EXECUTIVE SUMMARY

MANUFACTURING INSECURITY

AMERICA'S MANUFACTURING CRISIS
AND THE
EROSION OF THE U.S. DEFENSE INDUSTRIAL BASE

Report Prepared

for

Industrial Union Council, AFL-CIO

by

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I. Introduction

Even as America's armed forces were fighting wars in Afghanistan and Iraq during the Bush Administration's first term, the Pentagon embraced policies to globalize the American defense industrial base. Rather than relying on traditional U.S. defense suppliers, it looked overseas for sources of products, components, and materials for all but the most defense-critical technologies, claiming that this would lead to faster innovation while cutting costs. Defense industry executives echoed this position, arguing that the Department of Defense (DOD)—and its prime contractors—should not be restricted to domestic suppliers for its products.

Ironically, the Pentagon and industry calls for greater reliance on foreign sourcing—often argued in efforts to weaken Buy America requirements in defense procurement—are a tacit recognition that the United States lacks the commercial manufacturing capacity to supply vital products needed by America's defense industrial base. The DOD has conceded that there are advanced technologies critical to military systems—armor plate steel, defense-specific integrated circuits, night vision goggles—for which domestic sources are inadequate.[1]

However, a much greater number of items once supplied by U.S. manufacturers are now obtained from foreign suppliers—flat panel displays, machine tools, advanced electronics and information technologies—because they are not readily available from U.S. producers. According to Col. Michael Cole, of the U.S. Joint Forces Command, the problem is not just a matter of a handful of highly specialized items designed to meet narrow defense requirements, but the "eradication of U.S. industry capability." He also warns that current strategies to deal with an industrial base that increasingly is unable to supply the military with manufactured parts and electronic components are not working.[2]

The purpose of the study presented in this report, is to examine the extent this capability has been eroded, and the potential weakening of America's defense industrial base in the coming decades. In contrast to other assessments of the military's reliance on foreign sources that only focus on a small number of critical technologies or industries, this study seeks to evaluate the health and competitiveness of the nation's overall *civilian industrial base* upon which a strong defense industrial base—including the ability to produce specialized defense-critical products—ultimately rests. Specifically, drawing upon a large body of evidence from government and industry, the professional literature, and other sources, the study:

- Analyzes key domestic and international economic trends—which taken together show that the foundations of U.S. manufacturing have been deteriorating across the board, especially over the past decade.
- Describes the linkages between manufacturing and the defense industrial base, and how erosion in a wide range of American manufacturing industries is hurting the domestic capacity to supply critical products for national security, forcing the Pentagon to depend on less secure foreign sources.
- Explores how a diminishing domestic manufacturing base contributes to a decline in American technological leadership and innovation capacity, widely recognized to be vital for maintaining U.S. defense capabilities.

These findings are troubling enough for America's economic future, especially for working families and communities. The danger to our national security that these trends also signify, should elevate revitalizing American manufacturing to a very high priority among policy makers.

II. Indicators of Industrial Decline

No single indicator by itself can represent economy-wide manufacturing capabilities or trends. But several key indicators of domestic economic performance—value-added output, industrial capacity and capacity utilization, employment, and number of establishments—and global competitiveness—balance of trade in goods and import penetration rate—when taken together, provide strong evidence that America's manufacturing base has greatly weakened over the last decade. The former indicators reflect the economy's ability to maintain and increase output growth over the long run. The latter reflect the American manufacturers' ability to compete with foreign producers in domestic and global markets.

Indicators of Domestic Economic Performance

Although signs of America's industrial competitiveness problems first appeared in the 1970s and 1980s, the erosion of America's manufacturing capabilities began to deepen in the first half of the 2000s decade.

- *While manufacturing's share of U.S. Gross Domestic Product (GDP) has fallen steadily since the late-1960s, it dropped at nearly twice the rate between 2000-2008 compared to the previous fifteen years.*[3]
- *Although U.S. manufacturing's real value-added growth has generally been positive, its annual rate of growth since 2000 has been substantially lower than its growth rates in prior decades* (see figure ES-1). Its 1.3 percent real annual rate of growth between 2000-2008, was less than a third that of the previous decade. Many industries with weak or negative rates of real value-added growth after 2000 include are important to national defense.[4]
- *Both manufacturing industrial capacity growth and capacity utilization have been much lower since 2000 compared to previous periods.* The industrial capacity index for manufacturing accelerated to 6.8 per year in the 1990s, but slowed to 1.3 per year from 2000 on. Not including hi-tech industries, the index was 0.3 per year for the 2000 decade. Capacity utilization reached its lowest peak (79.2 percent) in 2006, slightly lower than the average utilization rate throughout the 1972-2008 period. It dropped precipitously to 67.0 percent in 2009, its lowest level for at least the last four decades.[5]
- *After steadily growing between 1990 and 1998—by over 25,000 or nearly 6.6 percent—the number of manufacturing establishments of all sizes in the United States has declined sharply—by over 51,000, or 12.5 percent—since 1999*. An additional 5,730 establishments disappeared in 2009, bringing the total losses to over 57,000.[6]
- *American manufacturing employment has declined since its peak in 1979, but it's fall from a relative peak in 1998 has been the most precipitous since the great depression—over 6 million jobs or one-third the U.S. manufacturing workforce have disappeared.* The aggregate trends in manufacturing establishment and employment are replicated in most manufacturing sectors and subsectors.[7]

Figure ES-1: Manufacturing Value Added, Real Average Annual Growth Rate

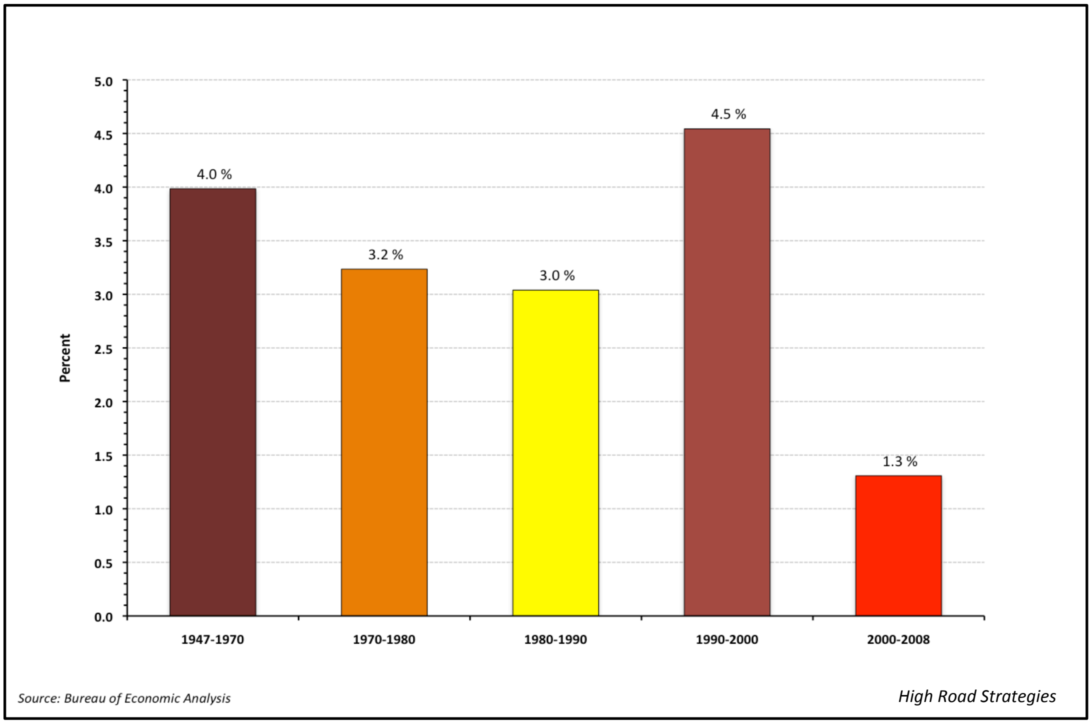
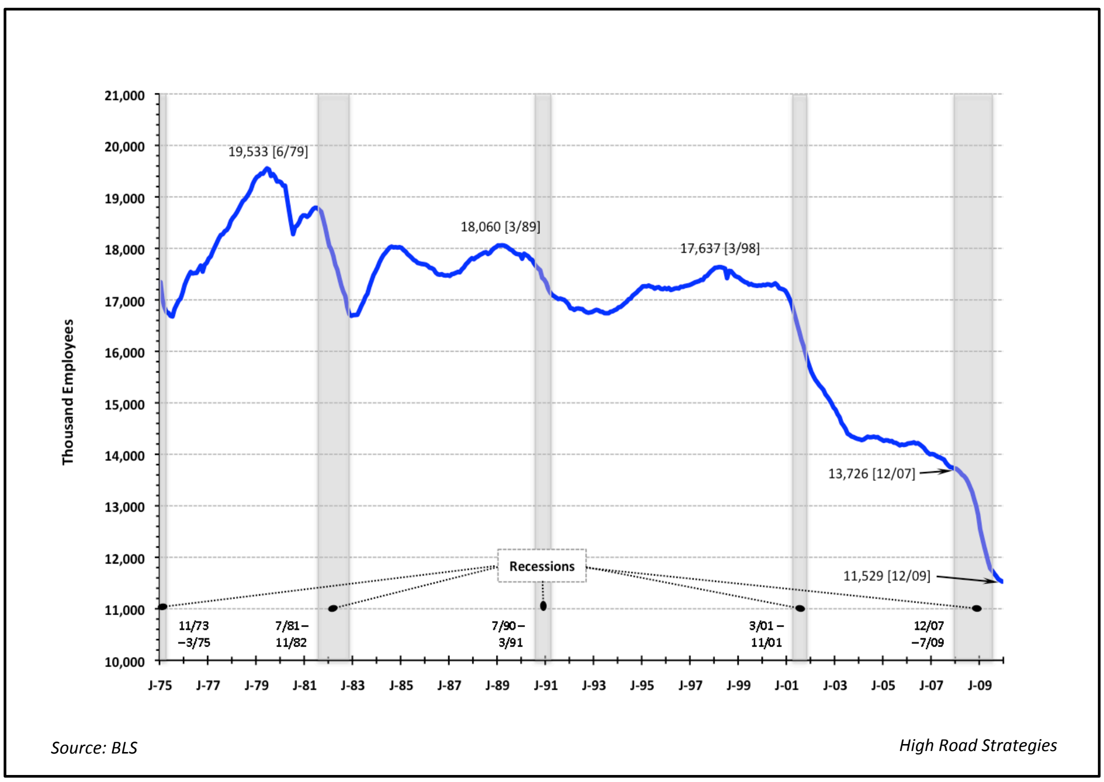


Figure ES-2: Manufacturing Employment, 1977-2009

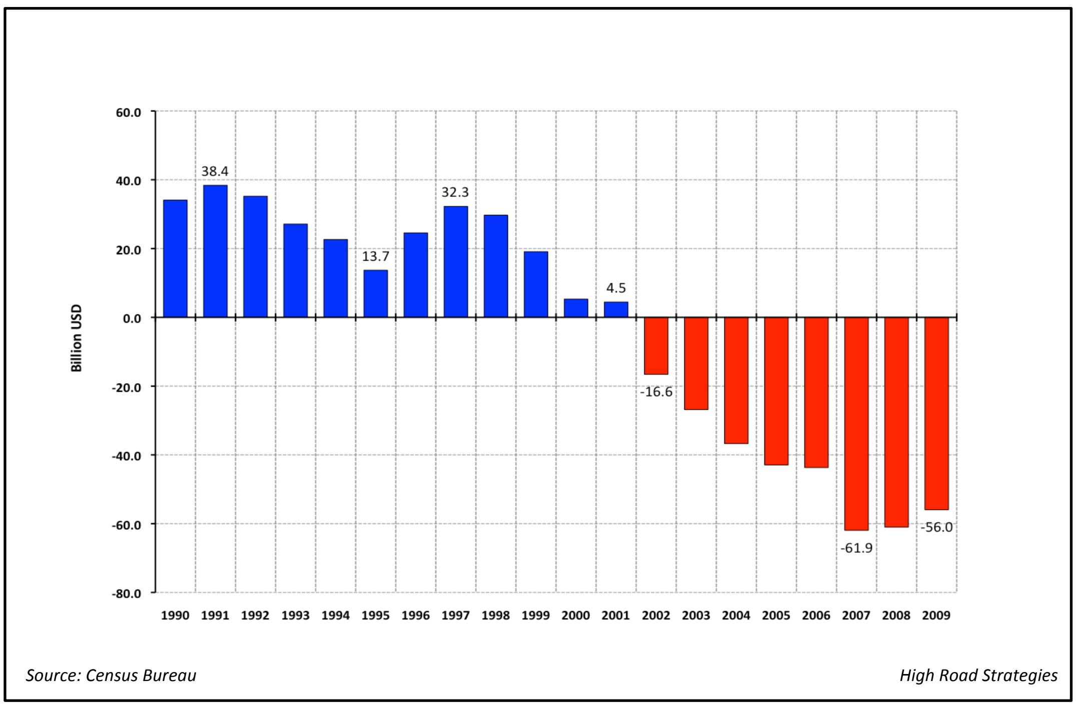


b. Indicators of Global Competitiveness

U.S. manufacturing competitiveness has been declining in global markets, as indicated by America's growing trade deficits in goods, including advanced technology products (see figure ES-3), and foreign import penetration into U.S. markets.

- *The annual U.S. trade deficit in goods has grown steadily since 1979, and at an especially rapid rate since 1998, rising to record levels of over $800 billion each year between 2006-2008—it was $816 billion in 2008, nearly 6 percent of U.S. GDP.* The United States imported more goods than it exported at a rate of $2.2 billion a day. In real terms, the deficit in goods in 2008 was 18 times larger than it was in 1980. This includes chronic goods trade deficits with every major trading country and region in the world.
- *Import penetration rate (IPR)—the share of the U.S. market held by imports—has been increasing for most manufacturing products and sectors.* There has been an across-the-board, aggregate increase in IPRs for 114 high-tech and capital-intensive sectors evaluate of 61 percent—from 21.4 percent of domestic consumption to 34.3 percent—between 1997 and 2007. That is, imports grew from one-fifth to over one-third of the value of this diverse group of items consumed domestically in one decade.[8]

Figure ES-3: U.S. Trade Balance in Advanced Technology Products, 1990-2005



c. The Eroding Base

The secular downward trends for almost all the indicators, especially when the linkages between them are considered, show that U.S. manufacturing has been losing capacity for well over a decade.

- The erosion is apparent in the concurrent trends of weakening manufacturing value-added output, acceleration in manufacturing's steady decline as a share of U.S. GDP, stagnant and even negative growth—the first time in seven decades—in industrial capacity, and the substantial drop in capacity utilization since 2000—not to mention the long-term average yearly decline in utilization.
- The peak levels in both manufacturing capacity utilization and manufacturing employment during business cycle expansions have been in secular decline from the 1970s on.
- As industrial capacity stagnated and fell, manufacturing employment and establishment numbers declined sharply from a little before 2000 to the present.

Manufacturing's erosion is even more evident when the domestic economic trends are viewed in light of growing trade deficits and import penetration. Demand factors and productivity alone cannot explain the large losses in manufacturing jobs and establishments, over the past decade in particular. Empirical studies show that millions of U.S. jobs have been displaced or job gains foregone as a result of international trade, including losses associated with specific trade agreements (e.g., the North American Free Trade Act). Some studies tie the growing U.S. trade deficit with China, to the hug loss of U.S. jobs. A large share of these losses, are linked to consolidations and plant closures arising from foreign competition for domestic and global markets, and the offshoring of operations by large OEMs and their suppliers in almost every major manufacturing sector.[9]

III. Eroding Industrial Sectors

America's manufacturing sector continues be the largest, most productive and technologically advanced in the world. But its lead in a number of industries vanished years ago, and many of its remaining areas of strength are facing powerful challenges. The broad domestic and global economic trends examined above reflect a sustained and potentially dangerous erosion across nearly all manufacturing industries, including many that supply products, components, and technologies that the Pentagon considers important to defense. The significant losses in plant capacity and jobs in these industries raise serious concerns about their ability to remain sufficiently innovative and robust to meet the Pentagon's supply needs, especially in times of political and military crisis.

The industrial capabilities required to serve national security needs, which constitute the defense industrial base, not only rest upon, but are embedded in, the nation's domestic manufacturing base. The Defense Production Act of 1950 (DPA), as amended, defines the "domestic defense industrial base" as those "domestic sources which are providing, or which would be reasonably expected to provide, materials or services to meet national defense requirements during peacetime, graduated mobilization, national emergency, or war.[10] A central question is, does the domestic manufacturing base have the capability to supply the huge array of items—technologies, materials, components, parts, subsystems—needed to meet these requirements, or will the U.S. national security system become increasingly reliant on foreign sources for critical products and service?

There is no bright line between the production systems that design, develop and manufacture defense-unique items with those the produce defense-critical products and processes. As a National Research Council study has noted, the boundaries between the defense industrial base—the set of industrial and military facilities devoted to the production of defense-related products—and commercial industry have become blurred.[11] Many of the most militarily valuable products are versions of commercially produced commodities modified for unique military functions.

However, several factors have contributed to a weakening ability of domestic suppliers to provide critical items needed in defense products:

- For a large number of defense-unique items, there often are only a single or small handful of domestic sources, which may in turn depend solely on their military customers to remain financially solvent.
- Many suppliers, which tend to be small and medium-sized, mainly serve commercial domestic and global markets, while tailoring a small part of their business to provide specialized products to military industrial customers. Many of these, as well as suppliers of commercial-off-the-shelf (COTS) items, face increasing foreign competition and are under pressure to relocate or outsource some or all of their operations overseas, to stay in business.
- Consolidations by suppliers in the face of stiff foreign competition also have contributed to shrinking the available number of qualified domestic sources for many defense critical items. Small, lower-tier manufacturers tend to be at far greater risk in these situations.

Critical Industries

Well-known examples of defense critical technologies where domestic sourcing is endangered include propellant chemicals, space qualified electronics, power sources for space and military applications (batteries and photovoltaics), specialty metals, hard disk drives, and flat panel displays (LCDs). University of Texas at Austin engineering professor Michael Webber evaluated the economic health of sixteen industrial sectors "within the manufacturing support base" of the U.S. defense industrial system, "that have a direct bearing on innovation and production of novel mechanical products and systems," and whose output "is used directly in the design process of other industries." Of the sixteen industries he examined, thirteen showed significant signs of erosion, especially since 2001.[12]

The HRS study examined a broader cross-section of the defense industrial base, to illustrate the full scope of the impacts of declining manufacturing capacity on the defense industrial base. They include several of Webber's industries (semiconductors, printed circuit boards, machine tools), and one not in his group, which nevertheless is important to the nation's innovation system (advanced materials). In addition, the study profiled the aerospace industry, the largest downstream systems integrator industry comprised of the large system-integrator firms that oversee the design, construction and assembly of major systems and weapons platforms used for the nation's defense. While some segments appear relatively healthy and globally competitive, the overall prognosis is one of a serious weakening of a wide-range of key domestic manufacturing industries, which could seriously undermine their ability to support critical defense requirements, resulting in an ever-growing dependency on foreign sources of vital defense products.

These industries supply critical materials, components and parts used in defense systems or they are enablers and enhancers of innovation within industries important to national security, including aerospace. The movement of these industries oversea, which increases the dependence of the defense industrial base on offshore or foreign-owned components and equipment (e.g., semiconductors, PCBs, machine tools), can adversely impact national security in several ways:

- Companies that serve U.S. military requirements need a direct connection to technology advancements in their industry. This linkage is weakened if not severed if production and R&D for critical technology products are moved offshore, hurting the ability of remaining companies to supply future military needs.[13]
- The U.S. may lack the manufacturing capacity to build weapon systems if access to state-of-the-art products produced offshore are limited if not cut off in times of emergency (including natural disasters) or war, when quick response and surge capacity are needed.[14] As, Dr. Paul Freedenberg, Vice President of the Association for Manufacturing Technology, observed, DOD's warfighting plan "does not seem to anticipate the threat of disrupted supply lines, a concern that existed during the Reagan Administration and was an integral part of all previous administrations' war planning."[15]
- Dependency on foreign sources of some products, such as microelectronics and PCBs, increases the possibility that "Trojan horses" and other unauthorized design inclusions, such as viruses and worms, or hard-to-defect defects placed by overseas companies seeking to sabotage U.S. defense systems.[16]
- Continued migration of manufacturing offshore is both undercutting U.S. technology leadership while enabling foreign countries to catch-up, if not leap-frog U.S. capabilities in critical technologies, important to national security.
- Once lost from U.S. shores, vital industrial capacity would be very hard to rebuild. For example, the Aerospace Industries Association (AIA) estimates that it would take at least ten years to make the American machine tool industry viable again, especially in the ultra-precision market in which the United States does not participate.[17]

Semiconductors

The importance of semiconductors to today's information-based "network-centric" military[18] is well understood. Preserving a world-class domestic semiconductor industry is vital to national security. Earlier in the decade, many high-level government and industry groups, prestigious independent bodies, and Congressional leaders,[19] began warning that the United States semiconductor industry was losing its capacity and leadership. As a result, the ability of U.S. semiconductor fabrication plants (fabs) to meet the Pentagon's integrated circuit needs is limited and diminishing. This erosion is increasingly apparent:

- The industry lost nearly 1,200 plants of all sizes between 1998-2008, a 17 percent drop, including a 37 percent loss in large establishments (over 500 employees) and a 41 percent loss of mid-sized plants (100-500 employees).
- By 2008, employment levels, number of establishments, and GDP for the industry had fallen below its 2001 levels.[20] In 2007, imports accounted for nearly one-half the U.S. market for

semiconductor and related devices.[21]

- The U.S. share of global semiconductor capacity has been in descent, falling to 17 percent in 2007, and 14 percent in 2009. Once the world leader in semiconductor manufacturing, the United States fell to fourth place in 2009.
- In 2009, of 16 semiconductor fabs under construction around the world, only one was being built in the United States. Meanwhile, the United States leads in fab closures: 15 out of 27 fabs closed worldwide in 2009, and 4 out of 15, in 2008.

These losses have been driven by the migration of critical microelectronic manufacturing capabilities to low-cost foreign locations, which could lead to a loss of "trusted" and "assured" supplies of high-performance microchips used in critical military applications. Although U.S. semiconductor firms typically have maintained control over their design work when contracting overseas for wafer fabrication, some U.S. firms—in order to maintain close contact with their Asian customers—have also been offshoring complex semiconductor fabrication and design services.

The primary beneficiaries have been Taiwan, Singapore, China, Korea, and Japan, which increasingly have been challenging U.S. leadership in semiconductor technology. Industry and defense officials have especially been concerned about China's rapid development in this area because of its military-industrial potential.[22] In 2006, China reportedly accounted for 70 percent of the semiconductor designing market in the Asia-Pacific region.[23] In 2009, China led the world in new semiconductor factory construction.

Printed Circuit Boards

As the underpinning of nearly all electronics systems, printed circuit boards (PCBs) are critical technologies for numerous military applications. The PCB industry, including its two main divisions, *printed circuit assembly* (NAICS 334412) and *bare printed circuit board manufacturing* (NAICS 334418), have experienced significant losses in its domestic production capacity and position in global PCB markets over the last decade.

- The U.S. PCB industry has shrunk an estimated 74 percent since 2000.[24] The number of U.S. PCB manufacturers fell from 400 in 2004, only 20 of which made military boards, to 300 by 2009. The industry's revenues fell dramatically, from $11 billion to $4 billion between 2000-2008.[25]
- The U.S. PCB industry once dominated global PCB production, with 42 percent of global revenues in 1984, falling to 30 percent in 1998 and to less than 8 percent in 2008.
- By 2005, between forty and fifty percent of North America's PCB orders had migrated offshore.[26] Between 1997- 2007, the PCB industry's import penetration rate increased from 24 percent to 35 percent, and the PCB assembly import rate rose from 37 percent to 47 percent.[27]
- Parts and materials suppliers to the PCB industry—including suppliers of laminates, drill bits, imaging materials, specialty chemicals, film and capital equipment—have also largely disappeared from the United States.[28]

While the U.S. PCB industry eroded, the PCB industries in America's major trade competitors grew, with China the chief beneficiary. By 2003, while Japan's top ten PCB producers dominated with 29 percent of the global market share, the United States had fallen behind China. By 2007, China/Hong Kong had moved to the top position, accounting for 28 percent of worldwide PCB production.

Today, high-volume, low-cost, PCB suppliers of components used in commercial durable goods (automobiles, appliances, heavy equipment) can provide few defense-specific components that meet sophisticated DOD requirements.[29] Analysts in the defense electronics community are even skeptical that the DOD's "trusted" approach to preserve U.S. PCB supplies will be sufficient. They view it as a stop-gap—like "putting a Band-Aid on a bullet hole."[30]

Machine Tools

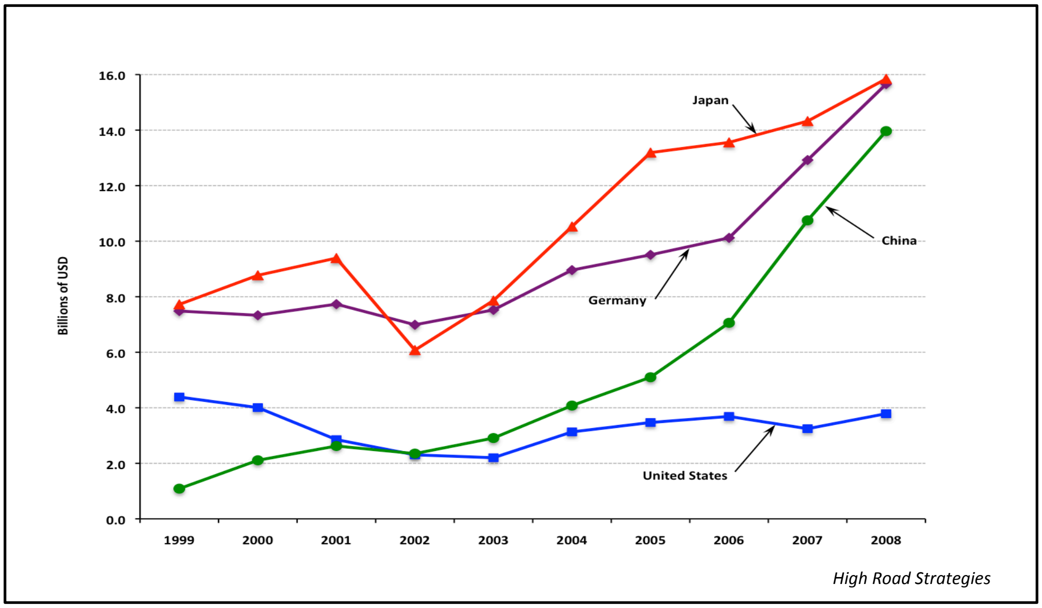
Machine tools are the principal devices used to cut and form metal, employed in nearly all manufacturing involving metals, from autos to airplanes to ball bearings. They are among the most critical industries in the defense industrial support base, because of their importance in producing weapons systems and other products the military relies on. By most measures, the U.S. machine tool industry—including its two main divisions, metal-cutting machine tool (NAICS 333512) and metal-forming machine tools (333514) manufacturing—has been in a steep decline for over a decade.

- Between 2001-2008, the metal cutting machine tool industry shed 16 percent of its establishments and 22.4 percent of its workforce (over 8 thousand jobs), and the metal forming machine tool industry lost 17 percent of its establishments and 14 percent of its workforce (2,200 jobs); another 5,000 jobs, and 2,700 jobs, respectively, were lost in the first 6 months of 2009 alone.[31]
- U.S. machine tool shipments fell to $2.2 billion in 2003, the lowest level, in constant dollars, since industry data began to be tracked in the 1920s.[32] Although both U.S. machine tool consumption and production grew again over the decade, by 2008 they reached only a fraction of their peak a decade ago.
- Foreign penetration of the U.S. machine tool market rose steadily from about 30 percent in 1983 to 72 percent in 2008. From 1997-2007, the import penetration rate for metal-forming machine tools rose from 63 to 91 percent; for metal-cutting machine tools it grew from 59 to 65 percent.[33]
- United States was surpassed by China in 2003 as the world's top consumer of machine tools,[34] and fell to fourth place by 2008. U.S. consumption was a little under 20 percent smaller than that of Japan and one-third that of China in 2008.
- The United States fell from the world's third largest machine tool producer in 2000 to seventh (behind Japan, Germany, China, Italy, Taiwan, and Korea) in 2008; In 2008, both Japan and Germany each produced four times, and China 3½ times the worth of machine tools produced in the United States (see figure ES-4).[35]

The U.S. loss of competitiveness in the five-axis machine tool market exemplifies the serious erosion in this sector. Five-axis machine tools are among the most technologically advanced machine tools, used in the production of precision components in the aerospace, gas and diesel engines, and automobile parts, and throughout the medical, textile, oil, glass, heavy industrial equipment and tool, industries. Between 2005-2008, U.S. producers' sales of five-axis machine tools fell 11 percent, and another 60.4 percent in 2009.[36] Only six U.S. firms dedicated to five axis machines reportedly remain, compared to least 20 in China and 22 in Taiwan.[37]

Dr. Paul Freedenberg, Vice President of the Association for Manufacturing Technology, observed that the decline of the domestic machine tool industry directly reflects decline in the broader U.S. manufacturing sector. The machine tool companies' industrial customers are disappearing, either closing down or moving to another country—often China.[38]

Figure ES-4: Machine Tool Production—U.S., Japan, Germany and China



Advanced Materials

Advanced materials encompass recent advances in the development of materials that enable further development and applications in other advanced technologies.[39] A 2005 National Research Council (NRC) study identified a range of materials science and engineering subfields as the most important to advanced production, for which there are important and often critical national security applications and products. These include biomaterials; ceramics; composites; magnetic materials; metals; electronic and optical-photonic materials; superconducting materials; polymers; catalysts; and nanomaterials.[40] Because materials are so technology intensive, keeping at the cutting-edge in materials R&D is critical for remaining globally competitive in manufacturing, as well as for national security.[41]

United States has long been—and remains—the world leader in most materials-related technologies, but during the first half of the 2000s decade, the NRC warned that this leadership was eroding. This is reflected in the doubling of the U.S. advanced materials industry's global trade deficits between 2002-2006, according to the U.S. Census Bureau's Advanced Technology Products (ATP) trade data, as foreign competitors make inroads into U.S. markets. The NRC found that:

- *Domestic materials production is disappearing and moving offshore.* Materials subsectors have consolidated since 2000, driven by financial difficulties and foreign competition. Plant capacity and employment both have declined, and production of critical materials, such as specialty steels, advanced ceramics, and magnesium, has been moving offshore.

- *Materials R&D and innovation is following production offshore*. The migration of materials producers and users has harmed domestic advanced materials R&D by inducing many U.S. companies to shift materials R&D overseas. The offshore movement of manufacturing is weakening U.S. R&D capabilities in several materials technologies vital to national security, including night vision systems, lanthanides (rare earth elements), and specialty metals.
- *The margin of U.S. leadership in advanced materials R&D is eroding and increasingly challenged by other nations*. The largest U.S. advanced materials trade deficit is with Japan, whose imports into the United States grew steadily over the decade, more than doubling between 2002-2008 ($417 million to $948 million). Until 2008, China's exports outpaced imports, reflecting its increasing appetite for advanced materials products that it currently lacks sufficient internal capacity to meet. However, China is aggressively seeking to develop its own technological and production capabilities in this area.[42]

Aerospace

Aerospace (NAICS 33641) is a core industrial sector fundamental to America's economic and national security. It is a major source of high-skilled, high-wage jobs in the U.S. economy, employing around 500,000 workers, or about 4 percent of the manufacturing workforce. Its primary divisions include aircraft, engines and parts, guided missiles, and space vehicles. The largest segment, the aircraft, engines and parts industries (NAICS 336411-13), depends on both commercial sales (commercial jets, regional jets, general aviation), largely tied to the health of the airline industry and the demand for air travel, and sales (military aircraft) to U.S. and foreign governments.

The end of the Cold War led to a massive downsizing, consolidation, and restructuring of the aerospace and defense industries. The number of primary aerospace firms fell from 75 over twenty years ago to only a handful of remaining prime contractors, today—Lockheed Martin, Boeing, Raytheon, Northrop Grumman, and General Dynamics—serving the federal national security and space agencies. These are major multinational corporations with interests transcending the domestic industrial base, and increasingly reliant on foreign sales. Their drive to lower costs in the face of fierce foreign competition, including offsets and other foreign trade practices, has led them to offshore large portions of their own production operations, and to rely on an expanding global supplier base.

Since the early 1990s restructuring, aerospace sales to both commercial and military customers fluctuated widely, sometimes counter-cyclically, which has kept the industry relatively strong. After another dip in the early 2000s, due partly to both the 9-11 attack and the recession, the industry saw a market upturn in the latter half of the decade; though its sales—$204.2 billion in 2008—as a share of GDP were down from 2000 and the 1990s. Aerospace has also been one of the sole bright spots in the otherwise dismal U.S. trade picture. It long has enjoyed a positive trade balance, led by commercial aircraft and military sales to foreign governments (often U.S. government subsidized).

There nevertheless are some troubling indicators in the industry:

- Employment levels fell dramatically after 1990, recovered later in the 1990s decade, and declined again in the 2000s decade. Total aerospace employment dropped 41 percent between 1990-2008, and 15 percent from 1998-2008. Aircraft manufacturing and aircraft engine and parts manufacturing each lost about 18 percent of their workforces between 1998-2008.
- Most losses were associated with a net loss in mid-to-large scale establishments. The aircraft engines sector, in particular, lost 9 percent of its mid-sized plants (100-499 employees) and 28 percent of its large plants (500-999 employees).[43]
- Import penetration in the aircraft, aircraft engine and engine parts, and other aircraft part and auxiliary equipment manufacturing industries rose 117 percent, 34 percent and 45 percent, respectively between 1997 and 2007.

The large second and third-tier supplier chains that provide subsystems, parts, components, and materials to the prime contractors also have been weakening.

In addition, the positive trade surpluses enjoyed by the aerospace sector also reflect the heavy dependence of U.S. aerospace manufacturers on international markets for sales, which increasingly is driven by the aerospace companies strategy to secure new foreign sales using offset agreements. These arrangements have been weakening American aerospace competitiveness not only by undermining domestic capabilities, but by transferring technological and production capabilities to foreign governments and companies, helping to enhance or create current and future foreign competitors.[44]

Offsets agreements require a U.S. exporter of articles and services to foreign customers (government or commercial enterprises) to produce parts of the exported items in the foreign location or agree to the purchase of goods and services unrelated to the exported goods. Most offsets involve the export of defense items, though major commercial deals, such as Boeing's foreign sales of its aircraft involve offsets as well. Offsets as a share of total contracts between U.S. firms and foreign customers was 50 percent in 2008. Offset arrangements totaled $68.9 billion or 71 percent of the total value of defense contracts over the 1993-2008 period.[45]

Other Sectors

Many other sectors provide critical materials, technologies, products and systems to the defense industrial base, ranging from the relatively "low-tech" bearings industry to cutting edge technology products such as optoelectronics. Erosion of U.S. capacity in these industries at opposite ends of the technological spectrum follows similar patterns as the sectors profiled in this report. It also illustrates the breadth of the endemic erosion in the U.S. manufacturing base that has been contributing to a weakening of U.S. defense industrial capabilities.

IV. Eroding Technology Leadership

The erosion and migration of domestic manufacturing is also weakening the America's R&D and innovation capacity and undermining its global technological leadership. The design, development and production of both commercial and defense-specific technologies and products are tightly linked. As Michael Webber warned, if the U.S. manufacturing base "that props up the entire national innovation system continues to deteriorate in the United States, but grows and thrives overseas, then large numbers of America's most innovative companies might be inclined to move overseas to be closer to production and the necessary support base. . . . Significant deterioration of companies that design and make discrete components is triggering a fundamental hollowing out of the national innovation system."[46]

a. Offshoring innovation

Defense procurement policy promotes civilian-military integration and the purchase of commercial-off-the-shelf (COTS) products, to cut costs and increase access to the most advanced commercial technologies. This has made it easier for defense contractors to go overseas to purchase needed items. However, a firm's ability to design, innovate and improve on critical technologies produced for defense markets depends on its ability to draw upon the technology edge obtained in its commercial business. But, as the commercial supplier base that the Pentagon relies on for these products globalizes, this technology transfer from commercial to defense-critical products, has become more difficult to achieve. Hence, the HRS study found the following trends associated with erosion of domestic manufacturing capacity across the range of industries it reviewed:

- Weakening innovation capabilities of domestic industrial suppliers.
- The transfer of cutting-edge technologies and know-how to economic rivals and potential military adversaries.
- A decline in America's technological leadership in the world, especially in areas critical to national security.

Laboratories of production. The close link between manufacturing and innovation is apparent in each of the profiled industries. As Dr. Jack W. Schilling, Chairman of the Specialty Steel Industry of North America testified, "[o]ur plants in the specialty metal industry are our laboratories."[47] Experts note that because of the link between manufacturing and technology development, manufacturing's migration contributes to the erosion of U.S. innovation and R&D capacity itself. For example, a Defense Advisory Group on Electronic Devices (AGED) report warned about the impact of the "off-shore movement of intellectual capital and industrial capability, particularly in microelectronics" on "the ability of the U.S. to research and produce the best the technologies and products for the nation and the warfighter." [48]

<u>*Semiconductor R&D*</u>. As semiconductor production has moved offshore to places such as Taiwan and China, research activities have followed in many instances. The DOD's Defense Science Board (DSB) has noted that maintaining U.S. leadership in semiconductors requires preserving the "close coupling of manufacturing with the development of advanced technology and the design of leading-edge integrated circuits," which is best achieved "if development and manufacturing are co-located."[49] But if production has gone offshore, the collaboration between process engineers and designers needed for leading-edge microchip development would become ineffective for the U.S. defense industry.[50]

PCB R&D. According to a NRC report on the PCB industry, which traced the loss of R&D to the loss and migration of manufacturing, "the traditional sources of R&D funding dropped by two orders of magnitude. In reality, the critical mass of R&D in this industry disappeared, reducing the investment in new technology to near zero."[51] U.S.-based PCB suppliers, another major source of R&D resources, spent about 10 percent of all U.S.-generated supplier sales on technical activities and new process and product R&D in the 1990s, but by 2003 this share was only 3 percent.

Advanced materials R&D. A NRC report on the globalization of materials R&D similarly concluded that, as U.S. materials manufacturing disappears and moves offshore, domestic materials R&D capacity also is lost. Research into the production, processing, and development of metallic materials in the United States has been declining since 1998. Many U.S. companies, attracted to the growing availability of lower-cost foreign intellectual resources, have shifted their materials science and engineering R&D activities to follow manufacturing operations overseas.[52] Notable examples are superalloys, composites, electronic and opto-photonic materials, ceramics, and catalysis, all with important defense and commercial applications.

Aerospace R&D. Aerospace is another a critical industry seeing a migration in manufacturing accompanied by diminished R&D capacity at home. For example, industry specialists David Pritchard and Alan MacPherson reported on Boeing's lack of R&D investment for its commercial product lines, noting that Boeing trailed Airbus with regard to R&D and capital spending for many years. The USCC has warned that "[t]he ability of the U.S. aerospace industry to attract investment and sustain a base for high-technology development is . . . reportedly at risk and may deteriorate further as more aerospace technologies migrate offshore."[53]

Measuring the extent U.S. industrial R&D has eroded warrants additional research. Existing evidence shows that U.S. innovation capacity in critical industries has weakened, and may continue to deteriorate as production in these sectors moves away. As the National Academy of Sciences report *Rising Above the Gathering Storm*, concludes: "Having reviewed the trends in the United States and abroad," it was "deeply concerned that the scientific and technical building blocks of our economic leadership are eroding at a time when many other nations are gathering strength."[54]

Migrating R&D. The offshore migration of U.S. innovation capabilities has also been a contributing factor in the buildup of other countries' R&D capacity The more U.S. firms build factories overseas, the more powerful the attraction of offshore R&D becomes, as multinational companies want their facilities to be in the closest proximity possible. For example:

- Aerospace offset arrangements foster technology transfer between U.S. commercial and defense firms and foreign companies, enabling countries such as Japan, China and South Korea to build up their own aerospace manufacturing and R&D capacity.
- NRC's study of materials R&D globalization identified several subfields—including composites, ceramics, electronics and opto-photonic materials, catalysis, and magnetic materials—where U.S. firms are moving R&D and customer support functions overseas to be

close to the new manufacturing bases they have created.[55]

While Taiwan is a principal location for contract design outfits, China and India are leading sites for foreign direct investment (FDI) by multinational corporations (MNCs) for establishing R&D centers. A Cambridge University study shows that emerging economies like India and China are favored destinations for global R&D with top MNCs, such as GM, IBM, Cisco, Motorola and GE.[56] The numbers and quality of U.S. investments in R&D centers in these countries have accelerated over the past decade. A major attraction is their abundant pool of highly-educated engineers and high-tech workers capable of increasingly sophisticated high-tech work, while working for wages far below U.S. or European levels.

China, in particular, has benefited from foreign corporate investment in R&D and technology transfer. The USCC's 2010 report noted that FDI in China had grown from a mere trickle of a few billion dollars in the 1980s to more than $80 billion annually by 2008; it bypassed the United States as the destination for the largest amount of FDI in the world in 2003.[57] Through the different arrangements China has forged with foreign corporations, from offsets to joint ventures and R&D centers, its ultimate goal is to greatly enhance its own internal capacity for producing globally competitive, world-class technologies and products. Thus, the migration of U.S. R&D capacity is boosting the technological capabilities critical to improving the military industrial prowess of a nation that the Pentagon worries could become a formidable military opponent.[58]

New world leaders? Although the offshore migration of American R&D resources may provide short-run competitive advantages to U.S. companies, America's overall technological leadership in the world has weakened, which translates into an erosion of U.S. leadership in technology areas critical to national security. Several studies indicate that although the United States remains a world leader, if not always *the* world leader, in technology competitiveness and innovation, its leadership has slipped over the past decade, not only relative to its traditional trading partners—Europe, Japan—but to major emerging economies, most notably China and India, but also other Asian nations, such as Korea, Singapore, Taiwan, and Malaysia.

The U.S. ability to assert or maintain leadership in emerging technologies also is jeopardized, such as in advanced materials R&D and semiconductors. For example, Intel's "teraflop research chip" and 45-nanometer technology was developed in Intel-funded labs in India, indicating a transfer of advanced microprocessor design capacity. Nanotechnology is another emerging technology area where the United States has been losing ground.

b. Offshoring Critical Skills and Know-How

As the United States loses its technological edge through movements of R&D offshore, underinvestment in R&D by U.S. industry and lack of attention by the U.S. government—with the shedding of millions of skilled workers as a result—the know-how needed for maintaining and advancing U.S. technology leadership vital for national security embodied in those displaced workers, is being lost as well. The dramatic loss of manufacturing jobs since 1998 afflicting almost every industrial sector, were accompanied by comparable losses in the number of manufacturing facilities in almost every sector, and for establishments of every size. Aside from the economic hardship suffered by U.S. workers, their families and communities wrought by this movement, the nation also is paying a long-term price for the loss of these jobs in the deterioration of U.S. industrial and technology leadership.

Specifically:

- The large-scale reduction in the American high-skilled production and science and engineering workforces as manufacturing migrates offshore is leading to the loss of critical technological know-how needed to maintain U.S. leadership in technology areas critical to economic and national security;
- The deterioration in the nation's manufacturing base and technology leadership has created significant barriers to meeting the nation's near and long-term needs for sustaining a high-skilled, high-tech workforce.

The loss of skilled production workers, scientists, engineers, and technical and professional workers across the manufacturing sector means that the next best idea, the next innovation, and the next generation of products, will be made somewhere else, not in the United States. This loss of manufacturing capacity—and the intellectual and technical capability to make things—is a profound threat to the nation's economy and national security. The seed corn of our future is being invested in someone else's economy.

V. Conclusion

Although America's manufacturing sector is still the largest, most productive and innovative in the world, the broad domestic and global economic trends examined in this report provide substantial evidence that the U.S. manufacturing base has been undergoing a steady and potentially dangerous erosion, especially over the last decade. The findings of this report point to important implications regarding public policies for strengthening the nation's defense industrial base. Programs such as the Pentagon's "trusted" investments in critical defense technologies for which domestic capacity has all but disappeared and the more controversial "Buy America" requirements on defense procurement remain important, and should be supported. But the secular decline in U.S. manufacturing competitiveness and technological leadership and the erosion in a wide range of industries critical to national defense suggest that such measures are not sufficient. Only a comprehensive strategy aimed at reversing the erosion in the nation's overall manufacturing base will be sufficient for preserving and revitalizing the nation's defense industrial base in the coming decades.

ENDNOTES

[1] "Assessment Of Industrial Base Assessments: There Is Little To Worry About, Or Is There?" *Manufacturing & Technology News (M&TN),* Vol. 12, No. 6 (March 22, 2005), 3-4. See also Department of Defense (DOD), *Annual Industrial Capabilities Report to Congress*, (Washington, DC: February 2005); —, *Foreign Sources of Supply: Assessment of the United States Defense Industrial Base* (Washington, DC, November 2004). These and other defense industrial base capabilities studies are available on the Internet, http://www.acq.osd.mil/ip).

[2] "U.S. Military Warned Again About Loss of U.S. Industry," *Manufacturing & Technology News,* Vol. 17, No. 2 (January 26, 2010), 1,6

[3] Data source: U.S. Bureau of Economic Analysis (BEA), http://www.bea.gov/industry/gdpbyind_data.htm.

[4] *Ibid*.

[5] Data source: Federal Reserve Board (FRB), www.federalreserve.gov/econresdata/releases/statisticsdata.htm.

[6] Data source: U.S. Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages (QCEW), http://www.bls.gov/cew/cewsize.htm.

[7] Data source: U.S. Bureau of Labor Statistics, Current Employment Survey, www.bls.gov.

[8] See Alan Tonelson and Sarah Linden, "Import Growth Depressing U.S. Industrial Output, Advanced U.S. Manufactures Keep Losing Ground in Home Market," *USBIC Import Penetration Survey 2010*, (Washington, DC: U.S. Business and Industry Council, 2010); Alan Tonnelson and Peter Kim, "Imports Seizing U.S. Market Share Throughout Manufacturing Sector; "High-tech" sectors just as vulnerable as "low-tech." USBIC Research Alert (Washington, DC: U.S. Business Industry Council, December 4, 2006).

[9] Robert E. Scott, "Costly Trade With China: Millions of U.S. jobs displaced with net job loss in every state," *EPI Briefing Paper #188* (Washington, DC: Economic Policy Institute, May 1, 2007), online: http://www.epi.org/authors/bio/scott_robert_e/.

[10] *The Defense Production Act of 1950, As Amended* (50 U.S.C. App.§ 2061 *et seq*.) Current through P.L. 107-47, enacted October 5, 2001 (Washington, D.C., April 2002).

[11] Committee on Defense Manufacturing in 2010 and Beyond, Board on Manufacturing and Engineering Design, Commission on Engineering and Technical Systems, National Research Council (NRC), *Defense Manufacturing in 2010 and Beyond, Meeting the Changing Needs of National Defense,* (Washington, DC: National Academy Press, 1999), 11.

[12] Michael Webber, "Erosion of the Defense Industrial Support Base." In Richard McCormack (ed.) (Washington, DC: The Alliance for American Manufacturing, 2009), 245-280. Webber employed three indicators to evaluate whether an industry appeared to be eroding between 1998-2008: employment, economic activity (contributions to GDP by shipments) and the number of establishments.

[13] NRC, *Linkages*; "Printed Circuit Boards to Become Part of DOD's Trusted Production Program," *Manufacturing & Technology News,* Vol. 15, No. 5 (March 14, 2008).

[14] *Ibid.,* 9-10.

[15] Paul Freedenberg, "Testimony of Dr. Freedenberg, Vice President-Government Relations On Behalf of the AMT-The Association for Manufacturing Technology, before the U.S. China Economic and Security Review Commission," Washington, DC, June 23, 2005.

[16] "Defense Department Hires Science Academy To Assess Vulnerability of U.S. Circuit Board Industry," *Manufacturing & Technology News,* vol. 12, No. 3 (February 9, 2005), 1ff .

[17] Aerospace Industries Association (AIA), "AIA White Paper on the Industrial Base Provisions (Title VIII, Subtitle B) in the House of Representatives version of the FY 2004 National Defense Authorization Act H.R. 1588)," (Washington, D.C., July 7, 2003).

[18] U.S.-China Economic and Security Review Commission (USCC), *2005 Annual Report to Congress*, (Washington, DC, November 2005), 97.

[19] Including the National Security Agency, the Pentagon's Advisory Group on Electron Devices (AGED), the Semiconductor Industry Association, National Academies of Science's National Research Council, the U.S.-China Economic and Security Commission, and U.S. Senator Joseph I. Lieberman (I-CT).

[20] Webber, "Erosion," 269. He reports that employment in this industry dropped more than one-third, from 310,000 in 2001 to 200,000 in August 2008, which is below the levels at the end of the 1991 recession. GDP dropped from approximately $76 billion in 2000 to $49 billion in 2001 and then rose up to $60 billion in 2005. The number of establishments (all sizes) fell from 1,640 in 2001 to 1546 in 2004, rose to 1,683 in 2006, before falling back to 1,564 in 2008. Establishment numbers are from *Bureau of Labor Statistics, Quarterly Census of Employment and Wages* (QCEW).

[21] See Alan Tonelson and Sarah Linden, "Import Growth Depressing U.S. Industrial Output, Advanced U.S. Manufactures Keep Losing Ground in Home Market," *USBIC Import Penetration Survey 2010*, (Washington, DC: U.S. Business and Industry Council, 2010); Alan Tonnelson and Peter Kim, "Imports Seizing U.S. Market Share Throughout Manufacturing Sector; "High-tech" sectors just as vulnerable as "low-tech." USBIC Research Alert (Washington, DC: U.S. Business Industry Council, December 4, 2006).

[22] William J. Spencer, "New Challenges for U.S. Semiconductor Industry," *Issues in Science and Technology* (Winter 2004), 79-86:84.

[23] "CHINA NEEDS TO BOOST SEMICONDUCTOR PROD'N TO MEET DEMAND: IXIS." *AsiaPulse News*. 2006. *HighBeam Research.* (July 2, 2010). http://www.highbeam.com/doc/1G1-152596852.html

[24] "A conversation with ... Michele Nash-Hoff: author, can American manufacturing be saved: why we should and how we can." *Products Finishing*. 2010. *HighBeam Research.* (July 3, 2010). http://www.highbeam.com/doc/1G1-218592026.html

[25] "America's Oldest Printed Circuit Board Company Closes Its Doors," *Manufacturing & Technology News,* Vol. 16, No. 13 (July 28, 2009).

[26] Roy Sakelson, "America's dynamic duo: two American printed circuit makers—Electropac and Hallmark—are on opposite sides of the country. . . . the harsh realities of the global economy," *CircuiTree*. March 1, 2005. *HighBeam Research.* (July 3, 2010).

[27] Tonelson and Linden, *USBIC Import Penetration Survey 2010*.

[28] Mike DuBois, "An Inside Look At The U.S. Printed Circuit Board Industry" *Manufacturing & Technology News,* Vol. 15, No. 17 (September 30, 2008).

[29] NRC, *Linkages.*

[30] "Printed Circuit Boards to Become Part of DOD's Trusted Production Program," *Manufacturing & Technology News,* Vol. 15, No. 5 (March 14, 2008).

[31] BLS, *QCEW*. The special tool, die, jig, and fixture manufacturing, industrial mold manufacturing and cutting tool and machine tool accessory manufacturing industries suffered even more significant losses. Employment losses were 37.9 thousand (40 percent), 17.9 thousand (37 percent), and 15.0 thousand (42 percent), respectively, between 2001-2009. They lost 26 percent, 27 percent, and 15 percent of their establishments (net), respectively, between 2001-2008.

[32] "U.S. Machine Tool Sector Hits A Low Not Seen Since The 1920s," *Manufacturing & Technology News,* Vol. 10, No. 5 (March 3, 2003), 11.

[33] Tonelson and Linden, *USBIC Import Penetration Survey 2010*.

[34] "China Jumps To Number One In Machine Tool Consumption," *Manufacturing & Technology News,* Vol. 10, No. 5 (March 3, 2003), 12.

[35] The machine tool consumption and production data derives from multiple sources including: "The 2009 world machine-tool output & consumption survey: the world survey at a glance." *Metalworking Insiders' Report* (February 10, 2009). *HighBeam Research.* (July 3, 2010). http://www.highbeam.com/doc/1G1-194701223.html; "The 2008 world machine-tool output & consumption survey." *Metalworking Insiders' Report.* (February 13, 2008. *HighBeam Research.* (July 3, 2010). http://www.highbeam.com/doc/1G1-175631351.html; and similar earlier year surveys in trade journals.

[36] "Precision Machine Tool Industry Loses Its Global Competitive Edge," *Manufacturing & Technology News,* Volume 17, No. 4 (March 5, 2010), 1ff.

[37] *Ibid*.

[38] Freedenberg, "Testimony to USCC."

[39] See http://www.census.gov/foreign-trade/reference/glossary/a/atp.html#general.

[40] National Materials Advisory Board, Division of Engineering and Physical Sciences, National Research Council (NRC) of the National Academies, *Globalization of Materials R&D, Time for a National Strategy* (Washington, D.C.: National Academies Press, 2005), 21.

[41] NRC, *Globalization of Materials R&D*, 83.Military needs have long driven the development and application of new materials. The DOD has unique demands for certain high-performance metals, ceramics, polymers, and composites. several specific materials applications important to warfighting capabilities: new lightweight materials with greater strength and functionality, materials that enhance protection and survivability, stealth materials, electronic and photonic materials for high-speed communications, sensor and actuator materials, high-energy density materials, and materials that improve propulsion technology.

[42] NRC, *Globalization of Materials R&D*; "Chinese Market for Advanced Materials Worth $60.5 Billion by 2012." *Business Wire* (January 21, 2008. *HighBeam Research.* (July 3, 2010). http://www.highbeam.com/doc/1G1-173972470.html

[43] BLS, *QCEW*.

[44] BIS, *Offsets In Defense Trade, Ninth Study* , 3-1; BIS, *Offsets In Defense Trade, Fourteenth Study,* 14: "Other kinds of offsets, such as technology transfers, may increase research and development spending and capital investment in foreign

countries for defense or non-defense industries, thereby helping to create of enhance current and future competitors for U.S. industry."

45 U.S. Department of Commerce, Bureau of Industry and Security (BIS), *Offsets in Defense Trade, Fourteenth Study, Conducted Pursuant to Section 309 of the Defense Production Act of 1950, as Amended* (Washington, DC, December 2009), 14. In 2008, BIS reported that 14 defense contractors entered into a total of 52 new offset agreements with 17 countries worth $3.48 billion, which equaled 57.1 percent of the $6.10 billion in related contracts for the sale of defense items to foreign entities. Over the sixteen-year period, 1993-2008, the BIS reported a total of 48 firms entering into 677 offset agreements with 45 different countries related to defense export sales totaling $97.13 billion.

46 Webber, "Erosion,"251

47 Jack W. Shilling, "Testimony before the U.S-China Economic and Review Commission," Washington, D.C., June 23, 2005.

48 Department of Defense Advisory Group on Electron Devices (AGED), *National Technology Leadership Forum Microelectronics Study,* Washington, DC. (September 24, 2002). Also cited in "DOD Technology Advisory Group Says Military Capability Is In Doubt Due To Loss Of Electronics Industry," *Manufacturing & Technology News,* Vol. 10, No. 10 (May 16, 2003), p.1, 4-5.

49 Department of Defense (DOD) Office of the Under Secretary for Acquisition, Technology, and Logistics, *Report of the Defense Science Board Task Force on High Performance Supply* (Washington, DC: February 2005),6.

50 Ibid.

51 NRC, *Linkages,* 44.

52 NRC, *Globalization of Materials R&D*, 85.

53 USCC, *2005 Annual Report,* 105.

54 Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, National Academy of Sciences (NAS), National Academy of Engineering, Institute of Medicine, *Rising Above the Gathering Storm* (National Academies Press, Washington, DC: October 2005); 2. Cited in USCC, *2005 Annual Report,* 94.

55 NRC, *Globalization of Materials R&D*.

56 "India, China top destinations for MNCs R&D: Cambridge Research." *PTI - The Press Trust of India Ltd* (March 12, 2009). *HighBeam Research.* (July 3, 2010). http://www.highbeam.com/doc/1G1-195470724.html

57 U.S.-China Economic and Security Review Commission (USCC), *2009 Report to Congress* (Washington, DC: USCC, November 2009), 58. Over the first half of 2009, largely because of the worldwide recession, China FDI fell by nearly one-fifth, though it retained its lead among the main destinations of FDI.

58 U.S. Department of Commerce, Bureau of Industry and Security (BIS), "US Technology Transfers to the People's Republic of China" (1999), 51-52. www.bis.doc.gov/defenseindustrialbaseprograms/osies/DefMarketResearchRpts/ChinaGuides/China1.pdf.