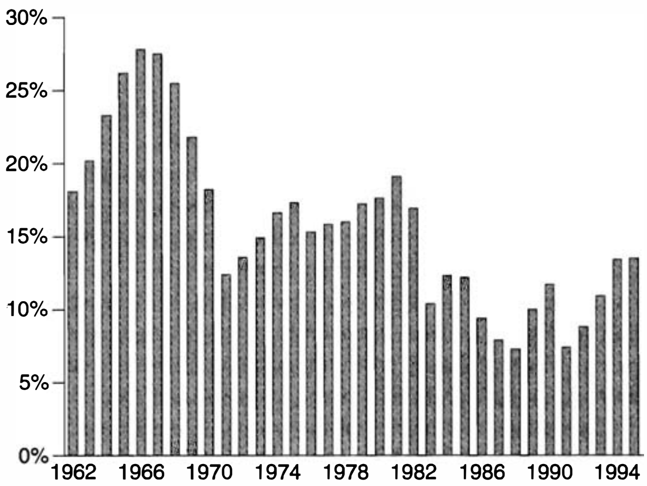
America's machine tool design sector has shrunk by two-thirds

by Richard Freeman

At a moment when the U.S. and world economies urgently require the capability of the U.S. machine tool industry, to provide for the Eurasian land-bridge and a world economic boom, that industry is unable to respond. The machine tool sector is in a shrunken state, a victim of the post-industrial society, pro-speculation economic policies that the British financier oligarchy unleashed in America in the mid-1960s. The machine tool industry was the energizer of the American System of dirigistic economics for 200 years, through the mid-1960s. Today, it produces only one-third of what it produced per capita in 1967. Its share today of world machine tool production is half what it was 30 years ago (see **Figure 1**).

The breaking point came in October 1979, when Paul Volcker, then Federal Reserve board chairman, jacked up interest rates, as part of a policy that he and the New York Council on Foreign Relations called "controlled disintegration." By February 1980, the prime lending rate reached a post-World War II record of 21.5%. Under Volcker's high-interest rate regime, orders dried up and the companies became starved for cash. Over the next eight years, more than half the companies disappeared from the Northeast and Midwest, which together account for more than three-quarters of the country's machine tool output, and much of its scientific drive.

FIGURE 1
U.S. share of world machine tool production falls



Source: "Economic Handbook of the Machine Tool Industry," various years, published by Association for Manufacturing Technology (formerly the National Machine Tool Builders Association).

The American machine tool-producing companies were—and are—overwhelmingly of the character of what is called in Germany, the *Mittelstand.* They are small, often family-owned, oriented not toward short-term or speculative profit, but toward making profit from constant scientific and technological advance in machine tool design. They are concerned about improved product and skilled workforce, not the parameters that concern Wall Street. Because of what they do, the *Mittelstand* are the most important component of an economy, but they have a very tiny capital base. America's trashing of its commitment to advancing science in manufacturing—typified by the virtual shutdown of the space program, nuclear power construction, and infrastructure building—killed off capital spending, leaving machine tool production in a depressed state.

If this state of affairs is not reversed, the United States will descend into a new dark age. The machine tool design sector is the key to the modern economy and the source of all real profit. It is the transmission belt for fundamental scientific discoveries into the entire economy. In the strictest sense, the machine tool design sector *physically impresses* this advanced technology into machinery, such as textile machinery, food-processing machinery, construction equipment, mining equipment, aerospace craft-building gantries, electric generators, wood-working equipment, and so forth, which, in turn, produce all the products of an economy, including new technologies of product design, product performance, and of productivity.

Therefore, the *rate* at which a nation inserts these more advanced technologies into increased productivity, and increased product quality, is the measure of performance in a physical economy.

America has always understood the importance of the machine tool sector. This has been true since Benjamin Franklin and his republican scientific network helped organize the Industrial Revolution in England, by developing the heatpowered engine of James Watt and Matthew Boulton in the 1770s. The history of America's economy is that of the interrelation among creative scientific discoveries; the development of capital-intensive, energy-intensive modes of manufacturing; and the machine tool design sector. This concept developed out of the work of Eli Whitney (1765-1825), who created one of the first milling machines, and continued through the nineteenth century, to the work of Henry Ford (1863-1947), who developed his design for an automobile while working as the chief engineer at the Edison Illuminating Company in Detroit. Ford intentionally developed the car so that its carriage and engine could be used as a *universal farm machine:* It could take people on a Sunday drive, but it could also take farm produce to market, haul hay, pull a plough, grind grain, and run a sawmill.

During the twentieth century, the machine tool, and much of engineering in general, was advanced through wartime economic mobilizations.

Machine tools make other machines

There are two types of machine tools: metal-cutting and metal-forming. (There are also jigs, fixtures, and so on, which hold the workpiece in place). A metal-cutting machine tool is a power-driven machine that performs operations, including boring, broaching, drilling, gear-cutting, grinding, turning, and milling, each of which primarily cuts metal (but also plastics and ceramics), by the distinctive action of a blade or tool attached to a rotating spindle (see box p. 52).

Rotational action is critical in machine tools, and in fact, in the development of all machines. The lathe is also classified as a metal-cutting machine, but its mode of operation is different from other metal-cutting devices: In the lathe, the machine tool piece is held stationary, and it is the workpiece itself—that is, the material being worked on—which rotates on a rotating platform.

A metal-forming machine tool is a power-driven machine that performs operations including forging, die-forming, bending, pressing, shearing, and punching.

Dozens of parameters indicate a machine tool's functioning. Just to mention one, which shows the advances over the last 200 years, is the increase in spindle speed. An increase in the rate of rotation of the spindle, to which the blade or toolpiece is attached, increases the work that can be done. During the nineteenth century, spindle speeds of 100 to 750 revolutions per minute were common. Today, spindles can rotate at 8-15,000 rpms. Speeds of 30-40,000 rpms may soon be routine.

This increase in spindle speed necessitated an increase in the hardness and tensile strength of the material that comprises the cutting tool piece: The tool piece has been advanced from tempered alloyed steel, to tools with cubic boron nitrate diamond coatings. Each advance in one area sets the stage for an advance in another.

Through the development of the machine tool, mankind has increased its power over nature, during the last 200 years, by three orders of magnitude.

Today, various advanced machine tools use lasers, controlled electron beams, or plasma sources, especially for cutting and welding. There are further advances through the use of numerically controlled machine tools, which use tapes, punched cards, pressed switches, or computers to program and run the machine.

The power of the machine tooling sector comes not from an individual machine tool per se—although there are many remarkable machines, like the five-sided machine tool—but from an ordered configuration of machine tools. This author recently had the opportunity to tour a manufacturing and assembly plant that uses 1,450 machine tools. The tour made it clear that it is the ordering of groups of machine tools into a series of configurations that accomplishes work, and utilizes the full power of any one machine tool. Thus, one can see that an inventor would collaborate with a machine tool builder to decide what kind of new machines would be needed to make a new product, and which new or redesigned machine tools would be needed to make the new machines that make the new product. It is the back and forth traversing, in the mind, of this entire integrated process in making new machines, starting with the human mind that creates the new idea, that is the power of the machine tooling process **Figure 2.**

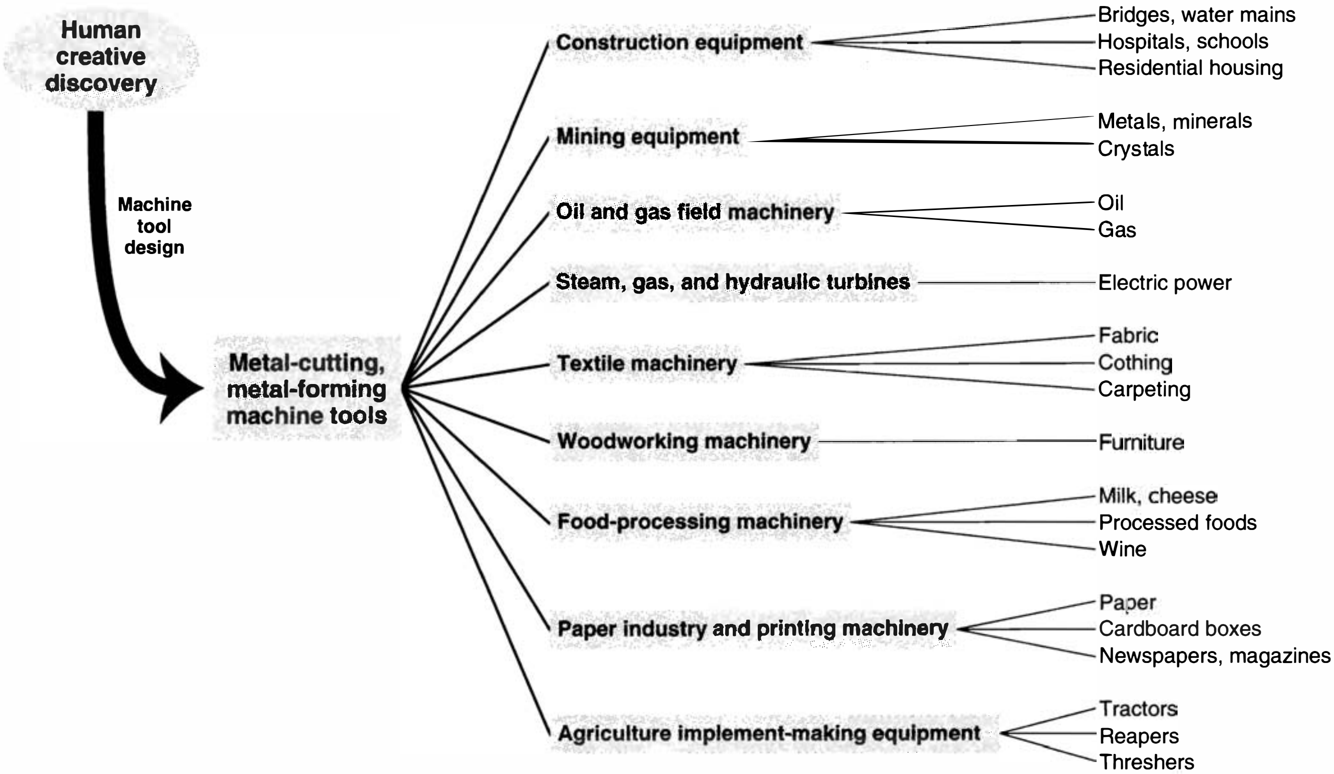
Our report here first looks at highlights in America's history that show the relation of scientific breakthroughs, universal machines, and the development of the machine tool, and shows the central role the machine tool has played in the U.S. economy. It examines the aspect played by wartime mobilizations during the twentieth century, and the *Mittelstand* character of the American machine tool firm. Second, we look at the condition of the machine tool design sector today, starting with its breakdown and contraction, beginning with the mid-1960s introduction of the financiers' post-industrial society policy into America.

American dirigism and machine tool design

The development of the machine tool design sector in America is inseparable from the development of republican networks, on the one hand, and general scientific advance, on the other. It was America's commitment to what came to be expressed as the General Welfare clause in the U.S. Constitution of 1787, which guided the unfolding of the machine tool sector. That clause states that it is the nation-state's commitment to its posterity, by giving its citizenry a Classical education, and dirigistically fostering scientific advancement in capital-intensive and energy-intensive modes of manufacturing, agriculture, and infrastructure, that leads to the well-being of its citizens.

That is the concept that guided that genius of the eighteenth century, Benjamin Franklin, in his work with the worldwide network of the followers of Gottfried Wilhelm Leibniz, to foster the Industrial Revolution in England, and

FIGURE 2
The central role of the machine tool in the economy



nearly every important advance in machine tool design since then. In many cases, the government directly financed or gave subsidies for railroad building, armaments, energy production, aerospace, and so forth, that provided the impetus for machine design improvement.

A strict statistical account would not capture the creative development and qualitative changes effected in the 200-year history of the U.S. machine tool industry. Instead, we highlight certain events to make the point.

Franklin and the Watt-Boulton steam engine

In 1757, Benjamin Franklin set sail for England, and over 1758-75, he helped organize and direct England's first canal-building, the invention of steam power, modern chemistry, and steel-making, which collectively provided the impetus for the development of what is called the Industrial Revolution. This exciting story is presented by Anton Chaitkin in "Leibniz, Gauss Shaped America's Science Successes," which appeared in the Feb. 9, 1996 issue of *EIR.*

We focus here on the steam engine. In February 1766, Matthew Boulton wrote to Franklin, soliciting his comments about Boulton's blueprints for a steam engine. Boulton was to build England's first great manufacturing plant, the Soho Works outside Birmingham. In March 1766, Franklin responded, addressing the central question of the steam engine: the fact that only a tiny proportion of the energy in the fuel was being translated into delivered power.

The Scottish mechanic-engineer James Watt was also working on experiments with the steam engine. In 1767, Watt visited Boulton's Soho Works, and there met the manager of the plant, Dr. William Small, a native Scot who had emigrated to Virginia in 1758. It was Franklin who secured for Small the position of plant manager for Boulton's Soho Works. In 1768, Dr. Small wrote to Watt, suggesting that Watt join him and Boulton in a new partnership in Birmingham that would develop the steam engine. This was all occurring under Franklin's guidance. Watt moved to Birmingham in 1774.

One of the knottiest problems that had to be solved to make the steam engine practicable, was to plug leaks in the engine's cylinder wall. At first, the piston was packed with stuffing material to close the gap with the cylinder wall and prevent the loss of steam pressure and force. However, the cast iron cylinder could never be shaped evenly for a tight fit around the piston. Here, the inventors turned to John Wilkinson, an ironmaster, who had further developed the boring mill, one of the earliest forms of machine tool, to make cast iron cannon. Wilkinson was also very close to his brother-in-law Joseph Priestley, a Franklin protégé, whom Franklin turned into a scientist.

On Jan 27, 1774, Wilkinson obtained a patent for a "New Method of Casting and Boring Iron Guns or Cannon." In *A Short History of Machine Tools,* author Lionel Rolt says that Wilkinson's boring machine: "consisted of a machine in which the solid cannon casting was rotated horizontally between bearings and the stationary boring head was advanced by a toothed rack on the boring bar, the feed being applied by a handwheel through suitable gearing. The bar advanced through guides on a supporting table." Like any skilled machine tool builder, Wilkinson was able to modify this original boring machine to the specifications required by Watt and Boulton to precisely and evenly bore the cylinder required for the steam engine. In April 1776, an ecstatic Watt wrote of Wilkinson's work, "Mr. Wilkinson has improved the art of boring cylinders so that I promise upon a 72-inch cylinder being not further from absolute truth [that is, tolerance] than the thickness of thin sixpence in the worst part." This enabled a workable steam engine to be made, with the promise it held for fostering all future industrial development. In turn, Wilkinson became the first industrial user of the Watt steam engine.

Eli Whitney and the arsenal system

The son of a Massachusetts farmer, Eli Whitney exhibited a wide-ranging mind at an early age. He outfitted a small metal-working shop on his family farm to make nails. In those days, nails were not purchased at the local hardware store, and if one didn't devise a method to machine them, one had to file them by hand. In 1789, at age 23, Whitney entered Yale University.

In 1792, Whitney went to Georgia to tutor, and he stayed at the residence of the widow of Gen. Nathaniel Greene, one of George Washington's most trusted generals. At the Greene estate, Whitney solved the problem of how to remove the seeds from green-seed, short staple cotton with his invention of the cotton gin ("gin" is an abbreviation of engine). The task of removing the seeds by hand was so arduous, that it rendered the crop a commercial failure. The cotton gin consisted of a wooden cylinder, bearing rows of slender spikes set half an inch apart. The spikes extended between the bars of a grid set so closely that only the cotton lint—and not the seeds—could pass through. A revolving brush cleaned the cotton off the spikes, and the seeds fell into another compartment.

Whitney wrote, "This machine may be turned by water or with a horse, with the greatest ease, and one man and a horse will do more than 50 men with the old machines. It makes the labour 50 times less, without throwing any class of People out of business." As a result of this machine, U.S. production of cotton rose from 2 million pounds per year in 1795, to 1.17 billion pounds by 1845—the fact that cotton was then grown by slavery cannot be blamed on Whitney—and helped foster the textile industry.

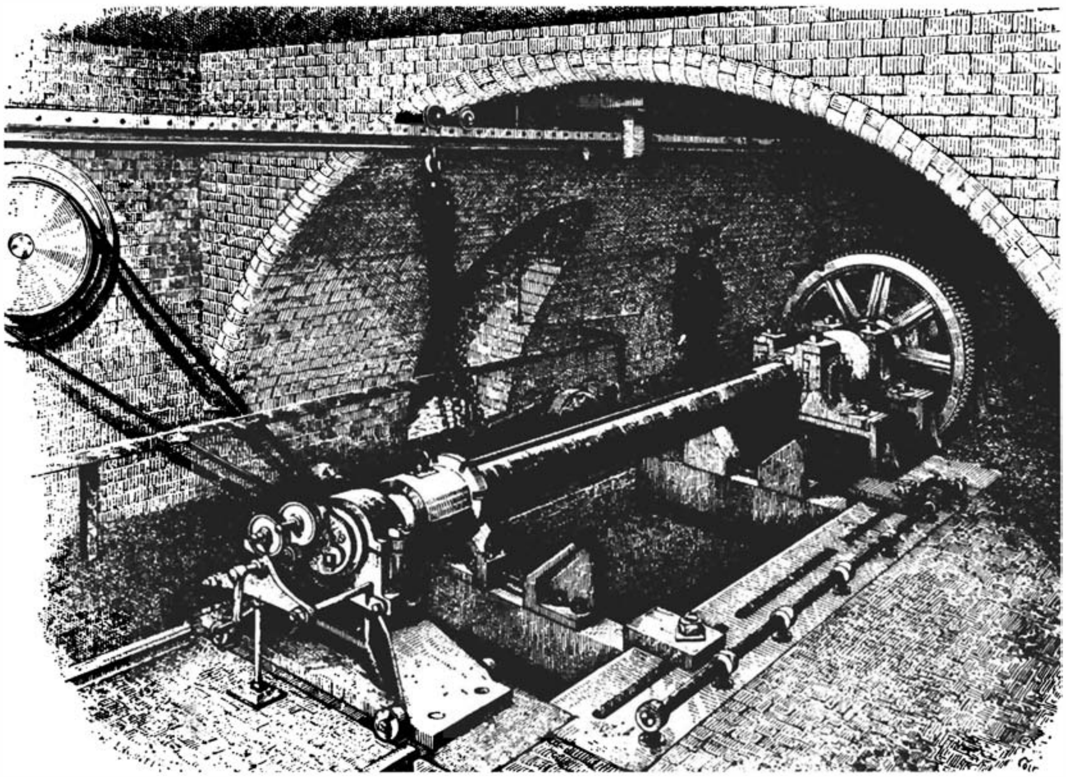
In 1798, Whitney secured a government contract for making 12,000 muskets. This was part of the U.S. arsenal or armory system, which gave contracts for products for war. Although the military products themselves have no productive value, their manufacture generates new technologies, which can be assimilated into the civilian economy, raising overall productivity. In his 1791 *Report on Manufactures,* Alexander Hamilton had argued for a national arsenal system to make and store weapons. To fulfill the rifle contract, Whitney built a factory in New Haven, Connecticut, and devised or further refined several machine tools.

In his letter applying for the musket contract, Whitney wrote: "I am persuaded that machinery moved by water, adapted to this business would greatly facilitate the manufacture of this article. Machines for forging, rolling, floating, boring, grinding, polishing, etc. may all be made use of to advantage." A working model of an Eli Whitney milling machine, built around 1820, still exists, though most of the other machine tools have been lost. Whitney's milling machine, which was not the first, represented a clear advance, anticipating the knee-and-column type of horizontal milling machine that came into common use during the late nineteenth century.

Whitney helped advance the process, begun in France during the late eighteenth century, of making "interchangeable parts"—that is, standardization. With standardization, the parts for 100 rifles, such as 100 locks, or 100 barrels, would always fit together precisely regardless of when or where they were made. This was the start of mass manufacturing. It replaced the costly and time-consuming method of customizing each rifle, the only known production method at that time.

Although some foolish, pro-British writers wrongly equate the interchangeable parts system with the essence of the American System of economics—conveniently leaving out protective tariffs, dirigist direction of credit, attempts to crush speculation, and so on—the most important scientific facet of standardization is, that advancement of machine tool technology made it possible.

In preparation for war with the British, in 1812, the U.S. government awarded Whitney's advanced factory a contract to make 30,000 muskets. Whitney's New Haven factory continued to improve machine tool design. It became the education center for other engineers and inventors, and a crucial spawning ground for the northeast machine tool industry. For example, Horace Smith was a workman at Whitney's New Haven armory before he founded the Smith & Wesson Company to build guns at Norwich, Conn. Col. Samuel Colt, the inventor of the revolver, went to the Whitney Arms Factory to have his revolver produced. Colt also studied and copied the armory's machines, before he built his plant at Hartford, Conn. Francis Pratt and Amos Whitney (the latter not directly related to Eli Whitney) worked and were educated at the Colt Armory. Later, they worked together for 10 years as foremen



A cylinder-boring mill from the Soho Foundry near Birmingham, England. In the 1770s, at this Soho Foundry, James Watt and Thomas Boulton developed the working steam engine.

at the Phoenix Ironworks in Hartford, which made many of the machine tools for the Colt Armory and other weapons companies.

After the Civil War, Pratt and Whitney went out on their own, setting up shop in Hartford, and becoming one of the first exporters of machine tools. The company developed a range of pipe threads, and eventually sired a whole line of advanced machines, including, in the twentieth century, the jet engine, which Pratt and Whitney produces today. This tradition accounts for the fact that Connecticut was the leading machine tool producing state in the Northeast region, until Paul Volcker destroyed it.

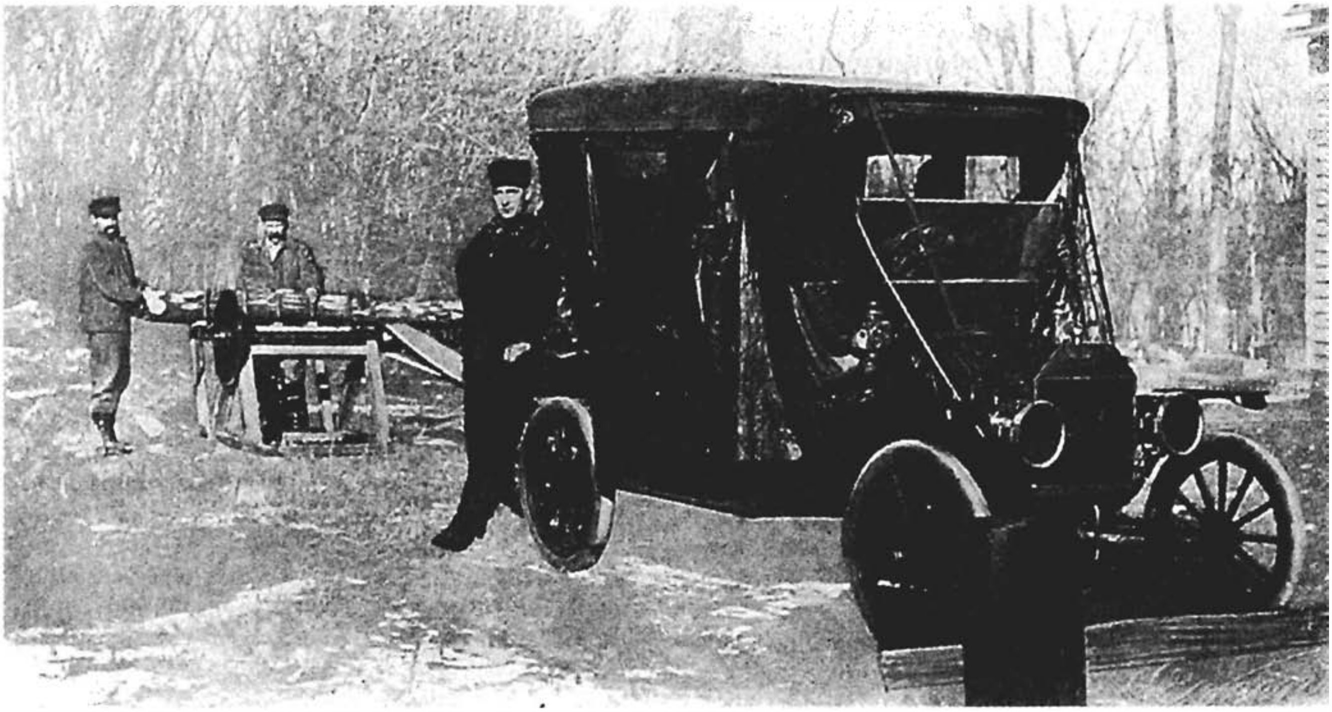
Advances during the Civil War

President Abraham Lincoln's need to mobilize the U.S. economy to defeat the Confederate insurrection during 1861-65, led to the first full-scale factory production of military uniforms and clothing, as well as the rapid expansion of locomotive and rail track production. More and more factories replaced water power with steam power, and new machine tools for the textile and locomotive and rail industry were developed. During the Civil War, the tolerance limit, i.e., margin of accuracy, of machine tooling improved to 0.01 inch. By World War I, it would improve to 0.001 inch.

In the 30 years after the Civil War, new machine tools were developed and old ones improved for the wood-working industry, agriculture implements industry (to make reapers and harvesters), shipbuilding, and the transmission and power industry. Machine tools were designed for sewing machines, typewriters, and bicycles. New inventions were made constantly, each of which increased, by 25% to 100%, the efficiency and power of a particular kind of machine tool.

To cite one example: during the 1880s, Frederick W. Taylor and his associates in Philadelphia—a major machine tooling center at this time—developed a type of steel that permitted machine tool bits to run at much higher speeds. Victor S. Clark writes in his *History of Manufactures in the United States, 1607-1860,* that this "made possible much heavier cuts at higher speeds in machining metals, *that more than doubled the output of a machine*" (emphasis added). At the same time, Clark says, "the station type of tools was introduced, enabling a succession of operations to be performed simultaneously upon the same piece of metal." Because this dramatically reduced set-up time, which is the largest block of time in any machine tooling operation, it resulted in additional increases of productivity of 50% to 100%.

The cumulative effects of more and more fundamental improvements began to cascade, offering the ability not only to increase spindle speed, but to have adjustable, rather than permanent spindle speed during the same tooling operation; or the ability to have more rigid jigs and fixtures, and so on. This increased capability radiated to the general metalworking and machinery industry, making it more powerful by a factor of 25 to 50 than it had been at the dawn of the nineteenth century. This was a tangible increase in man's power over nature.



The Ford Model-T could be rapidly changed into a traveling saw-mill. Henry Ford conceived the Model-T to be used as a universal farm machine.

During the Civil War period and the subsequent 40 years, Cincinnati emerged as a center of machine tool design. It was heavily settled by German craftsmen, so much so that a neighborhood not far from the Ohio River became known as Over-the-Rhine. A company founded in 1884 as the Cincinnati Screw and Tap Company, has been run for more than a century by the Geier family, originally from Bavaria, Germany. Today, it is known as Cincinnati Milacron. Cincinnati machine tool makers produced for the shipbuilding and repair industry, whose ships plied the waters of the Ohio River, and for textiles, but soon spread out to many areas. By 1900, Cincinnati produced one-eighth of all U.S. machine tools, and the machine tool center of gravity had shifted to the Midwest.

Henry Ford and the universal farm machine

Born at Springwells, Michigan, in July 1863, Henry Ford was raised on a farm. He developed the car as a universal farm machine. In his autobiography, *My Life and Work,* Ford writes that he took no pleasure in endless farm drudgery: "My earliest recollection is that, considering the results, there was too much work on the place. . . . Even when very young I suspected that much might be done in a better way. That is what took me to mechanics—although my mother always said that I was a born mechanic. I had a kind of workshop with odds and ends of metal for tools before I had anything else. In those days we did not have the toys of today; what we had were home made. My toys were all tools—they still are!"

Ford adds: "I have followed many a weary mile behind a plow and I know the drudgery of it. What a waste it is for a human being to spend hours and days behind a slowly moving team of horses when in the same time a tractor could do six times as much work."

In the 1880s, Ford worked on the maintenance, repair, and development of steam engines. During this time, he operated a Westinghouse portable steam engine for 83 days one fall, doing the threshing for the farmers in his Michigan neighborhood. It's important to remember that Ford was a farm engineer, one of a breed that sought to bring power to agricultural America. The steam engine was key. In 1880, a total of 1,200,000 steam-horsepower served agricultural purposes, while in 1910, the figure reached 3,600,000 horsepower, an amount equal to the strength of 7 million horses.

In the mid-1880s, Ford went to work for Westinghouse, and in 1891, he went to work for Edison Illuminating Company in Detroit, as an engineer. In 1893, he was made chief operational engineer, and he began his serious work on a gasoline-powered automobile. By 1899, Ford had produced an operable car, and he left Edison Illuminating to become superintendent of the Detroit Automobile Company, which he had formed with others to manufacture motor cars. First, he produced Model-N cars, but in 1908, he began to produce the Model-T; in the next 19 years, he sold 15 million cars. He also built one of the first tractors and marketed them in numbers to farmers.

While other car companies went in for changes in the style of their autos, to "market them better," Ford kept the style of the Model-T basically the same, and concentrated on quality. He also kept reducing the price. The Model-T cost $950 in 1909 and $490 in 1913. Then, on Jan. 5, 1914, Ford shocked the world, by raising the wages of his workforce from $2.34 per day to $5 per day, based on the idea that well-paid skilled workman produce better. While the $5 figure was reached through a profit-sharing bonus, which required six months' service and some other conditions, it was a stunning affirmation that labor power was valued.

The most remarkable feature about the Ford Model-T, and the later Model-A, however, is that it was designed to be a universal farm machine: It replaced the horse, and pulled haywagons and wagonloads of farm produce, milk, or pelts for animal breeders. Its engine could be turned into a portable power source; hooked up to a belt—turning the engine into a belt drive—it was used to power the grinding of grain and the operation of a thresher. In the same manner, the engine powered a sawmill to cut wood (see picture). Most important, the Model-T had another converter kit which allowed it to pull a plow or reaper. The Model-T was also outfitted with an accessory converter kit, in which the front wheels were replaced by ski-like contraptions, and the car was turned into a snowmobile to travel over the snow!

The improvement in the machine tool was critical in mass production and improvement of the Model-T; as a result, in the mid-1910s, the assembly time per Model-T was reduced from 12.5 man hours to just 1.5 man hours. This involved creating a moving assembly line, where each function had to be made by a variety of machine tools, some of which were greatly redesigned or invented. For better or worse, the auto industry became the market for approximately 25% to 30% of America's machine tools, a ratio that still holds today. (The aircraft-aerospace-defense sector, both directly and through subcontractors, accounts for an another quarter of all machine tool orders today.)

One example of machine tool technology is the development of the centerless grinder. One auto company using the centerless grinder increased the production of car valve tappets from 90 an hour in 1920, to 1,350 in 1929, a 15-fold increase in productivity within one decade.

The twentieth century war mobilizations

During the twentieth century, the mobilization for war and national defense during World War I, World War II, and the Korean War accounted for a good part of the forward drive and sustenance of the machine tool industry. In his book, *Arsenal of Democracy*, Donald Nelson writes that without the machine tool capacity, the economic mobilization for World War II could not have been waged, nor the war won. Nelson states:

"Long before the war, the Army and Navy Departments realized that machine tools would be the keystone of the industrial effort during the war. . . .

"By April 30, 1941, President Roosevelt had become aroused over the machine tool shortage. He wrote to [former General Motors president and Chief of Production for the U.S. Army] Bill Knudsen and [labor leader] Sidney Hillman urging the necessity of speeding up the manufacture of machine tools. A 24-hour day and a seven-day week schedule was recommended by the President, but although the machine tool bottleneck showed some improvement, it always remained narrow. This equipment was necessary to gear the whole production process, but the craftsmanship needed to build was a scarce article, and there were not many areas in the whole country where such craftsmen could be found. The United States undoubtedly had more machine tools than any other nation, but no shortage confounded our defense production as much as this one."

Indeed, during 1940 and 1941, the machine tool sector was like a throttle on the engine of war production. Because machine tools are the machines that make other machines, little else could be produced, and civilian plants, such as auto plants, could not be converted to war production, unless the machine tools were made first. During the economic mobilization for the war, the entire, indispensable, driving role of the machine tool industry for the industrial growth of the economy, throughout the entire post-1770 period, was condensed into a single moment.

This type of mobilization had occurred during World War I, such that, from 1914 through 1919, U.S. machine tool output rose from approximately 40,00 units to 150,000 units (using sketchy figures). Many scientific and technological advances were achieved. As **Figure 3** shows, after the end of World War I, machine tool production fell to a level of 50,000 or fewer machine tools produced per year. This level prevailed from 1921 until 1938, and reached fewer than 10,000 machine tools produced per year for 1931 through 1934.

The economic mobilization for World War II, which converged on the use of Hamiltonian methods of dirigistically running the economy, changed all that. With the government directly and indirectly funding machine tool plant refurbishing and enlargement, and worker training feverishly going on, machine tool production for the aircraft and other industrial sectors rose from 34,000 in 1938, to 307,000 in 1942, a nearly 10-fold leap in only four years (see Figure 3).

Technological development was necessary. For example, the building of a single airplace engine, such as the Wright Cyclone, required 80,000 machining operations. Writing in the Oct. 1, 1942 issue of *Automotive and Aviation Industries* magazine, George H. Johnson, then president of the National Association of Machine Tool Builders, provides an example of the improvements that had to be made:

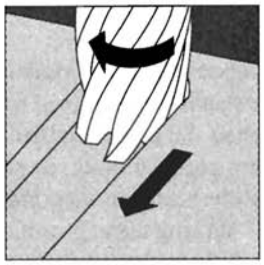
"One of the most difficult and important assignments given the machine tool industry was the design and building of hundreds of special-purpose machines, needed to convert the aircraft engine industry from small-lot to mass production. At the right is [a picture of] a specially designed machine

Characteristic action of major metal-cutting tools

Here are the characteristic work actions performed by some of the more important metal-cutting machine tools.

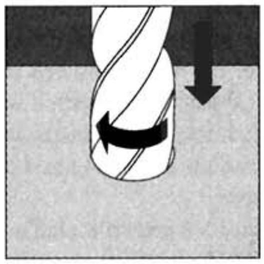
MILLING

Milling involves bringing a rotating cutter, with many teeth, into contact with the piece of metal material one is doing work on (the workpiece). The cutter rotates on a spindle which is horizontal or vertical. A milling machine tool would be used, for example, to cut a 2-inch groove across the face of a piece of metal.



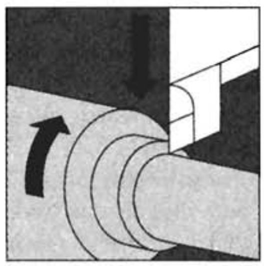
DRILLING

Drilling makes or enlarges holes in a workpiece. The machine usually holds the workpiece stationary, while the drill, on a rotating spindle, is fed into it. The drill's cutting edges are on the tip, and the spiral flutes carry the chips of cut metal away from the cutting edges. Reaming, tapping, and boring are processes used to enlarge and finish a drilled hole.



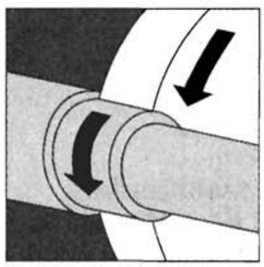
TURNING

Turning is used to machine pieces whose finished shape is concentric about a common centerline, such as cylinders, discs, shafts, and rings. With turning machines, also known as "lathes," the workpiece, held at one or both ends, rotates. A single-point cutting tool, fed into the work surface, peels the metal away.



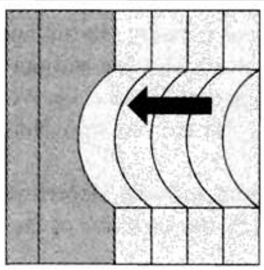
GRINDING

Grinding is for bringing a part surface to an exact dimension or finish. An abrasive wheel is moved into or across the workpiece. The surface of the abrasive wheel contains thousands of hard particles, each capable of removing tiny chips of metal. Grinding machines can grind shafts, gears, flat surfaces, inside diameters, and so on.



BROACHING

Broaching is a high production process that moves a many-toothed tool, like a giant file, across the workpiece, machining it in a single pass. The teeth are graded; each successive row of teeth is higher than the one before it, so each makes a slightly deeper cut.

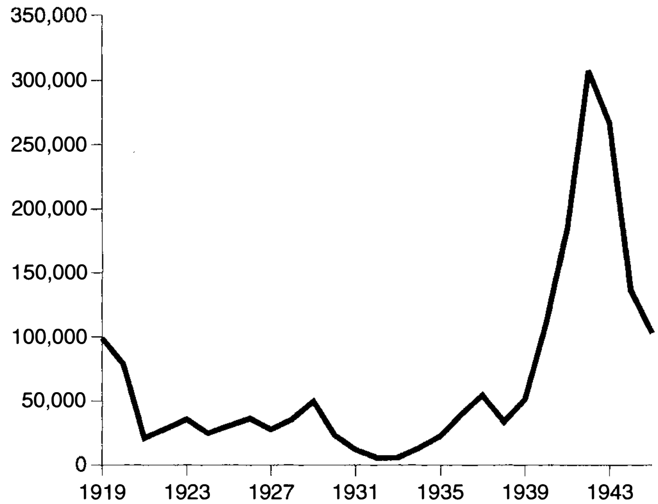


Source: Courtesy of Cincinnati Milacron Co.

FIGURE 3

U.S. machine tool production surges under Roosevelt 1939-43 mobilization

(units produced)



Source: "A Study of the Machine Tool with Emphasis on the Problem of Stability," 1962 Doctoral Thesis at American University by Robert Stanley Himes.

which drills, countersinks and spotfaces 22 identical three-eighth-inch holes in an aluminum airplane engine crankcase. It works simultaneously on 32 holes from two different directions. These operations previously took two hours 12 minutes. This one machine now completes the job in 23 minutes."

Thus, the new machine did the job in one-sixth the time; or, to put it another way, this single improvement made the machining operation six times more powerful. This emphasizes an important point: As a long wave over history, when the American economy was growing, America always simultaneously increased the productivity and power of the machine tool, and the number of machine tools produced. It was never a matter of doing one or the other. Today, some alleged machine tool experts attempt to cover up the collapse in production by saying that some machines are more powerful than those of 30 years ago. But technological improvement was always a feature of U.S. machine tool design, at the same time that it increased output.

After World War II, as a result of the fundamental failure of the United States to effect mass conversion of industry to peace-time production, machine tool production dropped precipitously, lasting until the Korean War began. The economic mobilization for the Korean War was like an extension of the World War II mobilization. The U.S. Director of Defense Mobilization pinpoints the role of the machine tool design sector in the Korean mobilization, in his "Fourth Quarterly Report to the President," released Jan. 1, 1952: "An industry so small that most employers know all their workers by their first names holds the key to success or failure for the nation's military preparedness effort.

"Despite everything that may have been or can be done to increase production, machine tools will remain the most important factor limiting military production for many months to come."

But once military-driven production stopped, the yo-yo effect of the machine tool industry continued. With the end of the Korean War, machine tool orders and production collapsed.

America's 'Mittelstand'

We jump ahead a little to situate the *Mittelstand*'s role in the U.S. machine tool sector. As the report of the Director of Defense Mobilization found, most of the machine tool companies were small enough that the owner knew his employees by their first names. In 1958, according to the 1958 Census of Manufacturing, published by the Commerce Department's Census Bureau, more than 95% of all machine tool establishments employed fewer than 500 persons each, were in most cases independently owned, and produced 49% by value of the industry's shipments.

This *Mittelstand* characteristic of the machine tool industry remains today, despite all the changes—many of them bad—that have occurred in the industry. **Figure 4** shows that in 1992, only 10% of all machine tool employees worked in machine tool establishments of 1,000 persons or more, and 65.9% worked in establishments employing fewer than 500 persons each. As the figure shows, this contrasts sharply with the shipbuilding, aerospace, automobile, and other industries.

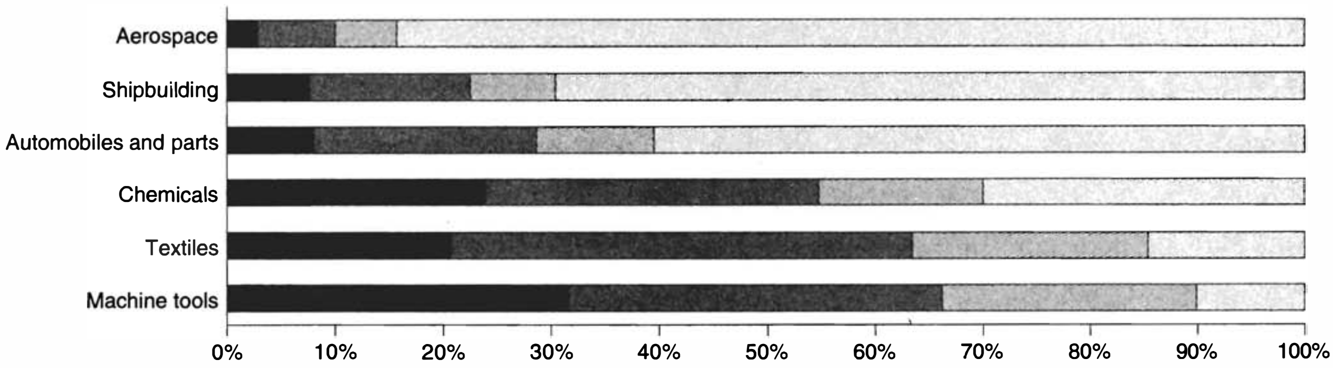
The erroneous policies of the Eisenhower administration plunged the U.S. economy into an recession-depression in 1957-58, which continued in force in the machine tool industry until 1960.

Then, the positive policies of President John F. Kennedy began to reverse the decline. The Apollo Moon mission was a science-driver for the entire economy. Every $1 invested in the space program, returned between $10 to $13 in technological spin-offs. Various machine tool makers invented tools and processes specifically for the space program, and expanded their facilities or opened new shops to become part of the space program, or of other, derived, cutting-edge scientific industries. Kennedy's 7% investment tax credit, enacted in late 1961 for implementation on Jan. 1, 1962, further abetted the process. This credit became available to industrial companies as accelerated write-offs for engaging in capital spending and buying new industrial equipment; in particular, this meant the purchase of machine tools. From the depths of the Eisenhower depression, when America produced only 170,982 machine tools in 1960, production surged to 311,472 in 1967, a near doubling. (Orders also increased, to some extent, because of purchases for weapons production for the Vietnam War.)

FIGURE 4

Percent of employment, of establishments in leading industries, by number of workers in the establishment

(percent of all establishments in the industry)



Source: U.S. Department of Labor, Bureau of Labor Statistics, "Employment and Earnings" for various years.

Paul Volcker and the post-industrial society

City of London bankers, through Paul Volcker, brought the positive effects of the Kennedy program to a sharp halt.

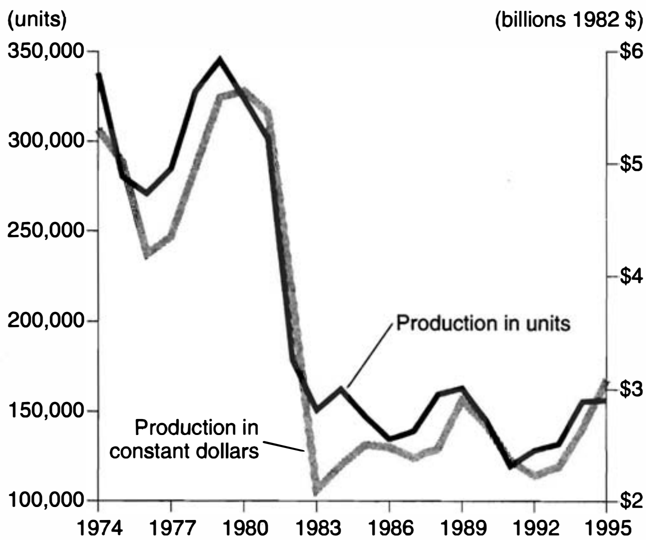
During the mid-1960s, the British financier oligarchy instituted the post-industrial society. This policy emphasized speculation over production, and began shutting down high-technology development, including killing the space program in the late 1960s. There were huge implications for the machine tool industry. In August 1971, the U.S. dollar was severed from the gold reserve standard, delinking foreign-exchange trading and financial flows from industrial production. In 1973-75, and 1978-79, came the first and second oil hoaxes, together increasing the price of oil 12-fold. While this crippled industry, including the machine tool sector, it also created a temporary reprieve for the machine tool industry: As the auto industry moved to build fuel-efficient cars, it needed a whole array of new machine tools. But the re-tooling of the auto industry extended only through the end of the 1970s.

In October 1979, Paul A. Volcker, chairman of the Federal Reserve Board of Governors, raised interest rates skyward. The prime lending rate reached 21.5% in February 1980, and stayed at double-digits for the next 10 years. While Volcker gave as the excuse for his actions that he was "wringing inflation out of the economy," in fact, he was a team member for the Council on Foreign Relations project that had been ongoing since the early 1970s, known as "Project 1980s." One of the project's 33 book-length studies, *Alternatives to Monetary Disorder,* forecast bringing the economy to zero and then negative growth, through a series of oil price shocks, credit crunches, and so on, which it termed the "controlled disintegration" of the economy. In November 1978, speaking in Leeds, England, Volcker proclaimed his allegiance to this policy, stating bluntly, "controlled disintegration is a legitimate objective of the 1980s."

Volcker did more damage to America's machine tool sector than any previous assault in American history. At one

FIGURE 5

U.S. machine tool production, in units and 1982 constant dollars

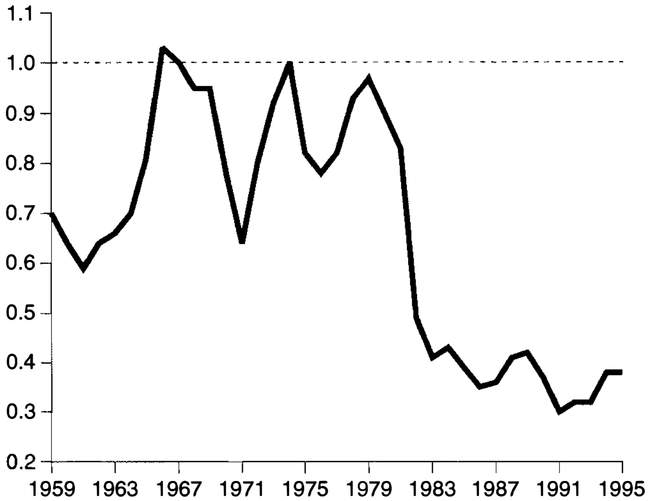


Source: Economic Handbook of Machine Tool Builders, various years.

FIGURE 6

U.S. machine tool output per capita collapses

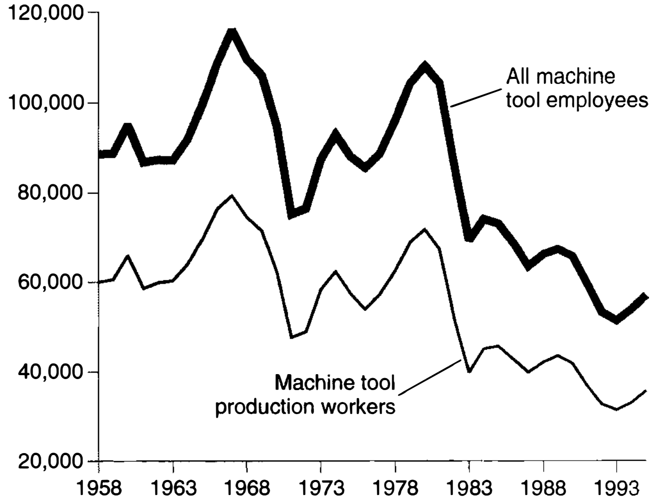
(index 1967=1)



Source: Economic Handbook of Machine Tool Builders, various years.

FIGURE 7

Number of U.S. machine tool employees and production workers halved since 1967



Source: U.S. Department of Labor, Bureau of Labor Statistics, "Employment and Earnings" for various years.

point, dozens of machine tool shops were closing up every week. The take-down of U.S. scientific capabilities and the enforced contraction of capital formation, combined with other post-industrial policies, such as the 1982 deregulation of the banking system, compounded the damage. There was a two-year delay before the policy demonstrated its full effect.

Figure 5 shows that in 1981, U.S. machine tool makers produced 301,313 machines. By 1983, output had plunged to 150,837 units, a fall of 49.9%. Between 1983 and 1995, output would not again reach the level of 170,000 units. Machine tool makers felt the impact in dollar sales. Figure 5 also shows that machine tool sales plummeted from $5.46 billion in 1981 to $2.10 billion in 1983, a drop of 60.1% (stated in 1982 constant dollars).

The fall was even deeper on a physical output per-capita basis. If for 1967, the annual machine tool output is divided by the population (in 1967 there were 158.4 machine tools produced per 100,000 Americans), and if that figure is set equal to an index level of 1, we can express all subsequent years' output per capita relative to 1967. Representing this on a per-capita basis, as in **Figure 6,** presents the power of the individual member of the economy over the entire industrial process: 1995's index level, at 37.6, had fallen to a level almost two-thirds below that of 1967.

Figure 7 depicts the decrease in employment. In reality, the number of workers employed in the machine tool industry—in 1967, 116,000 employees, of whom 80,000 were production workers—was pitiably small to start with. By 1995, the number of employees and production workers fell by half, relative to 1967.

Figure 8 shows the number of machine tools in operational use by metal-working industries; that is, by the textile machinery industry, the automobile sector, aerospace-defense sector, and so on. Thus, whereas there was a steady increase in machine tools in use by U.S. industry, from 1939 up through 1973, reaching 3.067 million machines in use. by 1995, that level had plunged by 25%, and an increasing share of the machines in use were imports. Moreover, as Figure 8 shows, in 1945, some 62% of all machine tools in use were under 10 years of age, while only 38% were 10 years or older. That has completely reversed, so that in 1989, 38% of machine tools in use were under 10 years old, while 62% were 10 years or older. Many industrialists emphasize that because of technological attrition, 10 years is the age at which a machine tool should be replaced.

Permanent restructuring

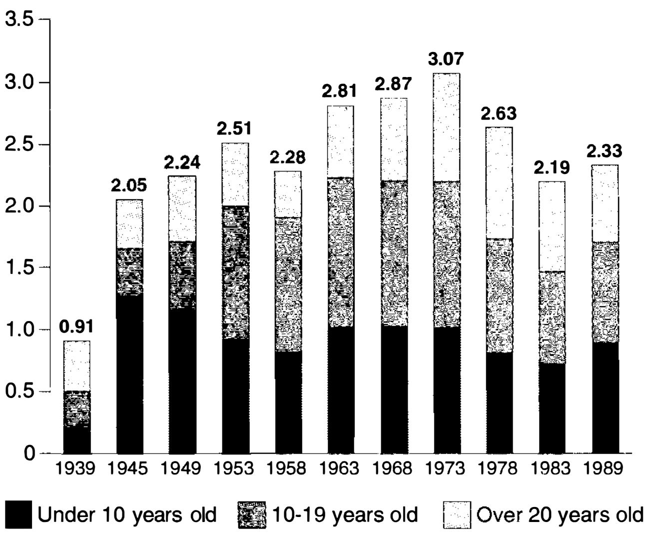
To fully understand what happened, we must look at the permanent restructuring. That is, it was not just a steady, but perhaps temporary, fall in production. The deeper problem is that America lost production capacity facilities *permanently.* If America were to decide to gear up machine tool production tomorrow, the capacity would not be there.

Figure 9 and its accompanying table, show the two predominant machine tool producing regions of the United States: the Northeast (Region I) and the Midwest (Region II). These two regions historically, down to the present, produce

FIGURE 8

Machine tools in use in U.S. metal-working industries, 1945-89

(millions of units)



Source: Economic Handbook of Machine Tool Builders, various years.

three-quarters of all American machine tools. In other words, very few machine tools are produced south of the Mason-Dixon line, or west of the Mississippi River. The U.S. Census performs a Census of Manufacture once every five years; in the table, 1977 was chosen as the starting year, because it is the closest year to 1979, and 1992 was selected because it brings us up to date, although most of the damage had been done by 1987.

Examine for a moment the destruction in Connecticut, for Region I, and Ohio, which is America's largest machine tool-producing state, for Region II. Connecticut, one of the cradles of the machine tool industry, went from 70 establishments, employing 6,400 workers in 1977, to 32 establishments, employing 1,900 workers in 1992. The establishments fell to less than half the 1977 figure, while the 1992 employment was only one-third of what it had been in 1977. As for Ohio, between 1977 and 1992, the number of its establishments fell by half, and the number of workers fell by 60%. The largest number of establishments that closed were those with 20 employees or less.

The damage is not just the loss of these machine tool producers, as injurious as that is; there is additional damage through the loss of the network of associated high-skilled, high-technology industries—sub-contractors, small machining-shops where machine tools are used to do small jobs, bearing plants, industrial electronic firms, and so on—which also went out of existence. This associated infrastructure would frequently cross-fertilize with the machine-tool-producing companies to develop new ideas. Thus, an infrastructure, representing a potential, was lost.

The leveraged buy-out mania

In this environment, in which the small, cash-starved machine tool companies were scorched by the Volcker high interest rates, the Wall Street leveraged buy-out mob moved in.

We give an example of how this asset-stripping worked.

In 1978-79, one of the first really large leveraged buy-outs (LBO) was Houdaille Industries, primarily a machinery-producer, which had absorbed a number of machine tool companies, including the Burgmaster Corp. In 1965, Burgmaster had become the largest machine tool maker west of the Mississippi, after developing a turret drill press in the late 1940s. Kohlberg Kravis Roberts, the dirty money asset-stripper tied to the George Bush apparat, undertook the Houdaille LBO for $355 million, which was 10 times the size of most of the LBOs up to that time.

"Wall Street recognized immediately that the rules were no longer the same. . . . There was virtually no limits on how large a buy-out could be," Max Holland writes in his 1989 book, *When the Machine Stopped.* The financiers made a killing, but Houdaille was devastated. Recounting an interview with Allan Folger, then president of Burgmaster, Holland writes, " 'After the buyout, Houdaille per se changed,' Folger recalled. 'It seemed to lose its equilibrium.' Financial expertise became the single most-valued resource, and understandably so. 'Accounting hires grew faster than manufacturing hires,' because managing for cash flow 'to service the debt became the whole end,' said Folger. Corporate headquarters now demanded so many extensive financial reports that even Folger, with his capacity for numbers, came to believe that it interfered with attempts to improve Burgmaster's product and defend its market."

By 1983, Burgmaster's backlog of orders was quite modest, only 2 to 3 months, compared to the 18 months that were common before the Kohlberg Kravis Roberts-arranged LBO. As money was being siphoned from production to pay pyramided debt service, Burgmaster's machines were becoming less reliable, but still they were being shoved out the front door. On Oct. 1, 1985, a bankrupted and destroyed Burgmaster machine tool company was shut down permanently.

Loss of skills and capital investment

The shutdown of many machine tool shops, and displacement of skilled workers, plus the natural aging of machine tool workers has meant a much-less-skilled workforce than existed 25 years or ago—or than exists today in Germany and Japan. (The average age of America's machine tool production worker is 50-55 years old, near retirement age.) A 1994 RAND Corp. study, entitled "The Decline of the U.S. Machine Tool Industry," documents the educational-skill loss in the machine tool sector. The report states, the U.S. "machine

FIGURE 9

Collapse of machine tool establishments and employment, 1977 to 1992

	1977			1992		
	Establish-ments	Establishments with 20 or more employees	Number of employees	Establish-ments	Establishments with 20 or more employees	Number of employees
Region I						
Connecticut	70	28	6,400	32	12	1,900
Massachusetts	37	10	2,200	22	7	700
New York	81	27	6,900	26	15	3,700
Pennsylvania	61	18	2,800	28	16	1,300
Rhode Island	20	7	2,400	3	3	100
Vermont	6	4	2,800	4	4	n.a.
Total Region I	*275*	*94*	*23,500*	*115*	*57*	*7,700*
Region II						
Illinois	118	64	12,900	73	42	5,800
Indiana	36	15	2,000	16	8	700
Michigan	248	96	11,100	127	74	5,900
Ohio	129	59	18,500	67	40	7,600
Wisconsin	36	18	3,700	34	23	2,700
Total Region II	*567*	*252*	*48,200*	*317*	*187*	*22,700*

Source: U.S. Commerce Department, Census Bureau, reports MC77-I-35C, MC92-I-35C, Table 2.

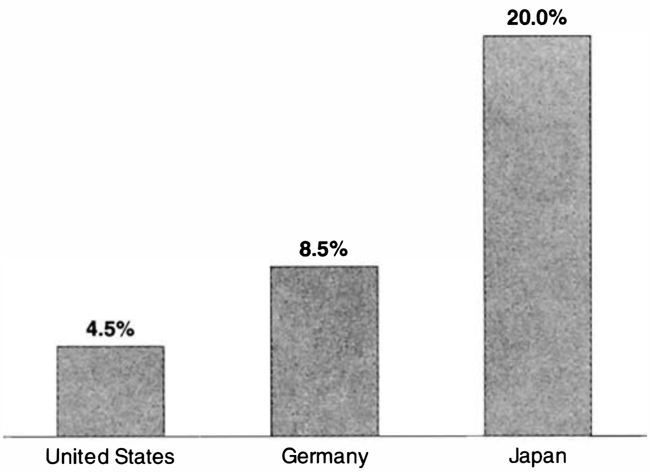
tool industry representatives consistently rated the lack of basic skills and the perceived anti-manufacturing bias of students leaving the U.S. public education system as the most pressing human resource problems facing their industry. This contrasts with Japan and Germany, where manufacturing continues to be held in high prestige and where machine tool makers and users can recruit from a pool of young people who have, in many cases, mastered two languages and advanced math and science."

This lack of skill and education in the U.S. machine tool workforce can be seen in two ways.

First, Germany has an excellent apprenticeship program, where the cost of administering the program is shared through a compulsory dues system of all Germany industry. Because the German machine tool sector has relied on maintaining high levels of quality and innovation, this training is seen as something that cannot be abandoned. In Japan, both the lifetime job guarantee, plus the fact that the Japanese Ministry of Labor subsidizes companies that have been hard hit by recession to retain their workers, gives Japanese industry the knowledge that these workers will be there permanently, not just passing through. In addition, Japan depends on high-technology production.

In contrast, in the United States, until the 1970s, Cincinnati Milacron, one of the largest companies, had a highly respected machinist apprentice program. But, because many of the apprentices got hired away by other companies after their training was completed, Cincinnati Milacron suspended

FIGURE 10
Percentage of machine tool workforce employed as engineers



Source: RAND/Critical Stuides Institute.

TABLE 1
Japanese firms employ more advanced manufacturing technology than the U.S.
(Japan/U.S. ratio)

New manufacturing technique	Small and medium-size establishments (SMEs)	Large establishments
NC/CNC machine tools	1.4	1.1
Flexible manufacturing cells	4.3	1.9
Computer assisted design	1.1	0.9
Automatic inspection	2.9	1.5
Handling robots	4.1	1.4
Automatic warehouse equipment	5.8	1.8
Assembly robots	2.1	1.2

Source: RAND/Critical Technologies Institute.

the program. In a recent tour of a U.S. manufacturing plant that employed 1,450 machine tools, one of the plant's chief manufacturing engineers, who has worked there for 35 years, told this author, "When they lose me and others who know the whole process, the company may have real problems." This engineer said that he had been trained at a technical school program at a community college, where he studied for five years while working; that program has been shut down.

Second, American companies have a low-skill approach in introducing their employees to advanced technology, such as numerically controlled machine tools. A leading distributor of both U.S. and Japanese machine tools reported: "The Japanese will purchase the latest million-dollar flexible manufacturing cell and put an engineer on it for the first few weeks to ensure that it is operating properly and to search for any ways of improving its performance. A typical U.S. firm will stick an operator on it whose only skill is knowing the difference between the red and green buttons. Then they wonder why they don't get the expected return on their capital investment."

This is reflected, as **Figure 10** shows, in the difference in the percentage of the machine tool workforce who are engineers in the United States, Germany, and Japan. Japan has four times the level of engineers than the United States has. This is often reflected in the kind of capital spending investment for high technology—or lack of it—within the machine tool sector itself. **Table 1** shows a ratio between Japan and the United States on the use of certain advanced manufacturing technology. The Japanese have an overwhelming lead.

Ironically, even though the U.S. Air Force and others developed numerical control for machine tools in the 1950s, forty years later, only 10% of the U.S. machine tool stock in use by industry consists of numerical control units. As for the production of computer numerical control machine tools, in 1990, the U.S. produced just 7% of the world's production of computer numerical control machine tools; the Germans produced 19%, and the Japanese 24%.

The scientific and quality level that the United States used to pride itself on, from the Civil War until 1967, is no longer there.

U.S. machine tool imports

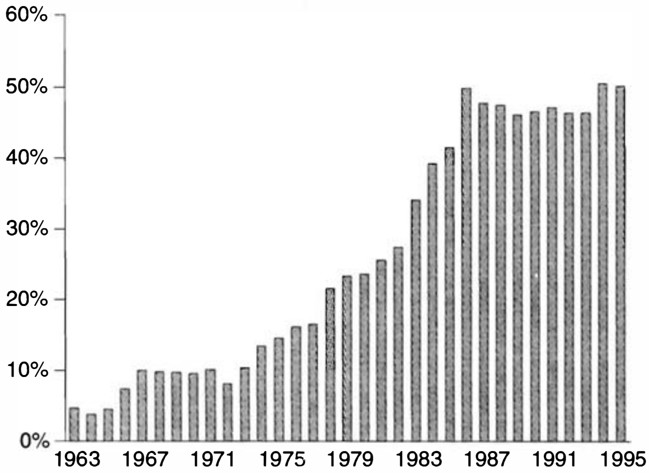
It is only in the above context, that one can consider the issue of imports. **Figure 11** shows the percentage that imports constitute annually of the new machine tools purchased by U.S. industry. **Table 2** breaks down the level of imported annual consumption by key types of machine, for selected years between 1982 and 1995.

It can be seen that imports constituted less than 10% of the U.S. market for all machine tools until 1972. Then imports rose to a level of 22% by 1978. It should be stressed that from 1900 up through 1976, the United States still exported more machine tools than it imported. Then, in the period 1978 through 1986, the entire import profile of the machine tool industry changed. Largely as a result of London's post-industrial policies (although there were some other contributing circumstances), foreign machine tool imports went from 22% to 50% of annual U.S. consumption. With that fundamental change completed by 1986, it has remained within the 50% range ever since.

This import situation must be changed; but to blame it primarily on the Japanese, Germans, Taiwanese, or whoever misses the boat. The problem fundamentally lies within

FIGURE 11

Imports as a percentage of U.S. machine tool consumption



Source: Economic Handbook of the Machine Tool Industry, various years.

TABLE 2

Import share, by type of machine tool, of U.S. machine tool markets, 1982-95

(percent of total U.S. machine tool consumption)

	1982	1985	1991	1995
All machine tools	26.4%	41.4%	45.1%	50.1%
Metal cutting	27.4	43.3	51.5	51.2
Metal forming	22.5	35.8	43.0	47.0
All NC machines	35.4	54.5	53.4	58.3
Boring and drilling	26.9	44.5	51.2	39.6
Gear cutting	27.1	39.5	48.9	34.7
Grinding	22.6	29.8	39.4	46.8
Horizontal NC lathes	48.2	57.1	70.2	68.2
Vertical NC lathes	27.7	52.0	34.0	53.4
Milling	26.6	45.4	28.4	35.4
Machining centers	36.9	63.0	49.4	53.0
Station type	1.1	4.9	35.2	15.3
Other metal cutting	35.0	54.9	74.3	70.7
Punching and shearing	34.6	40.0	30.8	34.1
Bending and framing	20.7	35.2	41.9	53.8
Presses	12.4	28.5	40.4	40.2
Other metal forming	35.4	42.3	46.6	40.5

Sources: Economic Handbook of the Machine Tool Industry, 1996-7; Rand Corporation report, "Decline of the U.S. Machine Tool Industry," Part I, p. 16.

America. It is our stupidity, by tolerating insane economic policies, that is the principal cause for this situation. When George Bush's friend Henry Kravis decided to destroy Houdaille-Burgmaster, can the Japanese be blamed? When Paul Volcker launched a scorched earth attack against American manufacturing, and most machine tool makers sat on their hands, can the Germans be blamed?

Still, there are the free-traders who rant that whether America imports its machine tools—the policy of outsourcing—or buys them from domestic producers, makes no difference. What they fail to comprehend is that economics is not a matter of cheap price; it is a matter of scientific and productive potential. The machine tool sector, with its skilled workforce, is not optional; it is the key to the future of America and of the world.

TABLE 3

U.S. share of combined six-major-nation machine tool production,* by type of machine

(percent of world total, in 1995)

Boring and drilling	28.3%
Gear cutting	27.5
Grinding	23.5
Station type/transfer	21.2
Milling	18.8
Machining centers	16.8

*Percentage of production of combined output of following nations: Japan, Germany, United States, Italy, Taiwan, South Korea.

Source: Economic Handbook of the Machine Tool Industry, 1996-97.

Can the machine tool industry be saved?

Despite the dramatic downsizing of the machine tool industry, there is a chance for revival.

Table 3 shows the U.S. share of the combined production by six of the world's largest machine tool producers for certain key types of machine tool machines in which America is still a leader. (These six countries, Japan, Germany, the United States, Italy, Taiwan, and South Korea, account for 75% of world machine tool production. One could not give percentages for the U.S. share of total world production of these types of machine tools because world figures were not available.) Further, U.S. machine tool builders still have research leadership or co-leadership in layered manufacturing, net shape manufacturing, flexible machining systems, laser welding and cutting, waterjet machining, and a few other areas, according to a 1994 RAND Corp. study.

Some U.S. machine tool companies are committed to excellence, where technological innovation—including building laser machine tools, five-sided machine tools, and so on—still goes on. But this is true for only a part of the sector, which is in a vastly shrunken condition. If the United States dumps the geometry of the bankrupt world financial system, in favor of a new Bretton Woods reorganization, combined with the Eurasian land-bridge project, it will need these machine tool companies as the core for future world economic growth.