, manufacturing jobs declined 15.5 percent, from 17.4 million to 14.7 million.[6]

Over the same 50 year timeframe, however, overall U.S. manufacturing output has remained steady if not grown. Between 1977 and 2001 manufacturing output (measured in 1996 constant dollars) almost doubled.[7] In terms of volume produced, U.S. manufactured goods have not been replaced by foreign goods on world markets.[8] Furthermore, when measured in constant dollars, manufacturing's share of the U.S. GDP over the same 1977-2001 period has declined only slightly.[9] The decline in manufacturing's share of U.S. GDP can in part be attributed to the fact that steeper increases in costs of other services resulted in those services assuming a greater proportion of the GDP.[10]

[4] STPI Report 4.
[5] STPI Report 4.
[6] STPI Report 57-58, 56.
[7] STPI Report 9.
[8] STPI Report 9.
[9] STPI Report 10.
[10] STPI Report 10.

The major reason that U.S. manufacturing has remained strong is the significant rise in U.S. productivity. As the analysis notes: "Both the rising volume of output and the falling price of U.S. manufactured goods are consistent with an increase in the productivity of American workers in the manufacturing sector."[11] A consequence of increased productivity is the fact that fewer people are needed to produce an equal volume of goods. Along with a decrease in manufacturing jobs, increases in productivity also result in higher wages and higher living standards.[12] The underlying basis for this increase in productivity has been continued IT innovation and the integration of IT into the manufacturing process. This IT integration has occurred very broadly through factory systems, automation and networks, via intelligent manufacturing devices (*e.g.*, computer numerical control machine tools, robotics), comprehensive quality control systems, and technology infrastructure (*e.g.*, measurement capability).[13]

One recent study by the Institute for International Economics (IIE) found that companies using IT intensively, by re-engineering their businesses, accounted for up to 75 percent of the productivity gains throughout the 1990s. Another 10-30 percent of productivity gains derived from companies pursuing a global business model. Additionally, jobs at IT-producing companies rose at 4 percent per year through the 1990s, while jobs at IT-using companies rose at 7 percent per year through the 1990s.[14] A recent compilation of studies by NIST's Senior Economist further supports the notion that IT is a vital force in productivity gains and economic growth.[15]

Considerable room for improvement remains. NIST's Manufacturing Engineering Laboratory estimates that large segments of U.S. manufacturing remain largely untouched by recent improvements in information technology.[16] Continued enterprise integration – the enhancement of interoperability across manufacturing enterprises – can result in productivity

[11] STPI Report 11.
[12] STPI Report 12.
[13] Presentations of Professor Dale Jorgenson and the Computer Systems Policy Project to the PCAST subcommittee.
[14] Mann, Catherine, *Globalization of IT Services and White Collar Jobs: The Next Wave of Productivity Growth*, Institute for International Economics, Policy Brief No. PB03-11 (December 2003).
[15] NIST Study 99-2.
[16] Presentation of NIST Manufacturing Lab to PCAST panel. Professor Jorgenson's presentation also stated the economy's productivity gains came initially from the IT industry itself, with the next wave to come from industries using IT.

gains that can improve the competitive position of many firms and continue to maintain strong manufacturing output. These productivity gains allow the U.S. to maintain its manufacturing capacity even in today's global environment, and manufacturing has an increasingly stronger reliance on IT tools to enhance its productivity and competitiveness. The IIE study reinforces these findings.

As the technological frontier pushes forward, potential productivity gains are created for companies to exploit. One result of recent IT innovations and the pressure of global competition is the importance of speed of change within the economy. The U.S. economy's flexibility generally provides a global advantage, and the pace of application of IT can help maintain the Nation's competitive edge.[17] The United States confronts a challenge in maintaining its leading position at the leading edge of the technological frontier, and in ensuring that the resultant productivity gains can continue to be realized swiftly and maximized across industries.

While the above discussion has focused on long-term trends, PCAST does not mean to ignore the short-term effects of the recent recession. Very recent statistics[18] show that U.S. industrial production fell 7.4 percent from June 2000 to November 2001, and rose slightly (0.6 percent) from November 2001 to June 2003. Manufacturing productivity has continued to rise -- 1.6 percent in 2001, 6.4 percent in 2002, and 4.9 and 4.2 percent in the first and second quarters of 2003, respectively. While these recent data show an increase in output and productivity trends, the job losses have been real and painful. Manufacturing employment in the United States stood at 14.65 million in July 2003, a 1.3 million loss since 2001.[19] Globally, estimates are that 22 million manufacturing jobs disappeared between 1995 and 2002, due in large part to these same productivity gains.[20] There is little question that total online manufacturing jobs as a percent of the total workforce will continue to decline, but jobs will be gained as consumers call for help in differentiating product choice and in applying the new technology products being made available.

[17] Presentation of Professor Jorgenson to PCAST panel.
[18] National Association of Manufacturers "*QuickFacts*" Data Sheet (December 2003)
[19] The most recent economic data show a rebound in economic activity and employment, with 234,000 net new jobs being created over the last two months (October - November 2003).
[20] See, e.g., Carson, Joseph, *Manufacturing Jobs' Global Decline (Part 1)*, AllianceBernstein (October 2003).

President Bush recently highlighted the impressive productivity of the American worker, but noted "there's a problem with the manufacturing sector."[21] He stated that "for a full recovery, to make sure people can find work," the manufacturing sector "must do better."[22] The PCAST focus on IT and productivity in this Report is intended to understand and improve what makes the economy most successful in creating new jobs and maintaining rising standards of living for the Nation's people – to help ensure that U.S. manufacturing *can* do better.

B. Information Technology Trends

In the face of global competition, U.S. information technology manufacturing has declined significantly since the 1970s, with an acceleration of the decline over the past five years. While the U.S. has largely remained dominant in leading edge design work, U.S. industry experts are increasingly anxious over losing this advantage.

The information technology manufacturing industries play a large role in the U.S. economy. Computer and electronics manufacturing provide the third highest level of employment for U.S. workers, behind only the fabricated metals and transportation industries.[23] The computer and electronics sector is also the third largest value-added industry.[24]

In terms of employment, domestic computer manufacturing jobs have declined considerably over the past five years. While overall domestic manufacturing employment declined 6 percent from 1997 to 2001, computer manufacturing employment particular declined 20 percent.[25] Further segmentation shows that semiconductor, electronic computer, and computer peripheral manufacturing employment have all declined over the period from 1997 to 2001.[26] More recent data show a loss of over 400,000 high technology manufacturing jobs from

[21] The President's Labor Day Speech, Richfield, Ohio (September 1, 2003).
[22] The President's Labor Day Speech.
[23] STPI Study 66 (2001 data).
[24] STPI Study 66.
[25] STPI Study 67.
[26] STIP Study 68 (Figure 4.10).

January 2000 – December 2002.[27] Overall, employment in high technology industries fell by 540,000 in 2002, and a further loss of 234,000 is expected in 2003.[28]

The high tech industry has always been a global industry. High tech exports account for 34 percent of total U.S. exports, with the United States being the world's leading high tech exporter.[29] Nonetheless, several other nations, particularly in Asia, are major players as well. Japan, Singapore, Taiwan and Korea combine to export more high tech goods than the United States, with China rising to be the world's 8th leading exporter.[30]

In the wake of a concerted Japanese effort, the U.S. semiconductor industry's global market share of memory devices declined from over 70 percent in 1979 to under 20 percent in 1986.[31] While memory device market share has never been recovered, the market share for all devices rebounded during the 1990s from 38 percent in 1988 to hold at about 50 percent through 2002. These gains resulted from high value added components such as analog products, microprocessors, application specific integrated circuits (ICs) and hybrid devices.[32] Aggressive U.S. government actions also contributed to the U.S. come-back in semiconductors. In 1986, President Reagan imposed unprecedented trade sanctions on Japanese imports into the U.S. market to force Japan to open its semiconductor market and to eliminate illegal dumping. The U.S. government and industry also launched SEMATECH, a research consortium that improved American manufacturing capabilities and strengthened the U.S. semiconductor manufacturing equipment base.[33]

As discussed below, there are important differences between the competitive challenges now facing U.S. IT manufacturing from China and other Asian locations, and those presented by Japan in the 1980's. Any U.S. government responses to the current situation must be tailored to the current competitive environment.

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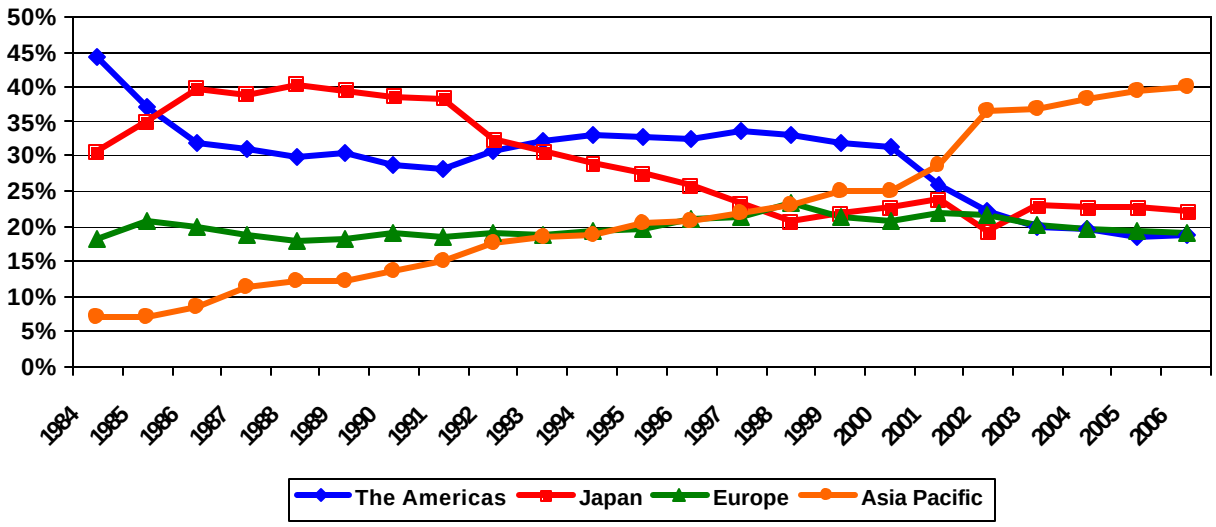
[27] American Electronics Association, *Tech Employment Update* (2003) (see www.aeanet.org/Publications/idmk_endofyear2002.asp).
[28] American Electronics Association, *Cyberstates* News Release (Nov. 19, 2003).
[29] STPI Study 81.
[30] STPI Study 81.
[31] STPI Study 26.
[32] STPI Study 28.

Because of its overwhelming population compared to other Asian competitors, China's rise as a high tech manufacturer has caused increasing concerns. China is a large emerging market and its industrial and economic policies associated with expanding this sector are likely to continue indefinitely. Some wonder whether China will some day replicate in leading edge technology the manner in which Japan became a force in semiconductor memory manufacturing in the 1980s. Still, at present, leading-edge semiconductor design remains with U.S.-based companies,[34] but the design process is becoming a 24-hour cycle that utilizes design centers that span the globe (*e.g.*, India, Israel and Ireland). China's design capabilities exist for lower end products only, and Singapore's design capacity is at the lower end as well.[35]

One measure of the growth of overseas information technology manufacturing is the purchase of semiconductors – a fundamental component of IT products. As noted in the chart below, the Asian semiconductor market surpassed the U.S. market in 2001 and is expected to widen the gap thereafter.

% Share of Global Semiconductor Consumption



Despite the maintenance of leading-edge technological dominance, the loss of information technology manufacturing has been a consistent area of concern running through the PCAST's discussions with outside industry experts. Many executives, academics and

[33] See STPI Study, Chapter 3, for a comprehensive analysis of the history of U.S. semiconductor manufacturing.
[34] Presentation of major business consulting firm to PCAST panel.

government officials express anxiety over the long-term effects of the loss of this manufacturing capacity (and increasingly services, as well). While the loss of manufacturing jobs does not by itself indicate a loss of U.S. competitiveness (for reasons outlined in the previous section), a concern does exist that overseas migration of such manufacturing will, over time, erode the Nation's ability to continue driving new technology development and innovation. IT manufacturing is not homogeneous or static, but as existing manufacturing moves offshore we want to ensure it is replaced by new high-value added manufacturing or other substitutes through new innovations and the creation of new industries.

Broader Societal Trends and Maintaining Personal Prosperity

In deliberating on this Report, many PCAST members noted how the manufacturing employment trends over the past 50 years closely parallel those that previously occurred in the agricultural sector. One hundred years ago, about one-half of the work force was engaged in agriculture, 50 years ago 20 percent was so engaged, and currently only 3 percent are engaged in agricultural production. Still, our Nation now "feeds the world" as agricultural productivity and output have not just remained steady but soared. Similarly, the percentage of manufacturing jobs in the Nation's workforce has been declining over the past 50 years from about 30 percent after World War II to 15 percent today. Similarly as well, manufacturing productivity has increased and overall output has remained steady if not improved. The societal implications of the agricultural "contraction" were significant, and the implications of a similar manufacturing trend will be significant as well. Still, the agricultural trend was disruptive but beneficial: personal living standards grew as the Nation successfully adapted to a shrinking agricultural workforce. Our recommendations here are intended to help achieve similar success in maintaining individual prosperity in the midst of modern economic trends.

[35] Presentation of major business consulting firm to PCAST panel.

2. Reasons Behind Foreign Inroads

"We are not just competing against foreign companies, but foreign countries."[36]

U.S. IT manufacturing is migrating offshore for a variety of reasons. These include traditional economic factors – such as obtaining lower-cost labor, and gaining proximity to emerging markets – as well as concerted foreign government programs. While labor costs are more important for simpler assembly operations, the high capital investment costs associated with leading-edge manufacturing plants for semiconductors, displays or other high-performance products make non-labor factors much more important.

The United States holds several major advantages compared to foreign competitors in attracting new high technology investment. These include:

- The world's best R&D system (through universities, government, and industry);
- The best workforce talent and research universities;
- The most flexible and entrepreneurial business climate;
- The best government and rule of law (and associated IP protections);
- The best infrastructure; and
- The world's largest market for high tech products.

These advantages are not unqualified, however, and are being eroded by global competition (and, in the case of certain infrastructures, by time and neglect). When the benefits of such advantages, on balance, are outweighed by other concerns – such as labor costs and proximity to emerging markets – U.S. IT manufacturing will move offshore, as the figures in the prior section demonstrate.

Information technology manufacturers told PCAST, loudly and clearly, that the movement of their manufacturing capabilities overseas was a matter of economic necessity and competitiveness, effectively demanded by customers. Where product cycles mature and the costs of labor come to dominate (and concerns over continued IP protection are alleviated), the United States loses its competitive advantages. Moreover, the ability of IT companies to manage

[36] Statement of high tech corporate official to PCAST panel.

complex global manufacturing networks is constantly improving, making offshore manufacturing even more attractive.

In addition, the United States' R&D advantages do not always outweigh the benefits of doing work overseas. In fact, U.S. IT companies are not only moving R&D and design capabilities overseas, but some are also providing higher-end design projects to overseas centers. This trend is likely to continue. The U.S. advantage in this area erodes as the quality of foreign universities and graduates improves. One company told PCAST that the cost of engineers in India and Asia stands at 1/3 of the prevailing wages in the U.S. One consulting firm told the PCAST panel that, overall, foreign engineers cost 90 percent less. To exploit these cost advantages, R&D centers are being established in these countries, as well as in Europe. While no company told PCAST its top-level R&D and design was occurring overseas, the confidence in foreign R&D centers is slowly improving and young technicians are learning supervisory skills. Just as the management of complex global manufacturing networks has led to more offshore manufacturing at earlier stages, improved confidence in and management of global R&D networks could lead to the migration of high-end R&D and design work as well.

Further augmenting these underlying economic trends, foreign governments are aggressively targeting information technology industries as key to their economic development. Concomitant national level policies are being pursued which make the cost advantages of foreign manufacturing even more compelling. Some of the most important foreign programs include the following:[37]

1. **Tax Benefits.** Foreign governments are providing tax benefits to attract foreign investment at both the corporate and individual levels. Perhaps the most controversial tax incentive is China's value-added tax (VAT) rebate on domestically manufactured chips. Foreign-made chips confront a 17 percent VAT, while domestic manufacturers are entitled to a refund of a portion (up to 14%) of the VAT paid on their locally produced chips. China and other Asian countries provide corporate tax holidays. In certain regions in China, IC and software firms can receive a "5+5" incentive plan, whereby the company receives a five-year exemption from central government taxes and 50 percent reduction for the following five years. For example, Shanghai offers a "5+5" plan, and Beijing offers "Shanghai plus 1."

[37] STPI Study 143-145.

As to personal taxation, China taxes stock options at par value and has no capital gains tax. In Singapore, each of Chartered Semiconductor's fabs receive a ten-year tax exemption, followed by a five-year period of reduced taxes.

One major U.S. semiconductor manufacturer informed the PCAST panel that the United States simply cannot compete on a tax basis – the effective differential offered by an Asian country for a major new plant was $1.3 billion out of a total investment of $3 billion.

2. **Subsidy Programs.** Foreign governments also offer direct subsidy payments, beneficial loan terms, and other forms of favorable treatment. For example, the government of Taiwan provided significant assistance to start-up Taiwan Semiconductor Manufacturing Corporation (TSMC) and United Microelectronics Corporation (UMC). Both TSMC and UMC were spun off from government-funded research institutes, and the government provided half of TSMC's initial $200 million investment. Taiwan also offers foreign companies two years of free rent in designated industrial districts, followed by four years of reduced rents. The government of Singapore reportedly provided 95 percent of the start-up costs of Chartered Semiconductor.

3. **Currency Valuation.** While evidence is mixed and the policy is not targeted at helping China's IT sector in particular, some estimate that China's currency peg to the dollar has effectively undervalued its currency by about 40 percent relative to the U.S. dollar.

4. **Science-based industrial parks**. In China, both the central and local governments are promoting science-based industrial parks that include R&D centers. Taiwan's free and discounted rent programs are offered to foreign companies that establish corporate headquarters or R&D centers in designated industrial districts.

5. **Worker training.** Singapore offers high tech firms grants toward education and training of engineers. China offers a broad range of incentives to Chinese students who were educated in the U.S. to attract them back to China.

Despite these direct incentives and other economic advantages, the ability to outsource is not limitless. Difficulties in managing a foreign enterprise, less than optimal foreign infrastructures, transportation costs, and the continued availability of skilled labor, among other issues, all place some boundaries on the ability of U.S. firms to outsource high technology work.[38] Aided by the development of the Internet and modern communications, however, current trends suggest other nations are becoming more successful in overcoming these barriers. Still, domestic manufacturing and jobs can be maintained by implementing competitive cost

[38] Biswas, Dipesh, *Offshore Outsourcing: Is It The TCO Slasher It Promised to Be*, Deloitte Consulting (2003).

structures and maintaining the features that make the United States an attractive entrepreneurial environment.

3. Implications and Concerns

"National priorities and corporate priorities are not aligned."[39]

The loss of U.S. high tech leadership would have serious detrimental effects on the Nation's economic security and its citizens' standard of living. While not in imminent jeopardy, a continuation of current trends could result in a breakdown in the web of "innovation ecosystems" that drive the successful U.S. innovation system.

The Nation's high technology dominance is not forever guaranteed. The PCAST panel devoted considerable attention to the risks that the loss of information technology manufacturing presents to the Nation's long-term economic health. It focused on the nature of the U.S. economy and its long-term strength deriving from its innovation leadership. This leadership has helped assure that the economy continues to build higher and higher "rungs on the economic ladder," not only by developing new technologies, but also by taking advantage of those developments. Historically, the Unites States lost its comparative advantages in certain manufacturing sectors as product cycles developed and the upward drive of our innovation system created new industries and jobs and higher standards of living. Continued innovations also provided the basis for increased productivity that helps improve the competitiveness of existing manufacturers and other sectors of our economy.

PCAST thus particularly focused on the process by which a detrimental outcome could result from a breakdown of the U.S. innovation system. Such an outcome cannot be predicted, but understanding the process by which it could occur can offer two sets of benefits: First, such understanding can lead toward the development of preventative measures should the risk be real; and, second, it can point to means for further strengthening the U.S. innovation system even if the risks are overestimated.

[39] Statement of one leading IT manufacturing executive to PCAST panel.

A. The R&D-Manufacturing "Innovation Ecosystem"

> ***"The proximity of research, development and manufacturing is very important to leading edge manufacturers."***[40]

The panel's analysis of current manufacturing and impending R&D trends, led it to ask through what processes the U.S. maintains its technological preeminence, and how this leadership position could be lost. To obtain answers, the PCAST panel explored the linkages between R&D and manufacturing as a cyclical, dynamic relationship that drives toward successfully innovating new leading-edge products as well as integrating improved IT into new and existing manufacturing processes for productivity gains. The operating principle of this inquiry has been that the research-to-manufacturing process is not sequential in a single direction, but rather results from an R&D-manufacturing "ecosystem," consisting of basic R&D, pre-competitive development, prototyping, product development and manufacturing, with successful avenues of research and development being assisted by an understanding of the manufacturing situation as it presently exists. Design, product development, and process evolution all benefit from proximity to manufacturing, so that new ideas can be tested and discussed with those working "on the ground."

This ecosystem is based upon the importance of human capital, and thus proximity, in the information technology arena. In the information technology sector knowledge – or human capital – is of extremely high value. As the velocity of technology development accelerates, the interdependency between new research and manufacturing becomes vitally important, and those linkages are provided by people.

While the ecosystem has many elements, two aspects appear to be the most important in driving continued innovation: Locations that possess both strong R&D centers and manufacturing capabilities have a competitive edge. Indeed, several major manufacturers told the PCAST panel that they decided to locate new plants in the United States, despite cost benefits of offshore manufacturing, due to the proximity of leading university R&D capabilities

[40] Statement of a leading IT company executive to PCAST panel.

(or a state's commitment to upgrade such capabilities). Should that R&D capacity and its linkage to manufacturing be lost, the plant location decisions being made five and ten years from now could be markedly different.

Further support for this "innovation ecosystem" effect comes from recent studies that have found regional "clusters" as being the most successful means of innovation and economic development.[41] These "Clusters of Innovation" are many and varied throughout the Nation, and do not exist solely in the information technology sector. Still, innovation does seem to emerge best from a clustering of manufacturing, R&D, appropriately educated and skilled workers, and other elements necessary for successful business development.

Finally, as noted in Section 1, an important feature of the nature of IT development and global competitiveness today is the pace of change. The United States has held an advantage in this regard because its economy is very flexible and has proven itself generally able to adopt swiftly to new IT innovations throughout its economy. Proximity between manufacturing and supporting R&D aids in this economic agility.

B. Implications for the United States

The dangers of a loss of high technology leadership are twofold: (1) our own ecosystems can be damaged by a loss of one of their key "anchors" (R&D or manufacturing), and (2) other countries are striving to replicate the U.S. innovation ecosystem model to compete directly against our own. Moreover, unlike natural resources, human capital can be relocated or created through financial investments, so foreign progress confronts no "natural" limits. As noted in Section 3(A) above, for example, other countries are moving swiftly to co-locate R&D centers of excellence next to the manufacturing plants they attract.

In particular, the entry of China into the high technology arena has created a new level of nervousness on the part of many industry and academic professionals. In part, this results from

[41] STPI Study 75-79. See also the Council on Competitiveness' "Clusters of Innovation" Reports at www.compete.org/publications/clusters_reports.asp.

China's size and its commitment to a high tech industrial policy.[42] Furthermore, because of the size of its population, many industrialized nations (including the U.S.) view China as a sizeable emerging market and opportunity for economic growth. Thus, the prospect of falling behind implies the possibility of losing the ability to take advantage of this opportunity. China, on the other hand, has an interest in seeing economic benefits accrue to Chinese companies rather than to foreign competitors. Moreover, China's size ensures its labor rates will rise more slowly than occurred with its Asian neighbors, and China enjoys a strong entrepreneurial culture and tradition. For all these reasons, it is expected that China's efforts to develop leading-edge high technology ecosystems will be significant, continue for a long time, and gain extensive assistance from foreign investment.

Additional concerns arise from U.S. education trends. Recent statistics have shown an increase in foreign students as a share of science, mathematics and engineering degrees at all levels, and an increased tendency of these foreign graduates to receive these degrees in their home countries.[43] These trends buttress not only the abilities of other countries to attract outsourced manufacturing, but also their desire to match the U.S. pre-eminence in leading-edge R&D and design.

Continued damage to U.S. information technology ecosystems through a degradation of its principal anchors – R&D or manufacturing – has serious implications for the U.S. economy and standards of living. An R&D-manufacturing innovation ecosystem is important for every manufacturing sector. However, this importance is accentuated for information technology because of its ubiquity (it is a common thread that weaves through every other major sector to help maintain U.S. productivity and strength), and also because the speed with which IT advances makes the proximity issue more critical.

[42] China also has a flexible, entrepreneurial culture, which some of its neighbors do not.

[43] For example, with respect to physical sciences and engineering Ph.D.s, U.S. citizens received 4,700 degrees in 1987, 5,100 degrees in 1997 and 4,400 degrees in 2001, while Asian citizens received 5,600 degrees in 1987, 17,700 degrees in 1997 and 24,900 in 2001. *Science and Engineering Doctorate Awards*, Science and Engineering Indicators, National Science Board (2002). Moreover, the percentage of foreign students receiving Ph.D.s from U.S. universities has dropped 15 percent since 1996. *Survey of Earned Doctorate*s, Science and Engineering Indicators, National Science Board (2002).

As noted in Section 1 above, IT innovation has been driving the Nation's sustained productivity gains, which have operated to maintain the health of the U.S. manufacturing sector. These benefits can continue to accrue through new innovations and through wider adoption of existing IT practices throughout the economy. While U.S. firms could purchase IT elsewhere, maintaining a domestic innovation cycle is vital to the long-term security of the Nation. The information technology industry offers extremely high value to the U.S. economy, and a robust technological innovation system holds many national and homeland security benefits, as well.[44]

Over time, should our own ecosystems weaken while foreign ecosystems grow in strength, the maintenance of U.S. technological preeminence is not assured. Thus, while some predictions of national economic decline are overblown, the issue does warrant concern by policy makers. More likely than some of the "doomsday" forecasts, the pace of our rising standards of living would be slowed through a long-term accumulation of many individual decisions, actions, and inactions. Decisions being made today are having evolutionary effects on our own innovation ecosystems, as well as those being developed by foreign competitors. Optimally, a "win-win" situation will result whereby foreign gains will not degrade our own standards of living, but the benefits of increased trade and economic relationships will accrue to all.

4. Domestic Success Stories

"U.S. states are competing against foreign states."[45]

Several states have been highly successful in attracting major high technology manufacturing companies. While details vary, these states followed several common "best practices." They understood the underlying characteristics of the ecosystem, such as the importance of a skilled workforce and university research infrastructure; they viewed competing with other states for those companies as an economic development issue; they devised a plan, and relentlessly pursued it, providing a broad spectrum of incentives in order to achieve their

[44] PCAST did not undertake an examination of the contribution that IT makes to National and Homeland Security, The contribution is significant, however, and increasingly important to the modern military, our intelligence services, and national homeland security efforts. See STPI Study 17-18.

goals. Such state actions have played a vital role in attracting and maintaining high tech manufacturing capabilities within the United States, and will continue to do so in the future.

The PCAST panel has examined the role of states in maintaining U.S. high technology preeminence. In discussions both with companies that have made recent decisions to locate manufacturing plants domestically, and with state officials, the panel found several common practices that everyone agreed played important roles in bringing new manufacturing capacity to the state (and thus maintaining its presence in the U.S., as well).

Most important of these "best practices" is a strong, sustained commitment from the political leadership of the state. The governor and the state's economic development officials must have a desire to attract information technology manufacturing and a comprehensive plan to do so. The legislature must be part of the process and be willing not only to support financial commitments when decision times approach, but also to demonstrate a sustained commitment beyond a single governor's term. This commitment and focus from the top – meaning it must be a strong priority of the governor – appears vital to implementing and maintaining a successful state program. Based on PCAST's discussions with corporate decision-makers, it is worth noting that the tax and financial benefits of locating a plant in another country are often overwhelming.[46] Thus, decisions to locate domestically must effectively be determined by other considerations, in part financial incentives, but also by other factors such as the proximity of strong R&D capabilities and a pool of appropriately educated and skilled citizens.

It is also worth noting that, in applying these "best practices" to attract manufacturing companies, states do not appear to care whether the company being courted is domestic or foreign-owned. From the state economic development perspective, benefits accrue to the state via job creation, tax revenues, and workforce improvement, regardless of corporate ownership. PCAST believes that taking a more holistic view (*i.e.*, the R&D-manufacturing ecosystem), it is

[45] Statement of executive of leading IT manufacturer to PCAST panel.
[46] For example, one company told PCAST that the strict economic (tax) benefit for building a plant in China was $1.3 billion for a $3 billion plant. This differential was never fully closed in dollar terms, but the state agreed to perform and provide support in other areas that were important to the company, such as a commitment to co-located university R&D.

important for the Nation to attract and increase domestic high technology manufacturing capability, even if foreign-owned.

Particular "best practices" include the following:

1) **Strong Support for University R&D.** Successful states have had a commitment to funding related university R&D. This commitment has manifested itself both in terms of organizing and coordinating the existing university structure to be attractive to business development, and through stepping up to new commitments (*e.g.*, in one case committing to building a new engineering building) as business desires become evident.
2) **An Educated Workforce**. A key element in the plans of successful states has been the commitment to provide a skilled workforce through strong support for education programs. This has included K-12 programs, as well as community college and university programs.
3) **Pre-Approved Sites.** Businesses have also found very attractive states' offering construction sites that have virtually no regulatory red-tape attached. Having all permits and other regulatory requirements pre-approved has made a big difference to potential manufacturers, particularly in a field where technological advances occur so swiftly making speed to market especially vital.
4) **Friendly Tax Policies** – Different states take different approaches to the tax aspects of attracting manufacturing, but companies do look for these benefits. Because foreign governments often have tax policies that the U.S. federal and state governments have not matched, every small tax benefit makes a difference. Such policies have included income tax relief, property tax caps, depreciation benefits, and sales tax relief. Some states have packages effectively pre-approved by legislatures provided that the manufacturer agrees to satisfy certain conditions (such as a certain level of investment and employment).

In discussing these issues with state officials, complaints were voiced over the difficulty of coordinating with federal R&D programs, as they try to accomplish R&D goals through their university systems. In practice, few significant federal R&D programs appear geared to

consider, or to make an effort to synchronize with, the R&D components of state economic development programs. Even when federal agencies are establishing large R&D "centers" in particular states, the states do not perceive any interest in attempting to coordinate with state economic development efforts.

Finally, the PCAST review of state efforts quickly demonstrated that IT manufacturers making location decisions are weighing U.S. state programs against foreign national-level incentive programs. Our states are thus not competing solely against each other, but also against foreign nations. This makes federal-state coordination, wherever possible, even more important.

Recommendations

Overview

The United States wants all nations to prosper and succeed, but also wants our own citizens' standards of living to continue their historical upward progression. To accomplish these dual objectives, the United States must remain a global leader in innovation and technological development. The "Findings and Observations" presented above describe several trends or issues that should be addressed in order to help sustain the nation's innovation leadership. These trends have caused a deep sense of anxiety in the IT community that our nation is not just losing the manufacturing capacity of "commoditized" products, as has occurred in the past, but also the loss of high value-added manufacturing and services that the U.S. has long dominated.

Foreign nations are challenging U.S. high technology leadership on two basic fronts. First, they are directly aiding their domestic producers and subsidizing the location decisions of foreign companies. Second, they are striving to replicate our own highly successful innovation ecosystems. Moreover, the Internet and other technological achievements are overlaying these efforts, making the world smaller and dampening the costs of establishing and relying on foreign operations. The resultant trends include the following:

- **Strong foreign incentives, particularly tax, for manufacturing investment**
  - Corporate tax rates effectively set at zero (to attract companies and in particular high capital intensive firms such as semiconductor manufacturing).
  - Stock option tax rates effectively set at zero (to attract human talent).
  - Other plant location incentives (*e.g.*, outright grants, loans at attractive rates, utility and infrastructure build-out, etc.).
  - Value Added Tax rebates (to aid local producers at the expense of imports).

- **Increasing foreign effectiveness in replicating U.S. innovation successes**
  - Steadily improving foreign education and university systems producing talented STEM graduates who are available at lower labor rates.
  - The establishment of foreign R&D parks that couple manufacturing presence with university (and business) R&D.
  - Improving success in transferring technology from nationally-funded R&D to business and commercialized products.
    - ✓ PCAST's 2003 Report, *Technology Transfer of Federally-Funded R&D,* discussed the success of the Bayh-Dole Act and associated legislation, and noted foreign nations' attempts to replicate our model.

- **Increased confidence on the part of U.S. companies in taking advantage of foreign incentives and using their foreign workers for high value-added type work**
  - A growing percentage of foreign students obtaining science, technology, engineering and mathematics (STEM) degrees, and an increasing portion of that population obtaining them outside of the U.S.
  - The Internet's contribution to more effective global enterprise management
    - ✓ Increased faith in, and utilization of, foreign services including high tech R&D and design
    - ✓ The beginnings of a 24 hour design cycle for leading innovating firms
    - ✓ Increased faith in foreign universities as a source of STEM talent in foreign countries
    - ✓ Increased ability to compete in and manage global supply chains.

Importantly, the United States remains a leading attraction for innovating talent and entrepreneurial activity. We have the best R&D system in the world, comprise the largest market in the world, and have a strong and flexible entrepreneurial business climate. Also, several states are pursuing high tech manufacturing and "clusters of innovation" in a sustained, systematic fashion. Accordingly, PCAST does not see the Nation as in the midst of a "doomsday" S&T or economic scenario, but does strongly caution that our continued high tech leadership is not automatic. Given the above trends, the U.S. cannot expect to remain exclusively dominant in the innovation arena. It must look at its competitive standing.

For the U.S. to maintain its high standards of living through continued economic prosperity, over the long-term, the basic components of the Nation's innovation ecosystems must remain healthy. To do that, we need continually to support their health in a flexible manner. We must also assess what foreign countries are doing to compete with our leadership, identify where and how inroads are being achieved, and respond appropriately with policies for the future. PCAST not only believes that the continued loss of high tech manufacturing will damage other parts of our innovation ecosystems, but is also confident that strengthening our innovation ecosystems' components will help attract manufacturing to locate or remain in the U.S.

PCAST's Recommendations

PCAST's recommendations are grounded in the belief that the trends discussed above are both important and potentially serious. While the U.S. holds a leadership position and maintains some significant innovation advantages, over 750,000 high tech jobs have been lost over the past two years.[47] The innovation ecosystems that have played a key role in the Nation's economic prosperity and high standards of living can be degraded.

PCAST recommends that the U.S. not become complacent that its historical high tech dominance will continue, but take note of these developing trends and respond. Specifically, PCAST recommends two fundamental courses of action: First, the United States should buttress the basic components of its own innovation ecosystems; and, second, the Nation should assess

[47] American Electronics Association, *Cyberstates* Press Release (Nov. 19, 2003)

the nature and effectiveness of direct foreign subsidies and develop appropriate responses for the future.

Buttressing the Health of the U.S. Innovation Ecosystem

1. Strengthen the Nation's R&D Capacity

The United States' R&D system is the world's best, and perhaps our principal competitive advantage. The Nation cannot afford to lose this advantage, and should continue to strengthen it.

a. Increase Funding for Basic Research in Math, Science and Engineering in Our Universities

PCAST's 2002 Report, *Assessing the U.S. R&D Investment*, presented the case for increased funding for basic math, science and engineering R&D, in the wake of NIH's budget doubling. PCAST notes and appreciates the Administration's positive responses to our recommendations in this area. Through this Report, PCAST further reinforces the need for a rebalancing of the federal R&D portfolio toward the physical sciences. PCAST is mindful of the federal government's difficult budget realities. This particular investment area, however, constitutes a major contributing factor to our continued ability to generate leading edge technological developments, and our Nation's R&D base constitutes its premier global competitive advantage. These investments are not only essential to stimulating economic competitiveness, but also vital in providing the tools for the advances in other important fields such as medicine, healthcare, and agriculture. We also recommend even further prioritizing these funds toward potentially high-payoff areas in terms of continued innovation, such as nanotechnology, information technology, and manufacturing R&D.

PCAST also reiterates our prior recommendation to establish new scholarship and fellowship programs, and recommends a program be established to enable the Federal Government to provide matching funds for state-funded basic research in the health and physical sciences.

Finally, our research universities are the envy of the world, but often operate with poor or obsolete equipment. Modernization of facilities will help maintain our advantages. We endorse the National Science and Technology Council's efforts to explore this issue (as well as changing "business models") and urge the Administration to give it priority treatment.

b. Better Coordinate R&D Efforts with State Governments

As noted in the preceding Findings section, PCAST spoke with several state governments that are striving to match the foreign incentives that are critical to plant location decisions. These governments are providing a friendly and complementary R&D environment through their university systems, focusing on educating a technically proficient workforce, providing state tax holidays should employment commitments be met, and offering "permit ready" sites so regulatory red tape is minimized.

These states highlighted to PCAST that areas exist where the federal government could help in their efforts. These include better coordination with federal R&D agencies to help match federal programs, to the extent possible, with state economic development efforts. Tax coordination is non-existent and would be beneficial to state efforts to attract manufacturing enterprises.

PCAST recommends that the President task the National Science and Technology Council (NSTC) with forming an interagency working group (IWG) devoted to this topic. The IWG should meet with state governments to determine where states find coordination lacking, as well as to identify areas where improved coordination can occur, including recommendations for regulatory or statutory changes where needed. By placing this activity within the NSTC, PCAST intends to have it focus on R&D coordination issues and on other areas that help drive technological leadership through maintaining healthy innovation ecosystems. The new Assistant Secretary for Manufacturing and Services could chair this IWG, with the Secretary of Commerce reporting back to the President with recommendations by June 1, 2004.

c. Consider a Next Generation "Bell Labs" Model

Over the course of the last two decades, the United States lost a significant R&D asset when the major industrial R&D centers, epitomized by Bell Labs, were shuttered or significantly contracted. This loss resulted from the convergence of several factors, including a more bottom-line oriented business perspective and, in Bell Labs' case, the loss of a monopoly-based funding source. Nonetheless, a valuable category of R&D has been lost (*i.e.*, fundamental corporate R&D, and ready technology transfer through the movement of people through the labs). PCAST will further study with OSTP how to create the right environment for a modern analogue to these activities, consistent with market conditions. Certain nanotechnology programs (such as nanotechnology centers) may present appropriate opportunities.

2. Improve Workforce/Education

Two critical factors in maintaining continued technology leadership and healthy innovation are the availability of scientists and engineers and a ready pool of skilled employees. The President's No Child Left Behind program has laid an excellent foundation to address the needs of K-12 education, and university and graduate education programs can be improved, as well. Also, the United States must find a way to convince more U.S.-born citizens to pursue a technical career. Another PCAST Report is addressing these Workforce/Education issues. This Report fully supports those efforts and concurs that the Workforce/Education issues are critical to our Nation's long-term economic security and innovation leadership.

3. Enhance the U.S. Entrepreneurial Climate

As noted in Section 3(A) above, one of the United State's primary competitive advantages is its ability to adapt swiftly to changing economic circumstances -- to take advantage of new technological developments to form new industries, and to integrate new technology so as to enhance the productivity of existing firms. The pace of technological change will only quicken in the future globalized environment, making economic flexibility all the more important to our Nation's continued innovative success and economic prosperity.

Our entrepreneurial climate has been very important in maintaining U.S. economic leadership, as startup companies are very efficient in exploiting new technologies. The rise of China presents a high tech competitor with an entrepreneurial culture. Accordingly, the United States needs to adopt policies that strengthen our entrepreneurial climate and economic flexibility.

The President's tax policies that lowered marginal rates, and reduced capital gains and dividends taxation, have had an important impact in this regard. Moreover, the President's Six Point Plan to Promote Economic Growth and Job Creation contains some important additional features. Specifically, making health care costs more affordable and predictable, reducing the burden of lawsuits on our economy, and streamlining regulations and reporting requirements would greatly enhance economic flexibility. PCAST fully endorses the President's efforts in these areas. In particular, we emphasize that enacting tort reform that would reduce the pursuit of frivolous claims, while allowing legitimate claims and compensation to move forward, would significantly enhance the entrepreneurial climate of the United States today.

4. Maintain an Aggressive Schedule of Infrastructure Improvements

The United States' infrastructure constitutes one of the Nation's primary competitive assets, and it should be continually improved and updated. The President's Energy Plan and the Administration's efforts to promote broadband deployment (including supporting permanent extension of the Internet Tax Freedom Act), as well as its plan to reauthorize the highway programs, are very important pieces of a continual plan to reinvigorate the nation's basic infrastructure.

Assessing Foreign Programs and Establishing Policies for the Future

In addition to adopting policies to enhance our national competitive assets, the United States should also identify those foreign programs that are specifically targeting our economic leadership (often unfairly) and adopt appropriate responsive polices for the future.

1. Optimize our Federal Tax System in Light of Foreign Tax Competition

a. Make Permanent an Expanded R&D Tax Credit

Given our present federal corporate tax system, having a stable R&D tax credit is vital. We appreciate that R&D credit permanence has been the President's long-standing policy, and recommend the President continue to urge Congress to adopt it. In doing so, Congress should address some of the issues that inappropriately limit the credit's applicability or cause unwarranted confusion. The R&D tax credit is a vital component of our national R&D program, but it can operate unevenly and unfairly.

b. Appoint Task Force to Assess Other Tax Issues

Given the steadily improving ability of businesses to manage a global enterprise, and the improving educational (and infrastructure) capacities of foreign countries, competing tax policies are rising to higher prominence in location decisions – both corporate[48] and individual. In this regard, companies making location decisions not only for manufacturing plants, but also for R&D and design (and service) work, are weighing locations in nations that offer incentives that amount to the payment of zero corporate taxes. These incentives offer a large tax advantage for foreign sourcing or, put another way, a large tax disadvantages for remaining in the U.S. Similarly, on an individual basis, other countries offer ownership rewards principally through stock options that effectively confront zero taxation. For entrepreneurial talent, this can be a very important factor and tipping point in where individuals choose to work.

Another tax matter raised by many in the PCAST panel discussions is the effects of the Chinese Government's Value Added Tax (VAT) policies. China presently imposes a 17 percent VAT on semiconductors but operates a program intended to rebate up to 14 percent of this VAT to domestic producers.

[48] During the December 2, 2003, PCAST meeting, several members made comments in this regard. It was noted: (1) that capital costs now dominate high-end semiconductor manufacturing with labor constituting only 10-15 percent of costs, meaning tax considerations are now even more important than lower-cost labor; (2) that the high expense of such plants' equipment is causing companies to co-locate manufacturing and R&D directly, so the same equipment can be used for both activities; and (3) that once a plant is built offshore the tax consequences of returning dollars back to the U.S. contribute to foreign, rather than domestic, expansion.

In light of these issues, PCAST recommends that the President form a Task Force among the Departments of Treasury, Commerce and others, as appropriate, to identify the tax competition we are confronting, and to explore ways to optimize our own federal tax policies to respond appropriately for the future. The mandate of this Task Force should be to return to the President with a report that identifies foreign tax programs of major competitors, and provides bold options for responding. The Task Force should report back within a defined, and relatively swift, time-frame (*e.g.*, six to eight months).

2. Aggressively Pursue Free Trade

The President has been pursuing fair trade policies in an aggressive fashion, and PCAST supports his efforts in this regard. The Secretaries of Treasury and Commerce recently traveled to China to deliver personal messages, and the Administration's efforts to obtain fair treatment for U.S. firms have been commendable. PCAST would like to highlight one particular suggestion as the Administration's activities continue in this area.

An Expedited WTO Process. PCAST recommends that the Administration and USTR work with WTO to implement an expedited dispute resolution procedure to deal with Intellectual Property (IP) violations and denial of market access. Technology products experience rapid obsolescence in the normal course of business. Thus, rapid resolution is becoming a mandatory requirement for effective relief.

3. Better Coordinate with State Governments on Plant Location Incentives

PCAST recommends that the President also establish a review of foreign plant location incentive programs, including recommendations on how the federal and state governments can improve their coordination in these arenas, where appropriate. This review can occur as part of the NSTC Review of Federal-State R&D coordination issues, or among a different set of officials if more suitable. If a separate task force is established, it should report back within the same time frame, however.

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Martha Gilliland
Chancellor
University of Missouri-Kansas City

Ralph Gomory
President
Alfred P. Sloan Foundation

Bernadine Healy
Medical Senior Writer & Columnist
US News and World Report
Retired President and CEO, American Red Cross

Robert J. Herbold
Retired Chief Operating Officer
Microsoft Corporation

Bobbie Kilberg
President
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Walter E. Massey
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Gordon E. Moore
Chairman Emeritus
Intel Corporation

E. Kenneth Nwabueze
CEO
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Steven G. Papermaster
Chairman
Powershift Ventures

Luis M. Proenza
President
University of Akron

George Scalise
President
Semiconductor Industry Association

Charles M. Vest
President
Massachusetts Institute of Technology

About the President's Council of Advisors on Science and Technology

President Bush established the President's Council of Advisors on Science and Technology (PCAST) by Executive Order 13226 in September 2001. Under this Executive Order, PCAST "shall advise the President … on matters involving science and technology policy," and "shall assist the National Science and Technology Council (NSTC) in securing private sector involvement in its activities." The NSTC is a cabinet-level council that coordinates interagency research and development activities and science and technology policy making processes across federal departments and agencies.

PCAST enables the President to receive advice from the private sector, including the academic community, on important issues relative to technology, scientific research, math and science education, and other topics of national concern. The PCAST-NSTC link provides a mechanism to enable the public-private exchange of ideas that inform the federal science and technology policy making processes.

PCAST follows a tradition of Presidential advisory panels on science and technology dating back to Presidents Eisenhower and Truman. The Council's 23 members, appointed by the President, are drawn from industry, education, and research institutions, and other nongovernmental organizations. In addition, the Director of the Office of Science and Technology Policy serves as PCAST's Co-Chair.

Members of the PCAST Subcommittee on Information Technology Manufacturing and Competitiveness

George Scalise – Chair
Michael Dell
Bobbie Kilberg
Gordon Moore
Steve Papermaster
Luis Proenza