The Development of American Machine Tools

by Pamela Lowry

> Huge mountains of Iron Ore are already discovered; and vast Stores are reserved for future Generations: This Metal, more useful than Gold and Silver, will imploy Millions of Hands, not only to form the martial Sword, and peaceful Share, alternately; but an Infinity of Utensils improved in the Exercise of Art, and Handicraft amongst Men. Nature thro' all her Works has stamp'd Authority on this Law, namely, "That all fit Matter shall be improved to its best Purposes." Shall not then those vast Quarries, that teem with mechanic Stone,—those for Structures be piled into great Cities,—and those for Sculpture into Statues to perpetuate the Honor of renowned Heroes; even those who shall NOW save their Country. O! Ye unborn Inhabitants of America! Should this Page escape its destin'd Conflagration at the Year's End, and these Alphabetical Letters remain legible,—when your Eyes behold the Sun after he has rolled the Seasons round for two or three Centuries more, you will know that in Anno Domini 1758, we dream'd of your Times.
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> —*Nathaniel Ames, in his* Boston Almanac *for 1758*

Many of the *Boston Almanac*'s readers wanted future Americans to have the opportunity to read what Ames had written, and so instead of throwing it into the fire at the end of the year, which was the usual way of disposing of almanacs, they put it away carefully in a trunk or desk drawer. Because of the care they took, the original copies of this almanac are still widely available today. And what does this have to do with machine tools? Everything, but unfortunately the U.S. Congress and the financial managers of the automobile industry seem completely incapable of grasping the connection.

"Machine Tools" is not a phrase you hear very often these days, and you would be hard-pressed to find it in an index of books on America's economic development, or biographies of inventors. Yet, machine tools and their relatively small group of designers are the lifeblood of a modern industrial economy. A nation which does not have a supply of machine tools is doomed to third- or fourth-world conditions. It's that simple: If the United States loses the machine tool capability embedded in its automotive sector, it gives up its ability to function as an industrial power.

Several officials of the United Auto Workers have stated the obvious, that there is really no problem with the auto industry because its machine tools "can make anything."[1] "Oh, no you don't!" comes the answer from the Globalization crowd. "We want to rule the world, and if you keep producing and making a better life, we won't be able to order you around."

The Americans of 1758 were very familiar with that policy, for Great Britain had just passed the Iron Act of 1750, which forbade its American colonies to produce worked iron products. Nevertheless, Americans continued to produce iron in locations more distant from the prying eyes of British enforcers, and by the time of the Revolution, Americans were producing one-seventh of the world's iron. The American Revolution and the War of 1812 were fought against that type of miserable repressive policy, which always seeks to put a lid on human creativity and production.

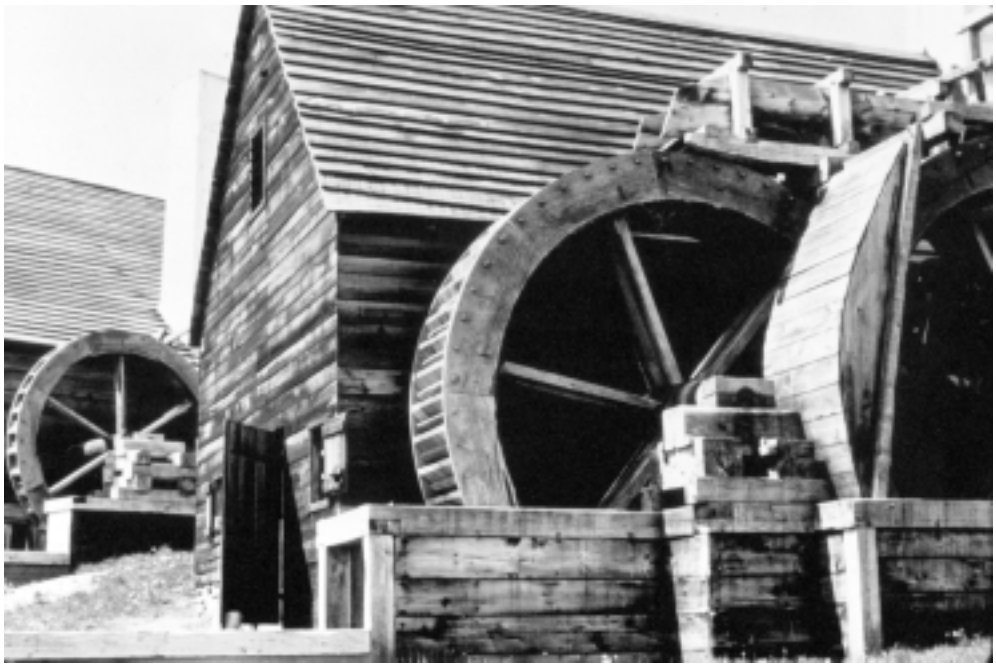
What the Americans of 2006 have lost sight of, is that the development of the nation's crucial reservoir of machine tools began as a conscious policy of the new United States government, and was brought into being by government partnership with private entrepreneurs. And, at crucial points in our history, further industrial development depended upon government intervention.

Throughout this process, it was taken as a matter of course that machine tools could be converted from one product to another, as the need arose. This retooling has happened again and again in American history, as a logical outcome of technological progress. In fact, it is the characteristic feature of machine tool development, which is never static, but always forges ahead with making improvements in what machines can do, and turns scientific discoveries into products which work for the benefit of man.

Creating a Republican Workforce

The United States of America had not even passed one decade under its Constitution when the government began a process of creating a technological innovation in production. It required four to five decades to bring the process to fruition, but it succeeded and spread to other industries and other nations. The new method was the production of muskets with

1. See interviews on LaRouche PAC's "Auto and World Economic Recovery" DVD, available at www.larouchepac.com.



The Saugus Iron Works in Massachusetts was established in 1647 as a complete iron-manufacturing establishment. The mechanics who trained here, moved out all over the colonies, to train others and set up new iron works. Here, a view of the rolling and slitting mill, powered by water wheels.

water-powered tools and with interchangeable parts, instead of handcrafted guns, which could not be repaired by using parts from other weapons. Gearing up for that type of production led to the design and construction of many types of machine tools. Once the basic prototypes of machine tools, such as millers and lathes, were up and running, they could be used to form many different products, including other machines.

The story of American machine tool development actually begins in the very early days of the Massachusetts Bay Colony, which had been founded in 1630 as a republic dedicated to the general welfare. The Massachusetts General Court (the name for the legislature) voted large subsidies for manufacturing, and John Winthrop, the leader of the republic, sent his son to England to recruit skilled labor for an iron-manufacturing facility. John Winthrop, Jr., returned in September of 1643 with men and equipment, and by 1647 the Saugus Iron Works had been completed.

The General Court had granted the company a 21-year monopoly, the necessary land, and a 10-year tax exemption. The conditions for the grant were that the company had to develop a complete iron-manufacturing establishment, from blast furnaces and forges to rolling and slitting mills. The company would only be permitted to export iron after the needs of Massachusetts Bay were met.

The rolling and slitting mill, powered by water wheels, was a very large machine tool, drawing malleable iron between rollers, which produced rods of several thicknesses. The thinnest of the rods were hammered into nails, a very necessary and valuable commodity. Bar iron was used for casting domestic implements and iron tools. By the end of its first year, the Saugus works was producing eight tons of wrought iron a week, way beyond the output of the finest iron works in England.

Dating from the founding of Saugus Iron Works, there is no break in the development of the American iron industry. Mechanics from Saugus fanned out all over the American colonies, spreading knowledge about industrial processes, as they trained other mechanics, and setting up hundreds of new ironworks. One example is provided by Joseph Jenks, an original Saugus mechanic, who designed and made machines for drawing wire, and also built a fire engine for Boston, the first one used in America. His son, also named Joseph and also an ironmaster, moved to Narragansett Bay and founded Pawtucket, one of the early centers of industrial development. The next Joseph Jenks, also an industrialist, became governor of Rhode Island.

The same was true of families named Leonard, Wilkinson, Brown, and Greene, including Revolutionary War General Nathaniel Greene, who had a cannon factory at Coventry, Rhode Island. A Wilkinson family member named David, who experimented with the steamboat, invented a slide lathe, which was patented in 1797. Although Wilkinson made patterns of his lathe which could be purchased for $10, he made little from it at the time. But 50 years later, Congress voted him $10,000 "for benefits accruing to the public service for the use of the principle of the gauge and sliding lathe, of which he was the inventor." This core group of largely New-England-based mechanics and entrepreneurs was utilized by the fledgling U.S. government to test and build the system of machine-tool-based production.

The large number of mechanics in New England is generally attributed in history textbooks to the poor quality of the

rocky soil and the shortage of labor, which "naturally" led to other occupations besides farming, and to the invention of labor-saving devices. But there are many areas of the world with poor soil and small population densities that do not abound in mechanics. It was the republican culture of New England that fostered the creativity shown by its citizens.

The New Federal Government Sponsors a Technological Revolution

Even though America won its revolution against the British Empire, it faced an uphill battle to develop its resources. Feeling no gratitude whatsoever for the major contributions made by an American, Benjamin Franklin, to create the industrial revolution in Britain, America's former "Mother Country" flooded the new nation with her manufactured goods, dumping them at prices below cost. Britain's aim was to discourage American manufactures, drive those already existing into bankruptcy, and reestablish America's dependence on the British Empire.

Parliament also passed stringent laws forbidding any technology transfer to its former colonies, and Britain policed its ports to prevent the emigration of skilled industrial operatives to America. A few enterprising mechanics, however, such as Samuel Slater of cotton-manufacturing fame, made it through by posing as simple rustics.

The motivation for this technological apartheid was not simply monetary advantage: The British Empire planned to recapture America, whether by economic or military means. Military means were tried in the War of 1812, and a surrogate military power, the Confederacy, was deployed in 1861. After the Union victory in the Civil War, Britain relied more heavily on economic techniques and various forms of corruption.

By the mid-1790s, the nation of France, America's former ally and the European leader in technology, had been devastated by the British-orchestrated Terror. To make matters worse, the newly installed government of "Revolutionary" France was hurling provocations at America, which threatened to lead to war. In this perilous situation, the Federal Government, under the Administration of President John Adams, made the decision to force a technological breakthrough.

This came in the form of a contract with Eli Whitney, which was the largest one the government had made to date. The contract specified that Whitney would produce 10,000 "stands of arms" to be delivered within 28 months, at a cost of $134,000. This was an unheard-of number of muskets in an incredibly short period of time, for up to that point, all guns had been slowly and painstakingly hand-crafted. The private gun shops, no matter how large, could never have fulfilled that contract, and the new federal armories at Springfield, Massachusetts, and Harpers Ferry, Virginia, had not yet been able to produce even 1,500 firearms in a year.

But Eli Whitney proposed to manufacture arms on a "new principle." He wrote about it to Secretary of the Treasury Oliver Wolcott in May of 1798, saying: "I should like to undertake the manufacture of ten to fifteen thousand stand of arms. I am persuaded that Machinery moved by water adapted to this Business would greatly diminish the labor and facilitate the manufacture of this Article. Machines for forging, rolling, floating, boring, grinding, polishing, etc. may all be made use of to advantage."

Library of Congress/Portrait by Mr. King

American inventor and manufacturer Eli Whitney undertook to fulfill a large government contract for firearms in a short time, at the end of the 18th Century, by basing the manufacturing on a "new principle." He used mechanization to eliminate much of the hand labor and made uniform parts for the arms. Later, he pioneered the manufacture of arms that had interchangeable parts, accurate to tolerances of 1/30th of an inch.

After he had spent a year constructing his factory and training his workers, Whitney wrote again to Wolcott: "One of my primary objectives is to form the tools so that the tools themselves shall fashion work and give to every part its just proportions, which once accomplished, will give exceptional uniformity to the whole."

Oliver Wolcott was a protégé of Alexander Hamilton, having served under him as Assistant Secretary of the Treasury during George Washington's Administration. Like Hamilton, Wolcott believed that the government could play a crucial role in developing manufacturing, and he was convinced that Whitney could establish an armory based on the most advanced technology.

Eli Whitney had grown up on a Massachusetts farm, where he spent his spare time putting his considerable mechanical talents to work, repairing violins and iron implements. During the American Revolution, he made nails in his

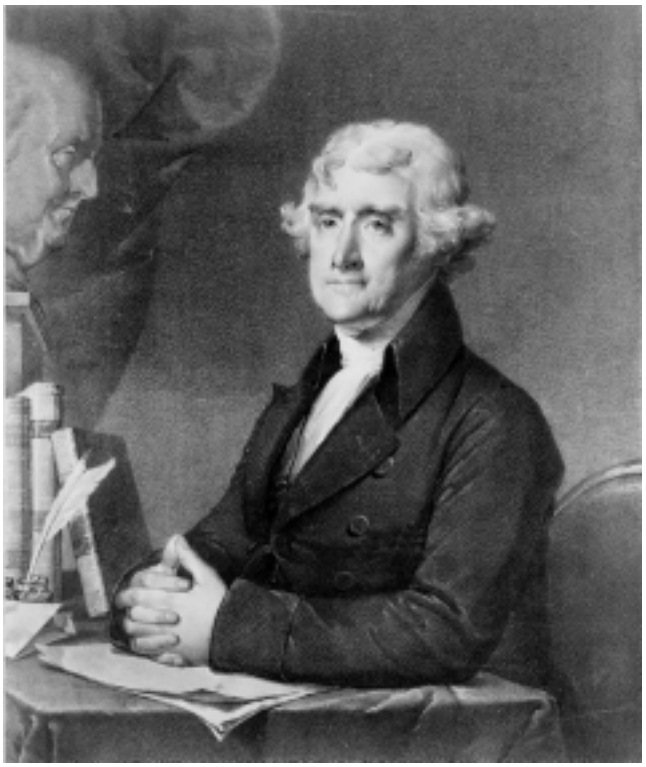
father's workshop and saved enough money to pay for tuition at Yale. There, he supplemented his savings by repairing the college's scientific equipment. His invention of the cotton gin as a favor to the widow of Revolutionary War General Nathanael Greene earned him fame, but very little money. It did, however, give him basic experience in designing a factory and training workers. Early support for Whitney's endeavor came not only from Oliver Wolcott, but also from Vice President Thomas Jefferson. Although Jefferson idealized an agricultural society, he believed in using the most advanced technology for that society. At his home, Monticello, he not only bought one of Whitney's cotton gins, but he installed a nail-making machine and one of Oliver Evans' completely mechanized flour mills, and later he purchased Evans' powerful high-pressure steam engine.

At the time of the 1798 government contract for arms, Jefferson was looking for a way to implement a process of arms manufacture that he had seen when he was the American Ambassador to France from 1785 to 1789. After the defeat of France in the French and Indian War, French General Jean-Baptiste de Gribeauval, the Inspector General of Artillery, proposed that muskets be manufactured with interchangeable parts. The inspector of three French Royal Arsenals, Honoré LeBlanc, developed a method which resulted in at least an approximation of interchangeability. In August of 1785, Jefferson had written to John Jay, asking that Congress be informed of the method and its possibilities. Jefferson attempted to bring LeBlanc to America, but did not succeed.

A Committee of the French Academy of Sciences confirmed the validity of LeBlanc's system, but when the French Revolution entered its British-controlled phase, both the Directory and then Napoleon rejected LeBlanc's method. But there was also another way in which the concept of interchangeability came to America. The Continental Army had depended heavily on French arms and equipment, and the French officers who came here spread the ideas of French military practice and technology. After the Revolution ended, some French officers continued to serve in America, and others returned from France later, as fugitives from the Terror.

One of these was Major Louis de Tousard, who had served under Lafayette and joined the U.S. Corps of Artillerists and Engineers when it was created in 1795. Tousard participated in designing fortifications, and taught his fellow officers the principles of artillery and engineering that he had learned in France. He also wrote a proposal in 1798 entitled "Formation of a School of Artillerists and Engineers," which he sent to the Secretary of War, James McHenry. It was a blueprint for the future West Point, based on French military and engineering experience.

President George Washington suggested to Tousard that he write a book on artillery, and it was published in three volumes in 1809 as the *American Artillerist's Companion.* The work became the standard textbook for American military officers at posts around the nation, as well as for the cadets at West Point. In his book, Tousard stressed the importance of "a system of uniformity and regularity," in arms and in military practice. One officer who served with Tousard was Col. Decius Wadsworth, who became the first U.S. Chief of Ordnance. From that position, Wadsworth did everything he could to help develop mechanized production and the interchangeability of parts.



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Thomas Jefferson, although he idealized an agricultural society, believed in using the most technologically advanced machinery, and he fully supported Whitney's efforts to invent labor-saving devices.

The System of 'Armory Practice' Begins

Eli Whitney and Thomas Jefferson had become friends when Jefferson bought one of Whitney's cotton gins, and the two shared an enthusiasm for labor-saving inventions. When Whitney began to build his factory on a river north of New Haven, Connecticut, he incorporated the idea of interchangeable parts into his production plans. But at America's current technological level, with no help coming from enemy Britain or from former ally France, Whitney knew he faced an uphill battle. As he wrote to Wolcott, the difficulty was that, "A good musket is a complicated engine and difficult to make, difficult of execution because the conformation of most of its parts correspond with no regular geometrical figure." In addition, what machines there were at the time were constructed of wood and iron, malleable substances that were not capable of producing parts which varied by only very minute tolerances.

EIRNS/Colin Lowry

These are machine tools—lathes for gun-making—at the Harpers Ferry, West Virginia, museum. The Harpers Ferry Arsenal was established by President George Washington. It became a laboratory for checking the worth of proposed inventions.

Nevertheless, Whitney wrote to Wolcott that his aim was "to make the same parts of different guns, as the locks, for example, as much like each other as the successive impressions of a copper-plate engraving." To begin, Whitney broke down the production tasks into their component parts and trained his workmen to perform one "single and simple operation" at a time. He designed a series of "jigs and fixtures" which fixed the parts and tools into their relative positions for each operation, so that the cutting of the part by the tool would be correct and consistent. Whitney had to hire largely unskilled workers, because those skilled in the mechanical arts generally moved from workshop to workshop. This peripatetic tendency was beneficial for spreading new production techniques, but it often gave headaches to the employers.

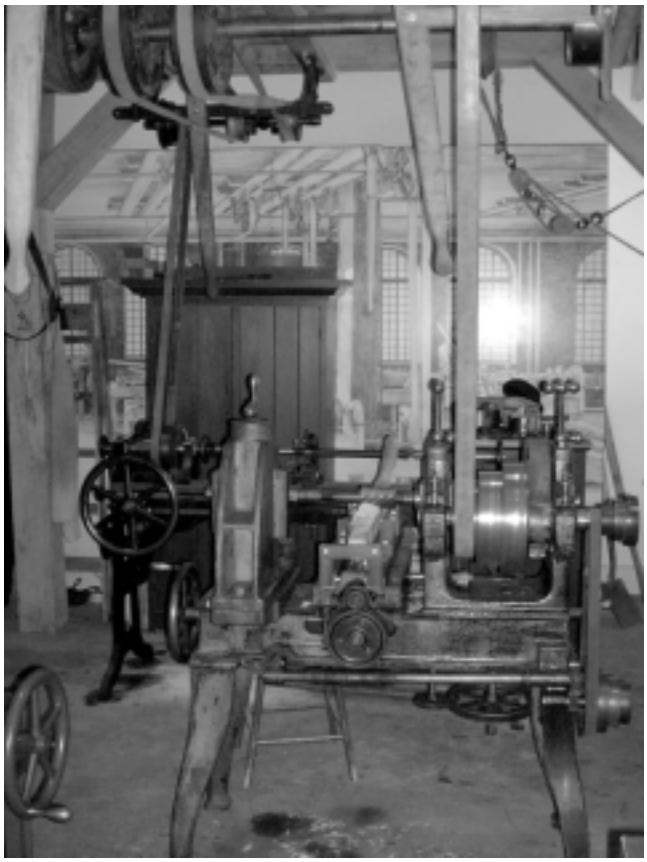
Whitney's unskilled workers often developed into highly skilled operatives, and Whitney noted that he was making armorers as well as arms. Many an unskilled worker progressed to supervisor, and then to entrepreneur with his own machine shop, training other workers to follow in his footsteps.

By January of 1801, Whitney still had not produced a single musket, because it had taken several years to set up the new system. The government was questioning whether he could fulfill his contract, and so Whitney took some of the gun parts that his company had produced and brought them to Washington. There, in a meeting attended by outgoing President John Adams, soon-to-be-President Thomas Jefferson, the Secretaries of War and Treasury, and leading Congressmen and military officers, Eli Whitney fitted together various musket parts using only a screwdriver. The parts had been finished by hand-filing to make them correspond, but many of the tolerances in his metal parts, molds, hammers, and gears were measured to 1/30th of an inch, which was excellent for the time. It was only by the end of the 19th Century that 1/1,000th of an inch tolerances were obtained.

The attendees at the meeting were encouraged, and Whitney continued his work. By that time, only 1,000 of the 32,000 muskets ordered by the government had been produced by all the private government contractors combined. Most of the contractors, working on the old handcrafting system, were substantially behind, or had gone bankrupt, highlighting the need for Whitney's new industrial technology. Although Whitney did not deliver all of the 10,000 muskets until eight years after the start of his initial contract, his production methods had improved so substantially by the War of 1812, that he was able to deliver 15,000 high-quality firearms on time, under a new contract.

More important, Whitney's production system was adopted by the Federal Government for its arsenals at Springfield and Harpers Ferry. It became known as "armory practice," and Whitney and his coadjutators continued to press for ever-increasing improvements. Two of Whitney's allies were Thomas Jefferson and Robert Fulton. Inventors such as Fulton were very dependent on mechanics, who could design tools and machine tools that would turn their inventions into reality.

Whitney and his two friends were members of the West Point Military Philosophical Society which had been founded by Jonathan Williams, the great-nephew of Benjamin Franklin. The Society was the repository for the records of the Corps



EIRNS/Colin Lowry

Another view of gun-making lathes at the Harpers Ferry museum.

of Engineers, and held its meetings in various cities to discuss and disseminate technological innovations. This was one way in which the details of armory practice reached other parts of the country. Another means adopted was for the U.S. Government to require the use of new methods in its contracts with private entrepreneurs. In 1813, the War Department made a contract for pistols with Simeon North of Connecticut, which specified that "the component parts are to correspond so exactly that any limb or part of any one Pistol may be fitted to any other Pistol of the twenty thousand." North adopted Whitney's system, and in 1816 he designed and built a milling machine, a machine tool that could cut and shape a flat or curved iron surface.

Just the year before, Col. Decius Wadsworth, chief of the U.S. Ordnance Department, had called for an important meeting at Eli Whitney's establishment in New Haven. In addition to Wadsworth, the participants included Whitney, Roswell Lee, the director of the Springfield Armory and a former employee at Whitney's factory, and James Stubblefield, the director of the Harpers Ferry Armory. After intensive discussions, the participants agreed on a strategy for standardizing the manufacture of arms, not just between the two government arsenals, but also between the arsenals and the private contractors.

The Springfield Armory, located within a dense network of New England mechanics' shops, would manufacture inspection gauges, and all components would be measured against the master gauge for that particular type of piece. The U.S. Arsenals would serve as research laboratories as well as production facilities, and private contractors were to be given access to their discoveries and offered generous terms so that they could retool their shops to meet government requirements.

In this process, American mechanics invented machine tools such as milling and grinding machines and the turret lathe, which held a succession of tools which could be swung into place to fashion the piece being worked. Springfield's director, Roswell Lee, travelled extensively, coordinating with Harpers Ferry and looking for technological improvements at the private machine shops, as well as sharing new ideas with them. A number of barrel-turning lathes were developed in the Springfield area, and that of Thomas Blanchard in 1819 used a mechanism that traced the form of a metal gun barrel and reproduced the model in wood. Blanchard was brought to the Springfield Armory and subsidized by the government, to enable him to perfect his invention and build his machine. It became part of a sequence of 14 machines for making gun-stocks that virtually eliminated manual labor from much of gun manufacturing, and was adopted at both Federal arsenals.

The U.S. Arsenal at Harpers Ferry had been established by President George Washington on the shortest route to America's Northwest Territory, a site on the under-construction Potomac Canal. The area lacked the surrounding machine shop infrastructure possessed by the Springfield Armory, but the proximity of the nation's capital made Harpers Ferry a laboratory for checking the worth of proposed innovations. One of these innovators was John H. Hall of Maine, who proposed to manufacture the breech-loading rifle he had invented, rather than the standard muskets which had to be loaded at the barrel.

Hall's manufacturing operation at first used space in the Federal arsenal itself, but after a few years it moved across the narrow peninsula to its own rifle works on the Shenandoah River. Hall designed 63 separate gauges to monitor the accuracy of his products, and invented the concept of the "bearing point." This consisted of a single reference point on the workpiece, from which all other fixtures were measured.

Hall's costs were high, but he was backed by George Bomford, a West Pointer and engineer who had succeeded Decius Wadsworth as head of the Ordnance Department. Through his wife, Bomford was related by marriage to statesman and poet Joel Barlow, and Bomford had invented a powerful cannon which he named the "Columbiad" in honor of Barlow's poem. The Barlows had been close associates of Robert Fulton during his steamboat experiments in France, and thus were part of the inventor/entrepreneur/mechanic circles who were eager to see further industrial development.

Hall ran into fierce opposition because of his costs and the

jealousy of Superintendent Stubblefield, who resented Hall's semi-autonomous status; but each time a government inspection team visited Hall's works, it was impressed by Hall's accomplishments. Finally, on March 8, 1827, Hall was given a government contract which specifically made his primary function the development of machine tools. His salary was doubled, and he was to produce 3,000 rifles a year with a royalty of one dollar for each one produced, a royalty paid not for the guns but for the use of machines "for cutting metallic substances," which Hall had patented. In addition, Hall agreed to improve "the methods of conducting the business" and to perfect "the machinery therefore."

Hall built his machines of very heavy forged iron and wood to compensate for variations in tolerance caused by motion or malleability of the machine itself. He used large and small drop forging machines with dies to compress and shape iron, a process which had been attempted by Honore LeBlanc in France many years before. Drop forging was also being installed by the Jenks and Leonard families, now in the fourth or fifth generation since the Saugus Iron Works, and there was much give and take of technical information among these private works and the national armories.

The Crystal Palace Exhibition

By the 1830s and 1840s, American machine tools were coming into their own. In 1834, Simeon North copied John Hall's gauges, which enabled him to interchange the parts of rifles made at his factory with those made at the U.S. Arsenal at Harpers Ferry. "Armory practice" was being extended to other types of manufacturing by arsenal workers who accepted other employment, and it was having particular success in the New England clock manufactories.

Eli Whitney died in 1825, the same year as his supporters John Adams and Thomas Jefferson. But his son, Eli Whitney, Jr., carried on his father's manufacturing business and outlook. One day in early 1847, Whitney, Jr. was visited by Samuel Colt, who had designed a six-shooter revolver. Colt was a colorful character who had been apprenticed by his father to a sea captain heading for India, after two of young Sam's fireworks displays for the Fourth of July had ended in blazing disaster. Colt designed a six-shooter gun, but technical problems plagued him, and he made the money he needed for further research by giving public lectures on the effects of laughing gas, with audience participation. Through the influence of the Texas Rangers and the endorsement of Sam Houston, Colt was able to obtain a government contract to produce a thousand of his revolvers, but he had no factory to produce them.

So Colt offered Eli Whitney, Jr., an unusual contract: Colt would pay Whitney to manufacture the guns, but then he, not Whitney, would own the machines. Whitney eventually accepted, designed the machines, and allowed Colt to stamp the guns with his name. Colt lost money on his government contract, but he took the machine tools and installed them in a factory in Hartford, Connecticut. This was probably the first time an entire factory of machine tools had been set up in one company by another.

Colt prospered and set up another factory in London. He hired and trained the workers, but after a number of years there were so many difficulties that he had to shut it down. There was too much British Government red tape, and the workers, used to the medieval craft system, tended to be inflexible and unable to produce a standard product. There were some excellent machine tool designers in Britain, but the machine tool itself was regarded as a craft object, and the concept of interchangeable parts seemed unattainable and, to many, unnecessary.

In the spring of 1851, Great Britain opened a world's fair in an iron and glass building dubbed the "Crystal Palace." All nations were invited to exhibit their products, and Britain, regarding itself as the "workshop of the world," was eager to showcase its accomplishments and also to see what it might need from others, especially as it still pursued a policy of breaking up or recapturing the United States.

The American exhibit was small and located in too large a space, and at first it produced nothing but scorn on the part of those who viewed it. Queen Victoria herself stated that she saw nothing interesting in it, and when that remark became known, some Southern newspapers started making derogatory comments about the Northern industries that had produced some of the exhibits. But when the exhibition's judges started to test some of the American machines and inventions, the tide turned. The McCormick reaper won a Council Award, and Goodyear's lifeboat, Chickering's piano, and Colt's revolvers all won praise.

The Robbins & Lawrence Company of Windsor, Vermont, had sent a set of their Sharps rifles, which were made with completely interchangeable parts. Increasing numbers of British military officers came to see this exhibit, and their pressure on the British Army Ordnance Department finally resulted in the founding of a Small Arms Committee which was to travel to the United States and view the armory system in operation. The Committee was allowed to visit the Springfield Arsenal and to watch production at a number of other firms.

As a result, the British contracted for their Enfield Armory (where armorers had been producing weapons at their individual benches), to be completely fitted out with 157 American machine tools, including 74 universal millers. The U.S. Government, which at this point was controlled by pawns favorable to British Imperial policies, allowed supervisors and workmen from the national arsenals to go to Britain and work at Enfield. This was the origin of the Enfield rifle. Many of these Americans did not return until right before the outbreak of the Civil War.

Winning the Civil War

President Abraham Lincoln was faced with a monumental task when the South seceded and war broke out. The United States was bordered by British Canada on the north, where

Library of Congress

President Abraham Lincoln was an advocate of new technologies for weapons manufacture, and often tested new gun designs himself, beyond the White House back lawn. Under Lincoln, America's machine tools and manufacture greatly expanded to meet the wartime needs.

British intelligence agents ran safehouses for Confederate agents and planned strategy to defeat the Union. Almost all the Crowned Heads of Europe supported the Confederacy, and in 1864 Napoleon III of France sent his troops to support Archduke Maximilian's installation as "Emperor" of Mexico. This would provide an open road south for the expansion of a slave empire from the Confederacy.

Because of its slave-based culture and economy, the South had little industry, but it was willing to use what the North had created. On April 18, 1861, the Confederates captured the U.S. Arsenal at Harpers Ferry and shipped off the machine tools, rifles, and other equipment by wagon and rail to Richmond. The Confederacy was also able to accumulate 400,000 Enfield Rifles by purchasing them in Britain before the war, or by sneaking them in around the Union blockade after hostilities began. The Enfield Rifles had been built by machine tools that the Confederates could not produce, and, like the British Empire, the Confederacy's leaders hated and feared the culture that had created them.

President Lincoln, an inventor himself, was ready and willing to give a hearing to any technological improvement that could help the Union win the war speedily. But he faced an Army Chief of Ordnance who was fixated on the fact that the Union Army was using many types of muskets and rifles with many different calibers of bullets. Because of the difficulty of supply, General James W. Ripley was dead-set against developing any new weapons, no matter how useful.

Lincoln had less trouble with the Navy, and he spent many days at the Washington Navy Yard, watching weapons tests and talking with inventors. When it came to the Army, inventors knew Lincoln would meet with them and try to get around Ripley. One example was the inventor Christopher Spencer of Manchester, Connecticut, who had been a workman at the Colt Armory. Spencer had patented a repeating rifle in 1860, and brought one of them to the White House in 1862.

So many inventors of guns had visited Lincoln, that he had set up a simple rifle range on the open ground beyond the White House back lawn. When Spencer came, they went out and shot at a board. Spencer reported later that Lincoln was a good shot, but that he tore his coat in the process of testing the rifle. The President remarked that Spencer shouldn't worry about it, because he "never had anything of value in it to lose." Lincoln succeeded in convincing Ripley of the value of the repeating rifle, and by the end of the war the government had ordered 200,000 of them.

The need for armaments, both existing and newly invented, caused a great expansion of America's machine tool supply. Two mechanics who produced arms for the Union during the Civil War set out to establish a uniform set of measurements and gauges in both America and Europe, which would firmly establish the machine tool industry's ability to produce absolutely interchangeable parts. One was Francis Pratt, who completed his apprenticeship with a Lowell, Massachusetts, machinist and eventually went to work at the Colt Armory. Two years later, Pratt became foreman of the Lincoln Iron Works and worked on designing and producing the "Lincoln Miller" for the Colt Armory. This all-purpose miller became the leading American machine tool, used for producing a multiplicity of products. More than 150,000 of these millers were eventually produced and sold throughout America and the world.

While Pratt was at the Lincoln Iron Works, he arranged for a fellow worker at the Colt Armory to join him. This was Amos Whitney, born in Maine and a member of a branch of Eli Whitney's family. Whitney had previously worked for the Essex Machine Company, which built cotton spinning machinery, locomotives, and machine tools. The two friends rented a small room and began to produce Lincoln Millers while still keeping their jobs at the iron works. With the advent of the Civil War, they moved into gun manufacturing, but when the war was over, they formed the company of Pratt & Whitney to manufacture machine tools. Like many others before them, they had progressed from apprentice to journeyman to foreman to partner in a firm.

Establishing Accuracy in Measurement

What distinguished Pratt & Whitney from many others with equally talented employees was its partners' decision to explore the basic principles of machine design and measurement. By the Civil War, mechanics were measuring in terms of 32s of an inch, but the actual size of that inch was still not established, and varied widely, as did the foot and the yard. Francis Pratt decided to establish the actual size of those measurements and to invest in research on hardening steel so that a product could not only be worked to an accurate size, but its material would also be able to maintain that exact dimension. Accuracy from product to product, and from machine tool to machine tool would ensure the production of truly interchangeable parts in large quantities and at a much lower cost.

As Secretary of State, John Quincy Adams had written a major history of weights and measures; and Alexander Dallas Bache at the Coastal Survey, which included the Bureau of Standards, had worked to coordinate Federal measurements with those of the states. This work was complemented by Pratt and Whitney, who established a Gauge Division which set itself the task of establishing a practical standard inch of exact dimensions. The work was completed over a number of years, and the standard was accurate to millionths of an inch.

This project required cooperation with scientists, and in 1879 came an opportunity to work with an eminent astronomer. William A. Rogers was a mathematician, physicist, and astronomer who then worked at Harvard University's observatory. He was put in charge of the newly erected 8-inch meridian circle, and his chief task was the observation of the catalogued stars between 50-55 degrees north declination. This was part of an international project by the German Astronomische Gesellschaft (Astronomical Society) to establish the accurate positions of all of the sky's brightest stars.

In 1879, Rogers was sent to Europe by the American Academy of Arts and Sciences to obtain copies of the British imperial yard and the French meter. Pratt & Whitney entered into a cooperative agreement with Rogers and his assistant, George Bond, to develop a machine which could make absolutely correct measurements within a limit of one 50/1,000ths of an inch. After obtaining the British and French standards, as well as a copy of the United States Standard Yard, all three were painstakingly compared with the copies which Rogers had made for Pratt & Whitney. To do the work of comparison, the two scientists developed a large machine called the Rogers-Bond Comparator.

By 1880, Pratt & Whitney had a set of master bars, accurate within millionths of an inch, and these became the standard for its machines and products. By 1885 the company had developed its own Standard Measuring Machine, which could construct and duplicate recognized standards of length. Although modern standard measurement of the meter has progressed to being based on the wavelengths of the orange-red radiation of krypton 86, and not on metal bars, Pratt & Whitney's establishment of exacting standards for American machine tools ensured their use around the world.

Retooling As a Given

Throughout the development of American machine tools, flexibility was an important factor. The mechanics and machine tool designers, often united in the same person, could design machines for making arms, clocks, railroads, or other machines. The all-purpose machines, such as millers, planers, drillers, and so on, could be used for many different products. A machine to bore the barrel of a rifle could also drill a hole in the crankshaft of an automobile, so that oil could reach the bearings. And so companies which had produced arms during the Civil War had no trouble in converting to making sewing machines, typewriters, or bicycles. Lincoln's policies for credit and industrial development during the war served as the basis for a rapidly growing economy, one which amazed those who had thought that America would be prostrated by the conflict. Instead, many European nations rushed to emulate the American system.

The machine tools of the late 19th Century began to be powered by electricity, rather than water or steam. Central to this development was the work of Thomas Edison, whose research laboratories at West Orange, New Jersey, contained a large machine tool shop. Edison's machine tools were used to develop prototypes of his many inventions, and then to produce them.

The turn of the century saw the development of two inventions which were linked, and which have epitomized the concentrated use of machine tools. The automobile and the airplane both relied on the bicycle makers and their machine tools for their early development. The Wright Brothers both repaired and made bicycles in their small shop, and used the principles of balance and lightness of materials to advantage in their development of the airplane. Henry Ford constructed his prototype automobile partly from bicycle parts and the principles of bicycle construction.

In the early part of the 20th Century, there was much give and take between airplane and automobile makers, and World War I caused several auto makers to move into airplane production. Henry Ford, who was a great admirer of Thomas Edison, grasped some of the implications of machine tool development very early in his automotive career. He enjoyed walking through the assembly area of his Highland Park plant and chatting with the workers. If a new employee was struggling with his machine, he would stop and show him how it was done. Afterwards, he would say: "That's what they make these machines for—to do the work. You don't want to work. When you go home you don't want to be tired. When you go home to your family you want to feel good."

Ford was always on the lookout for better ways to do things. He introduced the assembly line into production, sponsored research on vanadium steel—a particularly hard type of

FDR Library

President Franklin Roosevelt, here with plant workers in 1943, in Tulsa, Oklahoma. Roosevelt relied on America's machine tool capability, which his policies had preserved during the Depression, to mobilize industry to meet the demands of winning World War II. America quickly became the "Arsenal of Democracy."

the metal—and when his staff found a more efficient machine tool, they scrapped all the older models. The most spectacular example of machine tool replacement occurred in the mid-1920s, when the falling sales of the original Model T forced the company to design a new Model A, which required the purchase of 4,500 new machine tools. And all the automobile manufacturers became known for their retooling efforts each year, when their cars' new models came out, an effort to keep sales up by constantly changing the product.

America Becomes the Arsenal of Democracy

Because America's machine tool base had been preserved by President Franklin Roosevelt's policies during the Great Depression of the 1930s, the United States was in position to combat the growing fascist threat in Europe and Asia, but much still had to be done. In a message to Congress on January 12, 1939, the President reviewed the unprepared state of America when World War I began, citing the fact that it had taken at least a year to gear up, and that even in the autumn of 1918, American troops at the front were using French or British artillery and aircraft. Roosevelt cited the fact that he had already warned Congress, "We must have armed forces and defenses strong enough to ward off sudden attack against strategic positions and key facilities essential to ensure sustained resistance and ultimate victory." He had also warned them, "We must have the organization and location of those key facilities so that they may be immediately utilized and rapidly expanded to meet all needs without danger of serious interruption by enemy attack."

In addition to asking for appropriations to modernize the armed forces, Roosevelt told the Congress: "I suggest approximately $32,000,000 for 'educational orders' for the Army—in other words, to enable industry to prepare for quantity production in an emergency, of those military items which are non-commercial in character and are so difficult of manufacture as to constitute what are known as 'bottlenecks' in the problem of procurement."

By early August, a War Resources Board had been established to coordinate with the Army and Navy on developing an Industrial Mobilization Plan, and the work was completed by late November. Because of the breakout of war in Europe, FDR had proclaimed a Limited National Emergency in September, which was aimed at "the proper observance, safeguarding, and enforcing of the neutrality of the United States and the strengthening of our national defense within the limits of peacetime authorizations."

On May 26, 1940, Roosevelt delivered a Fireside Chat on the subject of national defense. He said that the Government, working with industry, was determined to increase the aviation industry's capacity to be able to produce 50,000 planes a year. He also talked about forcing necessary scientific and technological breakthroughs: "In this era of swift, mechanized warfare, we all have to remember that what is modern today and up-to-date, what is efficient and practical, becomes obsolete and outworn tomorrow. Even while the production line turns out airplanes, new airplanes are being designed on the drafting table. Even as a cruiser slides down the launching ways, plans for improvement, plans for increased efficiency

Ford Motor Company

The vast Ford Rouge complex in Dearborn, Mich. epitomizes the industrial development of America, building on the machine tool priciples inaugurated in the 1600s.

in the next model, are taking shape in the blue-prints of designers."

Echoing the intention of the Massachusetts Bay Republic in giving government credit to the Saugus Iron Works, and the U.S. government policy of developing mechanized machine tools and interchangeable parts, Roosevelt said: "I know that private business cannot be expected to make all of the capital investment required for expansions of plants and factories and personnel which this program calls for at once. Therefore, the Government of the United States stands ready to advance the necessary money to help provide for the enlargement of factories, the establishment of new plants, the employment of thousands of necessary workers, the development of new sources of supply for the hundreds of raw materials required, the development of quick mass transportation of supplies."

Because President Roosevelt also understood the concept of the general welfare, he stated that Americans must make sure, "in all that we do, that there be no breakdown or cancellation of any of the great social gains we have made in these past years. We have carried on an offensive on a broad front against social and economic inequalities and abuses that had made our society weak. That offensive should not now be broken down by the pincers movement of those who would use the present needs of physical military defense to destroy it."

President Roosevelt set up a Commission and Council of National Defense and named William S. Knudsen, the president of General Motors and a former executive at the Ford Motor Company, to serve as Director General of the Office of Production Management. Henry Ford, who had strong pacifist leanings and had spent a short time on the board of the isolationist America First Committee, reluctantly constructed the huge Willow Run airplane plant that produced both planes and the Pratt & Whitney engines that powered them.

On Dec. 29, 1940, President Roosevelt again addressed the nation over the radio. Over the preceding months, he had criss-crossed the nation inspecting the gear-up of its industrial plants, which were producing materiel to support Britain and Greece in their struggle against the Axis Powers, as well as preparing for the onslaught against America which was to come. On Oct. 30, he had visited the U.S. Arsenal at Springfield and the Pratt & Whitney plant in Hartford, Connecticut.

Speaking about the retooling going on in industries across the nation, Roosevelt stated that "American industrial genius, unmatched throughout the world in the solution of production problems, has been called upon to bring its resources and its talents into action. Manufacturers of watches, farm implements, linotypes, cash registers, automobiles, sewing machines, lawn mowers, and locomotives are now making fuses, bomb packing crates, telescope mounts, shells, pistols, and tanks."

There were industrialists, such as Henry J. Kaiser, who were known as "all-outers," people who were gladly willing to expand capacity to stop fascism. There were others, however, who were lukewarm about expansion, fearing that they would be faced with idle capacity when the war ended. Presi-

U.S. Office of War Information

Inside the Ford Rouge plant in 1944, where automobile machine tools were retooled for war production. As Roosevelt said, "American industrial genius, unmatched throughout the world in the solution of production problems, has been called upon to bring its resources and its talents into action." Today, we need to mobilize again for the survival of the nation and the world.

dent Roosevelt addressed this problem: "Our defense efforts must not be blocked by those who fear the future consequences of surplus plant capacity. The possible consequences of failure of our defense efforts now are much more to be feared. After the present needs of our defenses are past, a proper handling of the country's peace-time needs will require all the new productive capacity—if not more."

Towards the end of his radio broadcast, Roosevelt made his famous statement: "We must be the great arsenal of democracy. For us this is an emergency as serious as war itself. We must apply ourselves to our task with the same resolution, the same sense of urgency, the same spirit of patriotism and sacrifice as we would show were we at war."

The Attack Today

Today, the American auto industry and its workers are under an attack which threatens to destroy our nation itself. While Americans are distracted by the supposed "War Against Terror" at the front door, the Synarchist International has sneaked around to the back door, and is selling off America's patrimony for a mess of potage. They are selling the machine tools not for the profit involved, but to deprive the United States of the ability to resist their intention to install a bankers' dictatorship enforced by private armies.

There is a solution available: The foundation was laid by America's Founding Fathers and used by President Franklin Roosevelt. The auto industry is America's prime example of retooling capability; and U.S. government credit to turn its excess capacity over to producing much-needed infrastructure such as railroads, power plants, and water management systems makes perfect sense. Lyndon LaRouche has produced a draft outline of the legislation which is needed to carry this into effect.[2] What is needed are Congressmen who will introduce such a bill and "now save their country." In a desperate situation such as this, members of Congress have to be reminded that they are the representatives of the real sovereigns of America—the American people. President Roosevelt said it well in 1940: "For more than three centuries we Americans have been building on this continent a free society, a society in which the promise of the human spirit may find fulfillment. Comingled here are the blood and genius of all the peoples of the world who have sought this promise.

"We have built well. We are continuing our efforts to bring the blessings of a free society, of a free and productive economic system, to every family in the land. This is the promise of America.

"It is this that we must continue to build—this that we must continue to defend.

"It is the task of our generation, yours and mine. But we build and defend not for our generation alone. We defend the foundations laid down by our fathers. We build a life for generations yet unborn. We defend and we build a way of life, not for America alone, but for all mankind. Ours is a high duty, a noble task."

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2. "The U.S. Economic Recovery Act of 2006."