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JET ENGINE MANUFACTURING IN NEW ENGLAND

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Executive Summary

New England is the birthplace of the American jet engine industry. Employing 33,675 people, 128 firms in the industry build the complex parts, components, subassemblies, and control systems that make up a gas turbine engine. Massachusetts industry employment accounts for about 9 percent of total U.S. jet engine and engine parts manufacturing employment, and the state is second only to Connecticut in its concentration of aircraft engine manufacturing employment. Some twenty firms in Massachusetts employed 11,056 people in this industry in the first quarter of 1999. Building jet engines has traditionally been a successful, but often overlooked, example of Massachusetts firms' strengths in high-tech manufacturing.

The aircraft gas turbine is a technology truly indigenous to New England. The worldwide leaders in the industry, General Electric Aircraft Engines and Pratt & Whitney, whose combined market share totals 80 percent, both trace their roots to the region. The successes of these firms were historically based as much on the wealth of precision production skill in the area as on the engineering and scientific talent that was so abundant in the region, thanks to the technical strengths of New England's universities.

Throughout the post–World War II era, innovations in propulsion were the "pacing technology" that led the improvements in aircraft performance, which in turn grew the market for air travel. With each new generation of aircraft engines, air travel became faster, cheaper, safer, and less damaging to the environment. In many ways, the story of the jet engine industry epitomized the golden age of U.S. capitalism in which technological progress helped to grow new markets, providing more and better employment opportunities over time. New England was, for much of the postwar era, at the center of this industrial success story.

Recent trends, however, have been less than positive for workers in New England's aircraft engine industry. Though layoffs and industry consolidation have slowed somewhat since the dark days of the early 1990s, when a downturn in both the military and commercial segments of the aircraft market led to devastating job losses, they still continue. And though the mass job losses and wage stagnation experienced by workers in the industry during the early 1990s could be attributed to a drop-off in demand, the recovery of the demand for aircraft has by and large failed to restore employment levels or lead to real wage growth, either regionally or nationally. Between the fourth quarter of 1993 and the fourth quarter of 1997, at a time when manufacturing employment as a whole remained essentially flat, Massachusetts employment in the industry declined 7.5 percent. Nationally, jet engine employment fell 19 percent between these years, even though new orders in 1997 were 24 percent higher than they were in 1993.

These trends are troubling because they suggest a "divergence of fortunes" between firms' well being and that of workers in the industry. It appears that corporate strategies rather than market forces alone are shaping these employment trends. An increasing reliance of engine manufacturers on overseas suppliers, a desire on their part to exit manufacturing activities in favor of more profitable servicing activities, and increased pressures on the part of managers to deliver "value" to shareholders all seem to be playing a role. These conclusions present a particular challenge to state-level policy makers who might seek to stem the tide of job losses in the industry.

Introduction

The aerospace industry, the "crown jewel" of U.S. manufacturing, was for decades after World War II the source of the many good things advanced industrial economies are expected to provide: good jobs with growing wages, technological advances that allowed for both increased productivity and qualitatively better products, and the export of U.S. value-added to other countries. All these developments helped to ensure the health of firms in the industry while simultaneously contributing to improved U.S. standards of living.

This state of affairs was especially present in the engine-manufacturing sector of the aerospace industry. Since the introduction of the jet engine in the 1940s, U.S. firms have come to dominate the global market for aircraft gas turbine power plants. The design innovations engine makers built into each new generation of products allowed for air travel that was ever safer, faster, cheaper, and less environmentally damaging than earlier products; technological advances in propulsion improved aircraft performance and thus helped to grow the market for air travel. Alongside the growth of the market, employment opportunities expanded, and as productivity grew, better wages followed.

For much of the postwar period, New England was at the center of this industrial success story. The combination of production skill, technical expertise, and scientific talent embodied in the region's workforce contributed greatly to the prosperity of the leading firms in the industry and, in turn, the region's workers shared in the fruits of these firms' competitive success.

The industry has seen hard times of late, however. The end of the Cold War has, it seems, permanently reduced demand from the aircraft industry's single most important customer, the U.S. Department of Defense. The decline in U.S. government orders has meant fewer sales but at the same time has entailed a redefinition of "value" in the industry. As fuel prices dropped[1] and the product has matured over time, airlines have turned away from state-of-the-art engine designs, preferring simpler products with fewer parts that are easier to maintain. Producers of aircraft and engines are under more pressure than ever to offer equipment that is cost-competitive at the time of purchase *and* in operational service.[2]

Despite these challenges to firms in the industry, it should be remembered that air transportation, far from a saturated market, still enjoys healthy growth rates. Since 1975, annual growth in world passenger traffic has averaged a robust 6 percent per year, whereas world freight traffic has increased about 7.5 percent per year in the same period.[3] Moreover, the end of the Cold War has brought opportunities as well as challenges, opening new commercial aircraft markets in the former Soviet Union and Eastern Europe. In addition, NATO expansion will likely bring forth additional sales of military models, and economic growth in China has resulted in hundreds of millions of dollars worth of orders from that country in recent years.

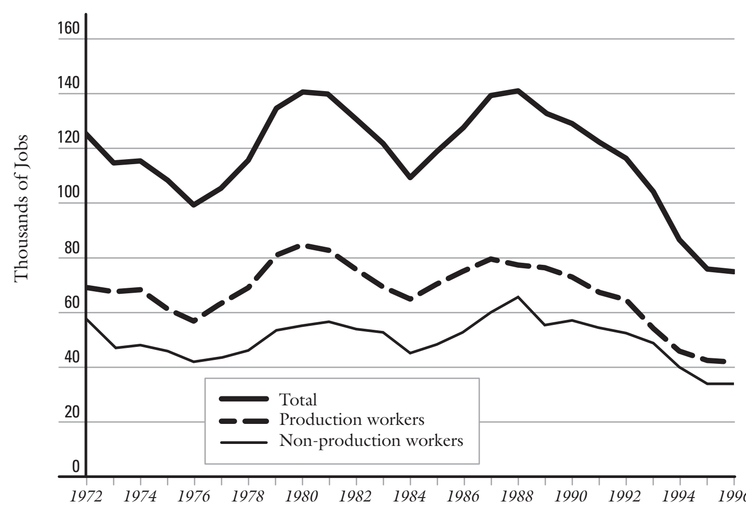
Indeed, there is ample reason to believe that the major U.S. engine makers have been quite successful in responding to recent market challenges and taking advantage of new opportunities. Building on the competitive lead they established during the 1950s and 1960s, General Electric Aircraft Engines (GE) and Pratt & Whitney, the two largest firms in the industry, have come to dominate the market. These firms trace their roots to—and maintain significant manufacturing operations in—New England. GE began building jet engines in the late 1940s in Lynn, Massachusetts, for the U.S. Air Force. Pratt & Whitney, headquartered in Hartford, Connecticut, is an aircraft engine builder with a history in the industry going back to the 1920s. In 1997, the two firms together received 80 percent of all new orders for large commercial jet engines worldwide.[4] GE's Aircraft Engine division's 1998 profits weighed in at $1.7 billion, on $10 billion in sales, translating into an impressive 17 percent operating margin for the division. For its part, Pratt & Whitney registered operating profits of $1.024 billion on $7.876 billion in sales in 1998, a 13 percent margin.

The competitive strength of the U.S. jet engine manufacturing industry would seem to be reflected in the high value of exports per production worker in the industry as a whole, which amounted to $178,085 in 1997. Similarly, value added per production worker in 1997 was $240,500, more than 50 percent greater than the level for U.S. manufacturing as a whole.[5] This productivity premium translated into substantially higher average hourly earnings for production workers in the aircraft engine industry than for other workers: $18.93 per hour in 1998 versus $13.49 per hour for overall U.S. manufacturing.[6]

Such observations might lead one to believe that workers in U.S. aircraft engine manufacturing escaped the effects of globalization and deindustrialization that traumatized workers in other manufacturing industries and their communities during the 1980s and 1990s. By virtue of competing in a product market in which price, however important, is less so than high quality standards, firms in this industry are less easily tempted by the lure of "cheap" labor markets and less stringent regulatory environments than their counterparts in other industries, such as consumer goods. This fact would appear to bode well for U.S. aircraft engine manufacturing workers and the cities and towns that host these manufacturing operations, but below this calm surface lies a paradox.

U.S. Aircraft Engine Manufacturing Employment, 1972–1996

Employment in jet engine manufacturing slipped 19 percent between 1993 and 1997.



Despite the apparent competitive strength of U.S. aircraft engine manufacturers, employment in the industry fell by nearly half in less than a decade. Employment on a national level, as measured by the *Census of Manufactures,* peaked in 1988 at

141,400 people. By 1996, the industry reported just 75,100 employees. Employment saw a slight rebound in 1997, reaching 82,900, but recent announcements of layoffs make it appear that employment is once again headed downward. It is interesting that in this industry, the effects of industry downsizing have not been confined only to the blue-collar workforce.

Production and nonproduction workers alike experienced the downsizing of the industry, seeing their ranks drop 37 percent and 46 percent, respectively, over the 1988 to 1997 period. A troubling stagnation of wages during this time compounded problems for the industry's workers. According to data from the Bureau of Labor Statistics' *Employment and Earnings,* average real earnings for production workers in aircraft engine manufacturing were just 0.5 percent higher in 1998 than they were in 1989.[7]

Economic recovery seems not to have turned the tide of employment declines, either regionally or nationally. Massachusetts industry employment in the fourth quarter of 1997 was 7.5 percent below the level registered in the fourth quarter of 1993, as measured by the Massachusetts Division of Employment and Training's ES-202 data. This is a period in which employment in manufacturing overall was essentially flat. The situation in Massachusetts mirrored a national trend; between 1993 and 1997, employment in jet engine manufacturing on a national level slid 19 percent, from 102,900 to 82,900 workers. What makes these patterns even more interesting is that they occurred even though this period (1993 to 1997) was one of strong recovery for the industry from the dark days of the early 1990s. New orders for engines and engine parts in 1997 were about 24 percent higher than they were in 1993.[8]

What happened? Are these developments a reflection of the post–Cold War status quo in the industry? Has the industry entered a new era in which the fortunes of firms' shareholders and workers, bound together in former times, have now become divergent? What have been the effects of these developments for the New England economy and the region's workers? What might they mean for the future viability of the region's engine manufacturing skill base? Do recent developments suggest that New England, the traditional cradle of jet engine manufacturing, is no longer a "competitive" location for this industry, or are regional job losses simply reflective of a reorientation in corporate strategy?

It is important to understand why the industry grew up in the region before concluding that its competitive advantage has shifted. Starting with a historical perspective that sheds light on the strengths of the New England location helps to understand policy proposals aimed at stemming the tide of job loss regionally.

Historical Roots of Jet Engine Manufacturing in New England

According to iMarket Inc.'s MarketPlace data, the aircraft engine and engine parts industry employed more than 11,000 people in twenty Massachusetts firms in the first quarter of 1999. Massachusetts industry employment represented about 9 percent of total U.S. jet engine and engine parts employment, and the state is currently second only to Connecticut in its concentration of aircraft engine manufacturing employment. In early 1999, Connecticut had close to 16,000 jobs across 95 establishments in this sector. The New England region as a whole was home to 128 firms employing 33,675 people, representing 27.8 percent of total U.S. aircraft engine manufacturing employment. How did New England become home to this concentration of firms?

When examining high-tech manufacturing industries like building jet engines, observers often have a tendency to highlight the centrality of a scientific skill base to regional competitive advantage. Certainly, the science-based disciplines an organization must master to manufacture aircraft gas turbine engines is impressive: thermodynamics, aerodynamics, heat transfer, combustion, structures, materials, and instrumentation and controls.[9] A strong scientific infrastructure is indeed crucial to regional strength in this industry. Equally critical, however, is the ability to develop and continually improve upon manufacturing processes, competencies often taken for granted by economists but whose existence requires significant technological and organizational investments.

What makes an aircraft engine a "complex product" is that it is made up of thousands of closely fitted parts that are subject to extreme operating conditions, the interactions of which may be unpredictable or difficult to model. As a result, the link between prototyping capabilities and design work is a close one. This link ties the ability to arrive at workable innovations in design to the availability of precision production skill. Moreover, manufacturing processes in the industry involve fabricating parts from specialty materials to extremely precise tolerances. The very same properties of these materials (e.g., strength, hardness) that make them desirable for the application at hand also make them difficult to work with. In many ways, then, the ability of scientists and design engineers in the aircraft engine industry to come up with ways to improve product performance has been constrained by the practical solution of manufacturing challenges.

The area of materials is a perfect example. Improvements in the development of high-temperature, high-strength, lightweight materials, including superalloys and metal matrix composites, and the development of methods to fabricate these into precision parts have to a large degree enabled advanced designs to move from the drawing board to the production line. These innovations have allowed the fuel efficiency of jet engines to keep climbing.[10]

The importance of local production capacity and skill to prototyping, design work, and even basic innovation activity was recognized as long ago as 1877 by Thomas Edison, who boasted that his famous Menlo Park research lab possessed capabilities for "castings, forgings, and can build anything from a lady's watch to a locomotive. Inventions that formerly took months and cost large sums can now be done in two or three days with very small expense."[11] A brief look at the history of aircraft engine manufacturing in New England supports the idea of a strong interdependence among science, engineering, and production capability in contributing to competitive success. The unique combination of *both* a precision production skill base *and* a scientific skill base contributed greatly to the locational advantage of New England to engine manufacturers.

THE EARLY DAYS: THE PRECISION PRODUCTION SKILL BASE

The ready availability of skilled craftspeople and the existence of a network of precision machine and toolmakers—not a supply of scientific talent—laid the foundations for the aircraft engine and parts firms that grew up in New England in the early days of the industry.[12] Indeed, only much later, at the dawn of the jet age, did the region's science skill base grow in importance. The story of Pratt & Whitney, whose base of installed engines represents an amazing 48 percent of all engines powering civil aircraft built outside the former Soviet Union currently in service worldwide, is instructive.

Pratt & Whitney was originally established as a machine tool builder just before the Civil War. Founders Francis Pratt and Amos Whitney had been employees of the Samuel Colt armory in Hartford before leaving to establish their own firm in 1860. The Colt armory and others like it were the birthplaces of the "American system of manufactures," where specialist machines and precision gauges were employed to produce interchangeable parts that needed no hand fitting.[13] This system represented a significant departure from manufacturing practices of the time, in which fabricated parts were hand-finished to fit with others as they were incorporated into the final product. The great leap forward in interchangeability was made possible by the use of dedicated machinery set to precise tolerances. The company Pratt and Whitney built was one of a number of firms in the Connecticut River valley that produced the specialized machines, fixtures, and gauges that supported the development and spread of this revolutionary American system, diffusing the manufacturing practices that would lay the industrial groundwork for the next big innovation in the organization of making things, mass production.

Pratt & Whitney's entry into the aircraft engine business occurred in 1926, when Frederick Rentschler, former president of Wright Aero, sought to set up a new business to develop new air-cooled, radial engines for the U.S. Navy. He believed such a design to be superior to the heavier liquid-cooled designs of the time, but his financial backers at Wright Aero were unconvinced. The Pratt & Whitney machine tool company had vacant, excess space in Hartford, and to Rentschler, the location was ideal. The combination of the engineering and precision production skill embodied in the region's "Yankee mechanics" and the ability to license the rights to use the Pratt & Whitney company name would allow Rentschler to translate his design concepts into an actual functioning engine with a brand name widely associated with quality and reliability. The product of that effort, the Wasp engine, was an enormous success. Within three years of its founding, the Pratt & Whitney Aircraft Company was the world leader in the industry, and with the onset of World War II, Pratt's dominance was cemented.[14] Pratt & Whitney, along with its licensees, built engines whose aggregate horsepower amounted to 468,222 between 1940 and 1944. The figure represents close to half the total horsepower delivered by the industry during wartime.[15]

Despite the strength of the production skill base in the area, the development of jet propulsion during the 1940s presented a fundamental competitive challenge to Pratt & Whitney and its regional suppliers. During these early years, the company was kept out of government-initiated aircraft gas turbine research and development efforts and was ordered to concentrate on producing existing piston engine designs in volume to sustain the war effort. As a result, "By war's end, Pratt was the clear leader in a technology with no future. What was worse, it was nowhere with the technology that did have a future—the jet turbine."[16] Unfortunately for Pratt & Whitney, the science underlying jet propulsion was based on fundamentally different principles than that of piston engine designs.

History is replete with examples of technological revolution in an industry leading to the demise of a region's competitive advantage in that industry. It is interesting that New England remained at the center of aircraft engine manufacturing even in the face of this technological revolution. The importance of the region's scientific skill base enters the story at this juncture. Once again, though, technological events can be traced back to the nineteenth century.

THE LEAP TO JET PROPULSION: TURBINE TECHNOLOGY AND THE SCIENTIFIC SKILL BASE

The aircraft gas turbine is a technology truly indigenous to New England. The application of the principle of using a turbine to generate power by capturing the energy from a flow was what made possible America's earliest manufacturing industry, the Lowell textile mills. The pioneering work of James B. Francis, whose system of locks and canals provided power to Lowell's factories in the middle of the nineteenth century, is an important technological ancestor of the propulsion systems that shuttle millions of air travelers across the world today.

Over the course of the nineteenth century, as the water turbine gave way to the steam turbine with the evolution of electrical power, New England remained at the center of developments in turbine technology. Thomson-Houston, main rival to Edison General Electric in the early days of electricity, was based in Lynn, Massachusetts. When those two companies merged in 1892, the Lynn "River Works" came under the General Electric umbrella and became the site of a corporate industrial research laboratory that was not only a key resource in contributing to the success of the company in electrical power generation equipment, but one that would lay the foundations of the company's eventual entry into the jet engine business.[17]

During the early decades of the twentieth century, GE's steam turbine division in Lynn was headed by a man named Sanford Moss. An engineer who had been active in gas turbine research since his graduate school days, Moss continued with this research after joining the company. He experimented with various compressor and turbine designs in an attempt to perfect functional components that would eventually allow efficient gas turbines to become a reality. That work finally bore commercial fruit as a small but successful business building aircraft turbo superchargers for piston engines for the U.S. military during the 1920s and 1930s.[18] The relationship between the company and the U.S. government developed further when the Air Force selected GE's gas turbine division to build the power plant for America's first jet aircraft in the early years of World War II. The engine would be based on the British-designed Whittle engine, which had already been demonstrated and proven airworthy. GE's selection by the Air Force to do this work was partly based on GE's corporate connections with British Thomson-Houston, which had been involved with the Whittle engine project during its development phase. In fact, during the late 1930s, Moss himself visited Britain to learn about the engine. Without the experience GE had gained in designing and building two of the essential parts of a gas turbine engine: the compressor and turbine, the contract may have gone to another firm and GE may never have entered the jet engine business.[19] The company did get the business, though, and the fledgling aircraft gas turbine division got its start in Lynn building engines for the new U.S.–designed military jets during the late 1940s. The division's unexpectedly rapid growth during the early Korean War years forced the company to move many of its operations to Evandale, Ohio, taking advantage of an empty plant that had turned out Wright Aeronautical engines during World War II. The division's headquarters remain in Ohio today. The River Works in Lynn, however, has continued as the site of GE's small gas turbine business, building engines that power a range of smaller aircraft and helicopters.

GE's story says something about the often-unpredictable nature of technological trajectories. Technological competencies developed as the result of one product line (electrical power generation equipment) may lead to the opportunity to enter an entirely new business (aircraft engines). Recognizing the importance of this type of phenomenon to competitive strategy, a number of management scholars have developed a "resource-based" view of the firm. This view sees the firm not as a mere aggregation of product lines but as a bundle of competencies, the most important of which are the technological knowledge and skill bases that form the basis of competitive advantage.[20] Pratt & Whitney's ability to reestablish its prewar level of dominance in engine manufacturing in the jet age, however, also shows that technological "first-movers" do not always have the advantage. Being first to the post in ushering in a new technology is not everything in competition; organizational strengths are important, too.

For Pratt & Whitney, the jump back into the jet race was aided by successfully leapfrogging the competition technologically. First, though, it needed to get a foothold in the newly redefined industry. During the immediate postwar years, the company produced Rolls-Royce designs under license. Soon, though, Pratt scored a coup when its J57 engine, which featured a novel dual-rotor, axial-flow compressor, was chosen to power the B-52 bomber. A commercial spin-off version, the JT3, went on to power the first U.S.–built jetliners, the Boeing 707 and Douglas DC-8, in the 1950s and 1960s. The JT3 was just the first in a long series of commercial engine successes. How, despite GE's head start, did Pratt surge ahead during the postwar years? Though the science of jet propulsion was based on fundamentally different principles than piston engine designs, the technical skills involved in actually producing jet engines were not all that different and were in ample supply within the Pratt & Whitney organization. Moreover, the final customers—airlines and the U.S. military—remained the same. The company knew what it took to make sales and keep customers happy: producing a reliable product and responding quickly if and when problems arose. As the 1960s drew to a close, Pratt & Whitney enjoyed a remarkable 95 percent share of "free world" engine orders and half of all military engine orders.[21] Successive design innovations over the years have ensured the firm's continued competitive position.

NEW ENGLAND'S SCIENCE AND TECHNOLOGY INFRASTRUCTURE AND REGIONAL AGGLOMERATION

As noted earlier, the jet age ushered in an era where the engine building business became based more in science. In this respect, the technical strengths of local universities supported the development of the technology. University research laboratories such as MIT's gas turbine lab, established in the early 1950s, contributed to an expanded understanding of the principles underlying jet propulsion and addressed practical questions of thermodynamics, gas flow, high-temperature materials, and so forth that improved the design and construction of engines. New England's institutions of higher education also supplied a steady stream of graduates, filling the needs of Pratt & Whitney and GE for mechanical engineers, materials scientists, electrical engineers, and other organizational personnel. The industry, of course, benefited from the millions in research and development funds that poured into the region's university and industrial laboratories from the Department of Defense. Such research was not restricted to (or even primarily directed toward) propulsion technology. Rather, advances in computers and microelectronics led to advances in systems controls and instrumentation. Illustrating the gains to be reaped from regional agglomeration, a number of New England firms contributed to the still-evolving technologies related to electronic engine sensors and control systems.[22]

The materials sector also benefited from government-supported research efforts. During the 1950s and 1960s, the central Massachusetts firm Wyman-Gordon, for example, was the recipient of $397 million in Air Force research funds to develop machinery for large light-alloy forgings. To this day, Wyman-Gordon remains a leader in this area.[23]

The competitive strength of New England–based firms, General Electric Aircraft Engines, Pratt & Whitney, and their many local suppliers, provided more than employment opportunities for thousands of engineers, technical personnel, and skilled production workers across Connecticut, Massachusetts, Rhode Island, and southern New Hampshire, Vermont, and Maine. It also served as the foundation for the economic prosperity of entire cities across the region. This dependence was especially true for Lynn, Massachusetts, and Hartford, Connecticut. The importance of aircraft engine manufacturing as a source of jobs and as a foundation for economic activity was not restricted to the cities that were home to the major plants. In Worcester, Springfield, and a score of smaller communities along the Connecticut River, establishments of all sizes carried out the range of precision metalworking activities, forging, casting, and precision machining involved in the fabrication of the thousands of jet-engine components. Subcontractors working for GE and Pratt & Whitney thus aided the diffusion of technological advances in materials (e.g., titanium and nickel-based superalloys, powder metallurgy) as well as precision machining techniques, spinning off to nonaircraft markets such as auto components, medical devices, and implants.

Beyond the regional benefits of agglomeration, other positive dynamics characterized the industry during the golden years. Innovations in propulsion were the "pacing technologies" that led the improvements in aircraft performance through the postwar era, contributing to the growth of the market for air travel. With each new generation of aircraft engine, air travel became faster, cheaper, safer, and less damaging to the environment. In many ways, the story of the aircraft engine industry epitomized the virtuous cycle of U.S. capitalism during these years where technological progress helped to grow new markets, providing more jobs, while also improving productivity, allowing for growth in wages. That business success would lead to more and better employment opportunities over time could be summed up in the idea "what was good for General Motors was good for America." Gains from economic growth were widely shared. The fortunes of U.S. workers were tied to the well being of U.S. corporations. And business cycles notwithstanding, if the latter did well, the former could expect to do well also.

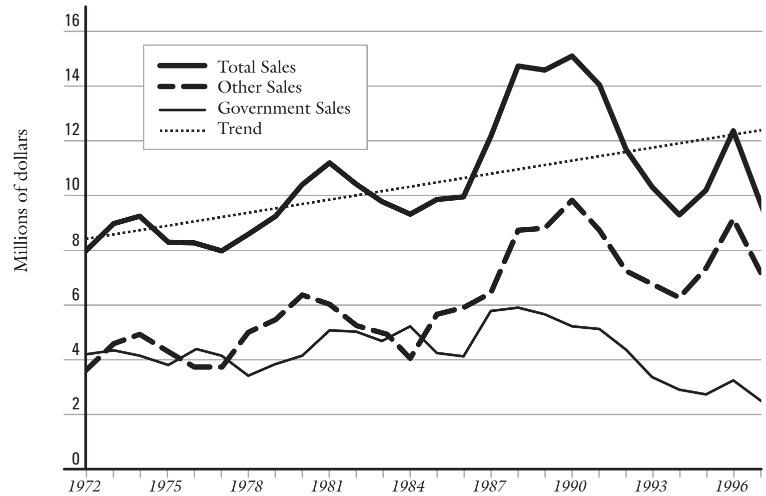
As has been documented by a number of researchers, however, this era drew to a close sometime during the early 1970s.[24] The financial health of U.S. corporations, which formerly had supported the expansion of the quantity and quality of employment opportunities, increasingly seemed at odds with it. There is some evidence of similar tendencies in aircraft engine manufacturing, where employment is approaching historic lows and wages appear to have stagnated, despite healthy profit levels and growing productivity. Of course, the dramatic culmination of this "divergence of fortunes" was the massive downsizing of the industry that occurred in the early 1990s.

Downsizing of the Industry

In New England, downsizing of the jet engines industry was dramatic and drawn out. Though it abated somewhat during the mid-1990s, job cuts continue. Total employment at GE in Lynn, for example, was projected to fall to an all-time low of 4,800 by the year 2000.[25] The plant had employed close to 9,000 hourly workers in the mid-1980s. Pratt & Whitney's production workforce, 14,000 strong as recently as 1988, had fallen to 6,600 by 1998.[26] By the middle of 2000, Pratt & Whitney's union-represented production workforce in Connecticut numbered just 4,700.[27] A former Textron-Lycoming plant in Stratford, Connecticut, that had once employed over 5,000 production workers building small gas turbines was closed following its 1994 acquisition by AlliedSignal, which sought to consolidate those operations with its other facilities in Phoenix, Arizona. The consequences of contractions at plants where final engines were built rippled through local suppliers. During the 1990s, one of the largest plants, Wyman-Gordon, a maker of specialty forgings with a half dozen plants in New England, reduced its workforce 43 percent, and it was certainly not the only regional aerospace supplier to do so. As these layoffs occurred, a negative multiplier effect contributed to the contraction of the entire regional economy.

U.S. Aircraft Engine Manufacturing, Real Value of Sales, 1972–1997, (1987=100)

Between 1988 and 1997, the end of the Cold War contributed to a 57 percent decline in sales to the U.S. government.



There is a temptation to attribute the hardships borne by laid-off aircraft engine workers in New England to the end of the Cold War. Indeed, the events of the late 1980s and early 1990s contributed to a decline in sales to the U.S. government of 57 percent between 1988 and 1997, as measured in real terms. This decline in itself, however, is not sufficient to explain the magnitude of job cuts experienced during the 1990s. If commercial sales had continued at the pace of growth witnessed during the 1980s, changes in demand in the two market segments would have largely offset one another and stabilized total sales. That situation was actually the case for the first two years of the military sales downturn. Commercial sales climbed to levels that more than offset the loss in military business, reaching a peak at $9.8 billion in 1990.

Then disaster struck the industry. A widespread, global recession that set in during 1991 forced airlines across the world to cancel or postpone purchases until air traffic rebounded. As a result of this dual downturn in orders, the industry experienced a 39 percent drop in sales between 1990 and 1994.[28] The magnitude of the decline in employment (47 percent since 1988) appears to be out of line with the scale of the contraction of demand experienced by the industry.

What of the longer run, however? At the time of the industry downsizing, many observers remarked that along with the pain of downsizing would come a "peace dividend." Land, labor, and capital would be freed up and the workings of a dynamic U.S. market economy would ensure that those resources would be efficiently reemployed elsewhere in the economy. Indeed, this has taken place. The U.S. and New England economies have been robust: corporate earnings have been up, and economic growth moved at a healthy clip throughout the second half of the 1990s.

Divergence of Fortunes

The future holds many questions. What will be the fate of the jet engine industry in New England? Are today's job losses predictors of future loss of market share to enterprises abroad? Or will shedding employment in New England and the United States be the very *source* of U.S.–based producers' competitive advantage as they invest in their "core competencies" of high-value design, engineering, and marketing activities, spinning off production activities to firms elsewhere?

To answer these questions, we must examine the strategies being pursued by enterprises in the industry. At the macro level, economists have identified two trends that seem to be behind the "divergence of fortunes": developments in trade and developments in technology. Proponents of the trade theory attribute the divergence to globalization or the increased flows of trade and capital across borders. According to this theory, U.S. workers are subject to growing international competition with low-wage workers in other parts of the world, which has lowered wages and employment prospects, especially for less-skilled workers in the United States. Adherents of the technology theory maintain that the 1980s and 1990s were marked by "skill-biased" technological change (especially computerization) that hurt prospects for blue-collar workers, while simultaneously improving prospects for white-collar workers. Which theory holds for aircraft engine manufacturing? Developments on both fronts have made contributions, but not exactly in the way economists have traditionally framed them.

Because of the systems integrators' responsibility for ensuring compliance with regulatory production standards (and their liability if such standards are not met), suppliers in the aircraft engine industry must meet high quality standards, demonstrate proficiency with sophisticated production techniques, and have well-documented procedures. According to information provided by the Federal Aviation Administration, with the exception of half a dozen firms, all Pratt & Whitney and GE suppliers are currently located in nations that belong to the Organization for Economic Cooperation and Development. Most are located in countries that are generally characterized as having significantly less flexible working conditions (and often higher wages) than the United States.[29] Thus, it is difficult to characterize the internationalization of production as a "race to the bottom" search for low wages and poor working conditions, but it is also more generally inconsistent with many characterizations of globalization as affecting only blue-collar production workers.

Recent Orders for Commercial Engines at Pratt & Whitney

3.4 billion in recent orders is committed, up front, to foreign supplier firms.

Date	Customer	Order	Engine Model	RRSP-Adjusted Pratt & Whitney Share
		($ million)		*($ million)*
February '03	UPS	1,500	PW4184	945
December '02	TWA	400	PW6000	400
November '02	International Lease Finance Corp.	250	PW6000	250
October '02	U.S. Airways	800	PW4168	504
April '02	United Airlines	550	PW4000	346
April '02	LanChile, Tam, TACA, etc.	2300	V2500	759
April '02	FedEx	112	PW4000	71
April '02	TWA	200	JT8D-200	152
	TOTAL	**6,112**		**3,427**

Both production activities as well as design activities are being outsourced by GE and Pratt & Whitney. This has taken place within a number of cooperative production arrangements with supplier firms referred to as "risk- and revenue-sharing partnerships" (RRSPs).

RRSPs typically involve the commitment by a supplier firm to fund some share of the product's development costs in exchange for a defined work share for the length of the product's production run (which usually extends over two to three decades).[30] Originally used on the military side of the business as a way of securing market access, RRSPs have become increasingly popular over time on the commercial side of the business as a means of tapping into inexpensive capital for product development purposes.[31]

For the systems integrator, the logic behind offering an offset or RRSP participation to a potential supplier is clear. If a foreign airline (which may be government owned or subsidized) knows that a portion of the work for building engine A is being done locally, it may be swayed to purchase engine A over another engine. Both GE and Pratt & Whitney, each looking to get an edge on the competition, end up doing exactly the same thing, and neither is better off at the end of the day.

Of course, U.S. workers who see increasing shares of work going overseas see themselves as unequivocally worse off. For this reason, labor unions representing workers in the industry in the United States have voiced vigorous opposition to RRSPs and to offsets. They note that early RRSPs and offsets agreements essentially amounted to long-term, "build-to-spec" subcontract arrangements, but have evolved to the point that supplier firms are taking on more and more design activities over time as well.[32]

How significant are these RRSPs in dollar terms? No exact figures exist, but one way to gauge their impact is to adjust the dollar value of orders for the stake of the program that the systems integrator actually retains. For example, in a sample of recent Pratt & Whitney orders totaling $6.1 billion, $3.4 billion is committed up front to foreign supplier firms, because of RRSPs. Of course, these foreign supplier-partners may in turn subcontract work to U.S. suppliers and, by symmetry, a fair share of the work "retained" by Pratt & Whitney will go out to other suppliers, both foreign and domestic. Therefore, assessing the impact of RRSPs is far from straightforward, but the increasing reliance on international sources of supply is difficult to refute.

So who is the competition? The top five producers of turbine engine parts—France, the United Kingdom, Germany, Canada, and Japan—account for close to 80 percent of U.S. imports of

Turbine Engine Parts: Sources of Imports

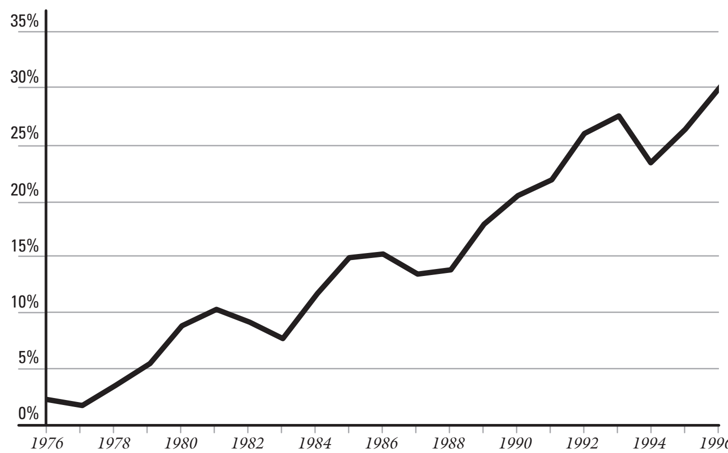
Country	1998 Imports *($ million)*	Country	1998 Imports *($ million)*
France	1,902	Switzerland	68
United Kingdom	1141	Belgium	56
Germany	755	South Korea	54
Canada	517	Norway	51
Japan	277	Turkey	46
Israel	217	Ireland	32
Singapore	206	Netherlands	28
Italy	158	Brazil	16
Sweden	108	China (PRC)	13
Mexico	79	Taiwan	12

these components. Thus, it is difficult to make the case that up to this point the globalization of aircraft engine manufacture has been based on low-wage, foreign competition. Still, a contingent of newcomers is making rapid inroads in joining the supplier ranks. Imports of turbine engine parts from Israel, for example, increased from $41 million in 1989 to $217 million in 1998. Imports from South Korea, valued at $54 million in 1998, are close to triple their 1989 level of $19 million, whereas imports from Turkey saw a similar growth pattern, from $12 million in 1989 to $46 million in 1998.

Far and away the fastest rising star is Singapore, whose exports of engine parts to the United States have increased tenfold since 1989 (from $20 million to $206 million).[33] For most of these emerging sources of engine parts, military offset programs and coproduction agreements appear to have been an important source of learning opportunities. Based on these

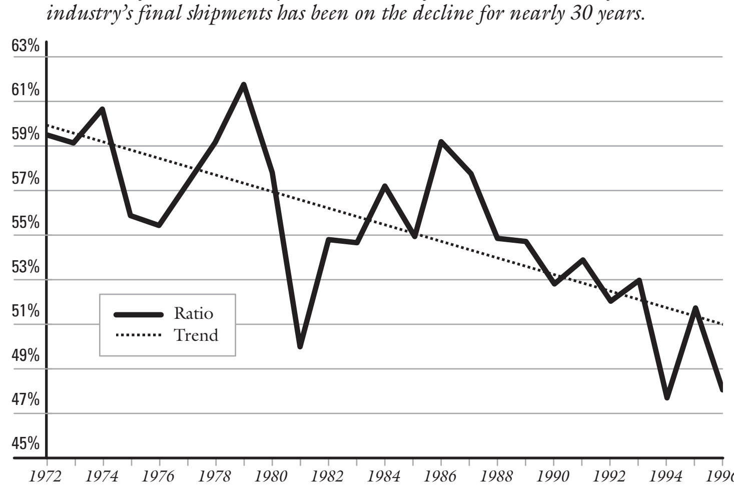
Ratio of Import Value to Value of U.S. Industry Shipments

Trends reflect the rise in cooperative production agreements with foreign supplier firms.



Ratio of Value Added to Value of Industry Shipments, U.S. Aircraft Engine Manufacturing

The ratio of value-added by domestic manufacture to the value of the industry's final shipments has been on the decline for nearly 30 years.



data, the fears of U.S. labor unions about the employment, trade, and competitive effects of offsets and RRSPs do seem to be founded. The issue is one worthy of further investigation. In the final analysis, it appears that factors other than wage differentials or comparative advantage are fueling disinvestment from U.S.–based production activities.

Turning now to the question of technology, is there reason to think that technological change had something to do with the "divergence of fortunes?" The answer is yes, but again, the economists' traditional characterization of the phenomenon is somewhat off base. During the first half of the 1980s, both GE and Pratt & Whitney pursued a "factory of the future" production technology strategy, centered on skill-displacing capital investment, much of it located in the southern United States. The concept behind this investment was for a high degree of automation and dedicated machinery, including robots, that would eliminate direct production worker time and effort.[34] Eventually, however, these firms saw that such a strategy was less than ideal for the short production run, precision work that building engines entailed. As Japanese "lean production" models have demonstrated, unless production runs of standardized components are long, it can be difficult to synchronize cycle times and maintain flow production that will result in cost savings. "Batch and queue" production often results from a "factory of the future" type of strategy, translating into high inventory costs and expensive rework. Thus, in many instances, multi-purpose low-tech machines capable of quick changeovers and tended by multiskilled workers can be a superior production technology to high-tech, inflexible machines designed to decrease direct labor time.[35]

In the early 1990s, both GE and Pratt & Whitney abandoned the "factory of the future" in favor of "lean" work organization. GE implemented a "kaisen" continuous improvement program and more recently has adopted the six-sigma concept made famous by Motorola, which focuses on lowering defects and improving efficiency.[36] For its part, Pratt & Whitney has focused heavily on reorganizing work along "lean" production principles, relying on cellular manufacturing and improved flow lines. Industry-level productivity figures suggest that such moves are paying off, which can mean good things for the industry in the future. Firms have effectively figured out how to do more with less.

Looking to the Future

Will firms be able to do more with more? This question must be answered if we are concerned with the sustainability of today's profit levels, market share, and employment levels. According to Stephen Roach, chief economist at Morgan Stanley, it is indisputable that the wave of downsizing witnessed in the 1980s and 1990s restored profit levels and may have contributed to improved efficiency in U.S. firms. He wrote, "But if that's all there is to the script, you have to wonder what U.S. businesses can do for an encore."[37] Roach sums up a concern that many other researchers have voiced about the apparent preference of U.S. businesses to pursue short-term over long-term strategies. GE, for example, is often singled out for such criticism. The response of corporate leaders to the downturn in aircraft industry demand in 1993 illustrates the point.

GE'S RESPONSE TO DOWNSIZING

The aircraft engine division, an odd one in GE's traditional business mix of appliances and electrical equipment, was historically left alone by top corporate management. The aircraft engine business was spared the full brunt of GE's corporate downsizing and managerial housecleaning of the early 1980s. In fact, Brian Rowe, aircraft engines chief, was the only business president who retained his job after John Welch took over GE. This state of affairs changed, however, as the engine division's profit stream slowed to a trickle in the early 1990s.

The engineering ranks, which numbered 10,000 in 1991, fell to just 4,000 by the mid-1990s.[38] Rowe himself was a casualty. Employment in the division during the early and mid-1990s fell to less than 20,000 from 44,000 as recently as 1987, when it was GE's largest business. These drastic cuts had some unintended effects. At the time, GE had a major new engine program, the GE90, in development. The engine, designed for Boeing's new 777 wide-body airplane, was scheduled to enter service in 1995. The program, however, was plagued by design flaws and production difficulties, perhaps not surprisingly, given the scale of the cuts the division experienced. The Federal Aviation Administration withheld certification of the GE90 until it was satisfied that the problems were corrected, and the program turned out to be a great embarrassment for the company.[39] The public relations problems were only part of the costs to GE. By the time the GE90's problems were resolved, the financial costs associated with fixing the problems totaled $275 million, which GE took as a charge against earnings in 1997.[40]

Though this example seems like a textbook case of the effects of short-term horizons, there is evidence that longer-term, "high-road" strategies are also being employed in the industry to boost profits in sustainable ways. Pratt & Whitney's successes with "lean" production principles, documented by Womack and Jones, has had the effect of freeing up cash flow by reducing inventories and work in progress while improving quality and productivity. Yet the million-dollar question, as Roach points out, is "What happens to this cash flow?" The answer is critical for firms, for their shareholders, and for other stakeholders, workers, and communities in the United States and in New England. Are these resources being reinvested in the business, directed toward acquisitions, or distributed in the form of dividends and stock repurchases?

TRENDS IN USE OF CASH FLOW

A glance at what GE and Pratt & Whitney have done with their profits recently indicates two primary trends—acquisitions and distributions to stockholders—neither of which appears to bode very well for employment prospects for New England's aircraft engine workers. New capital expenditures are failing to keep pace with profit growth. Rather, acquisitions and distributions to stockholders seem to be the favored use of cash flow between the two leaders in the industry. As part of an effort to pump up profit margins, GE and, more and more, Pratt & Whitney have sought to increase their presence in the aftermarket segment of the business. Aftermarket activities such as repair, maintenance, and leasing services contribute to the high margins of the engine manufacturers because of their particularly lucrative nature. Essentially, the manufacturer makes money twice, first on the sale of spare parts and then on the servicing activities. GE's expenditures on acquisitions and investments in the overhaul and maintenance business in recent years have dwarfed those of its rivals, amounting to $9.5 billion since 1995. Such investments are part of a broader corporation-wide strategy to become more involved in servicing all kinds of equipment with the GE name, from medical diagnostic imaging machinery to power generation equipment. GE engine services aftermarket activities (which include leasing activities carried out under the GE capital umbrella) are a $45 billion business, with half of this representing repair and overhaul operations.[41] Likewise, at United Technologies, Pratt & Whitney's parent company, growth through acquisition reached $1.241 billion in 1998. The company acquired two overhaul and repair businesses in 1997 and 1998 and set up a new overhaul and repair joint venture in Singapore. Such acquisitions are certainly growth strategies, but unfortunately are not geographically targeted investments that might spell a reversal in the continuing downward employment trend for the industry in New England.

The second trend is perhaps even less encouraging. In the name of maximizing shareholder value, both GE and Pratt & Whitney, like many large U.S. corporations, have made setting high dividends and repurchasing shares high corporate priorities. Such an emphasis appears to be part of what is driving the push into high-margin after-

Cash Flows at General Electric and United Technologies: Trends in Cash Flows and Their Uses

Company/ Year	Net Cash Flows from Operating Activities	Capital Expenditures	Share Acquistions	Dividends	Repurchases
	(millions of dollars)				
General Electric					
1994	6,100	1,700	n/a	2,500	1,100
1995	6,100	1,800	n/a	2,800	3,100
1996	9,100	2,400	1,100	3,100	3,300
1997	9,300	2,200	1,400	2,200	3,500
United Technologies					
1994	1,357	759	125	238	270
1995	2,044	780	204	252	221
1996	2,079	770	317	265	459
1997	2,090	819	584	291	849
1998	2,509	866	1,241	316	650

market segments. GE's stellar profitability has made it a pacesetter of sorts, putting pressure on its product market competitors to deliver similar levels of shareholder value. Karl Krapek, Pratt & Whitney's president, told *Forbes* magazine, "I am trying to get our margins to match GE's 17 percent. We have made it to 13 percent and our aim is to achieve 16 percent by 2003."[42] As any businessperson knows, margins are important. Without a healthy cash flow, there is little or no money for new investment, new product development, or strategic acquisitions. Ironically, when achieving high profitability becomes the aim to be pursued beyond all others—when the goal is simply to make money for the sake of disbursing it to shareholders—the long-term prospects of the enterprise itself may be endangered. When the obsession with delivering returns to shareholders leads to an overemphasis on short-term results, corporate policies can seriously undercut the very sources of enterprise competitive advantage, as the example of the GE90 shows.

RETAINING THE SKILL BASE

In the end, the patterns of investment and disinvestment by the major players in the aircraft engine industry suggest that attributing continuing job losses in New England to slack demand conditions or to a lack of regional competitive advantage would miss the mark. Recent declines in employment seem more reflective of a reorientation of corporate strategy in a new, post–Cold War era. Factors such as industry consolidation, the eagerness of firms elsewhere to break into the ranks of world-class supplier tier, and risk aversion on the part of large manufacturers have all contributed in some way to the flight of jobs from New England. Such a conclusion is, from a state policy maker's perspective, a tough nut to crack; affecting any of these conditions is impossible given a state-level policy makers' economic development tool kit.

Still, policy makers can do more than just sit on the sidelines and watch the continued flight of good jobs from the state. One should be wary of the "if you build it, they will come" approach to regional economic development, however. It is easy to be lulled into thinking that it is sufficient to beef up university engineering programs to retain the employment and skill base that is so crucial to economic vitality in the region. As illustrated here, scientific talent is just one half of the high-tech manufacturing equation.

Equally critical to competitive advantage are the ability and the willingness of enterprises to make the significant technological and organizational investments in skill development, investments that will pay off in the form of manufacturing processes that turn out qualitatively better products at lower economic costs. If enterprises are unwilling to make these investments, then such a situation is especially problematic from a policy perspective; the high-tech policy cure-all—"invest in education and R&D"—may not hurt, but it may not be the ultimate solution. Still, devoting resources to maintaining and upgrading the region's scientific infrastructure as well as its precision metalworking skill base is one proactive policy that, although it may do nothing to reverse industry trends in aircraft engine manufacturing, will at least serve to ensure that the conditions necessary for growing and attracting other high-tech manufacturing operations are in place. To the extent that there exist strong links between design, prototyping, and precision production activities, the scientific and skilled production skill bases are the two ingredients without which a high-tech manufacturing infrastructure has no chance of being sustained. The example of the jet engine manufacturing industry illustrates these links. To abandon the development of these skill bases would be equivalent to abandoning the goal of an economy centered on high-tech, high-wage manufacturing that offers the promise of good-paying jobs to both white-collar and blue-collar workers.

Endnotes

1 Fuel costs represented 11.6 percent of cash operating expenses for U.S. airlines in 1997, down from 30 percent in 1980 (Aerospace Industries Association of America 1999, 90).

2 At the same time, however, there is an important fundamental difference between engine manufacturers and the rest of the aircraft industry. Profits for engine manufacturers have as much to do with how many existing aircraft are flying as with how many new aircraft are ordered. Because of the need to maintain engines in service continually, sales of spare parts represent a significant source of revenue for engine manufacturers. (For United Technologies, for example, sales of spare parts represent 40 percent of total corporate pretax earnings.) As a result, overall sales and employment for engine makers have traditionally been more stable than those of other aerospace firms.

3 Author's calculations are based on International Civil Aviation Organization data as reported in Aerospace Industries Association of America (1999, 75). Passenger traffic is measured as passenger miles performed, and freight is measured as ton-miles performed.

4 "Flight International Engine Directory 1997—Order Backlog" 1997, 31.

5 Author's calculations are based on figures from the U.S. Department of Commerce, International Trade Administration, provided by Aerospace Industries Association (1999) and the U.S. Department of Commerce, Bureau of the Census (1997), *Census of Manufactures*. Manufacturers of aircraft engines and engine parts are designated SIC 3724 by the Standard Industrial Classification system.

6 Author's calculations are based on figures from U.S. Department of Labor, Bureau of Labor Statistics (1998) *Employment and Earnings.*

7 Author's calculations are based on figures from U.S. Department of Labor, Bureau of Labor Statistics (1998 and 1989) *Employment and Earnings*.

8 Author's calculations are based on figures from *Current Industrial Reports,* U.S. Department of Commerce, as reported by Aerospace Industries Association of America (1999).

9 Prencipe 1997, 1269.

10 U.S. Department of the Interior, Bureau of Mines 1990, 5.24.

11 From a letter authored by Edison on 14 November 1887, as quoted in O'Boyle (1998, 22).

12 The importance of such agglomeration effects has been documented by a number of scholars both historically (Bluestone et al. 1981, chapter 2) and more recently (Forrant and Flynn 1998).

13 Womack and Jones 1996, 153–54. See also Best (1990, chapter 1) for a detailed history of the role of Connecticut River valley firms in the evolution of the American system of manufactures.

14 Womack and Jones 1996, 155–59.

15 Lilley et al. 1968, 124.

16 Womack and Jones 1996, 159.

17 O'Sullivan 1996, 108.

18 Constant (1980) presents a comprehensive discussion of the technological path of GE's entry into the jet engine business.

19 General Electric Company 1990, 45.

20 See, for example, Tecce et al. (1997).

21 Womack and Jones 1996, 160.

22 One of today's industry leaders in the field of full authority digital engine control for small engines is Chandler-Evans, a West Hartford–based company, whereas Ametek, of Wilmington, Massachusetts, a GE spinoff, is a leader in engine sensors and instruments. See Markusen and Yudken (1992) on the links between and among the U.S. military and the aerospace, computers, and electronics industries.

23 Bilstein 1996, 95.

24 See, for example, Harrison and Bluestone (1988).

25 "GE to Lay Off 200 Engine Workers at Lynn Plant" 1999, C3.

26 "Cooperation in Contrast to Past Acrimony at Pratt" 1998, D1; "New Look for Pratt to Erase 1,000 Jobs in State: Restructuring to Move Engineers from Florida" 1998, B1.

27 Data supplied by Strategic Resources Department, International Association of Machinists and Aerospace Workers, AFL-CIO.

28 U.S. Department of Commerce, Bureau of the Census various years, "Aerospace Industry: MA-37D."

29 In particular, firms in Western Europe are generally seen as being "burdened" with a much more stringent regulatory framework with respect to labor relations than their U.S. counterparts. The contentious assertion by many in Europe and the United States as to the need for more labor market flexibility is predicated on the assumption that European-style labor regulations stifle growth and innovation on the Continent, the aircraft engine industry would seem to be an exception to this "rule."

30 Prencipe 1998, 9.

31 On military projects, RRSPs are referred to as "offset agreements" or "offsets," insofar as they

allow a purchasing nation to offset the negative balance of payments effects of importing big-ticket aerospace items with the export of domestically produced components.

32 See, for example, Richard Samuels' (1994) comprehensive study of how Japan effectively used offsets to leverage aerospace purchases to provide access to advanced technology and opportunities for learning for domestic aerospace producers.

33 Author's analysis of figures is from the U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.

34 "Pratt and Whitney's 'Factory of the Future' Draws Praise" 1987, D1.

35 See Womack and Jones (1996, chapter 8).

36 Carley, p.E1.

37 Roach 1996, 82.

38 "Just Imagine if Times Were Good" 1995, 78–80.

39 O'Boyle 1998, 225–26.

40 O'Boyle 1998, 230.

41 "OEM's: Partners or Competitors?" 1998, 38.

42 "No More Yo-Yo" 1999, 131.

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