12. 'Grow your own' in the new economy? Skill-formation challenges in the New England optical networking industry[1]

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I. THE NORTHEAST MASSACHUSETTS REGIONAL ECONOMY

For an industrial regional economy engaged in global competition, the growth, distribution and stability of income are dependent on changes in technology and markets that typically occur far beyond the region's boundaries. When major changes occur, structures of business organization and systems of skill formation that have served the region well may no longer generate competitive outcomes. For a region, the problems of economic change may be exacerbated when the strategic decisions concerning the new forms of business organization and skill formation that will be put in place are made, as is typically the case in a globalized economy, in corporate offices that are also located outside the region. Under these circumstances, those who are concerned with stable and equitable regional economic growth require a sound understanding of the processes of change that lie beyond those that are subject to the region's control (see Lazonick, 1993).

This chapter provides a case study of such a process of change as it has occurred over the past four years in the optical networking industry of the Merrimack Valley region of northeastern Massachusetts – a region that is part of the Massachusetts high-technology industrial district, known generally as 'Route 128.' In the early 1990s Route 128 was in a sorry state (Saxenian, 1994). First the minicomputer industry, dominated by companies such as Wang, Digital Equipment Corporation and Data General, went into precipitous decline. Then drastic cuts in defense spending affected not only major corporations such as GE and Raytheon but also hundreds of small subcontractors in metalworking, electronics and plastics. Especially hard hit were the areas in and around Lawrence and Lowell, the two major cities in the Merrimack Valley region of Northeast Massachusetts. In the 19th century, this region had been dominated by the textile industry, but during the first half of the 20th century the region experienced a decline of its traditional manufacturing base as textile production shifted to the southern United States. In the 1980s the Merrimack Valley region had finally begun to recover from this industrial decline as the electronics industry of Route 128 expanded geographically to include the Merrimack Valley region centered on Route 495.

At the peak of the 1980s boom – which, just in advance of its collapse, became widely known as 'the Massachusetts Miracle' (see Dukakis and Kanter, 1988; Lampe, 1988) – the average annual unemployment rate had fallen to as low as 3.3 percent in the Lowell area in 1987 and 4.0 percent in the Lawrence area in 1988. By 1990 the unemployment rate averaged 6.6 percent in the Lowell area, but then shot up to 9.9 percent in both 1991 and 1992. In the Lawrence area, the unemployment rate was 7.2 percent in 1990, 10.4 percent in 1991, and 9.6 percent in 1992. By way of comparison, the unemployment rate in Massachusetts averaged 6.0 percent in 1990, 9.1 percent in 1991 and 8.0 percent in 1992. Recovery set in slowly from 1993, but it was only from 1997 that the Merrimack Valley region experienced a new period of sustained boom. The Lawrence area lagged behind the much more dynamic Lowell area, where the average unemployment rate fell to 2.5 percent in 2000, and where, from 1996 in contrast to earlier years, the unemployment rates were lower than for Massachusetts as a whole. Nevertheless, even in the Lawrence area, the unemployment rate fell as low as 3.8 percent in 2000. For the entire Merrimack Valley region, the unemployment rate fell from 4.6 percent in 1996 to 3.7 percent in 2000 (MTC, 2001, p. 19).

The region has a high concentration of employment in the computer and communications industries. In 1999 the Merrimack Valley region had a total employment of 247 793 people, with average earnings of $42 700. Just under 28 percent of this employment was in nine 'innovation clusters' in which average earnings were $69 805. Of these clusters, the highest concentration of jobs was in computer and communications hardware (28 percent of the 'innovation cluster' jobs), and software and communications services (19 percent of these jobs). Together, these two sectors accounted for 13 percent of the region's total employment in 1999 (MTC, 2001, p.19).

Playing a large part in driving the resurgence of the region was the rapid growth of the information and communication technologies (ICT) industries that were seeking to take advantage of new business opportunities opened up by the Internet revolution. Of particular importance within ICT has been optical networking, an industry in which 'old-economy' telecommunications companies such as Lucent Technologies, Nortel Networks, and Alcatel compete fiercely with 'new-economy' networking companies such as Cisco Systems, Ciena and Sycamore Networks. Optical networking seeks to combine the bandwidth advantages of fiber optics with the packet switching capabilities of the Internet in transmitting voice, data, and video over long-haul, regional and local networks (Carpenter and Lazonick, 2001; Carpenter *et al.*, 2002). Most of the major optical networking companies have a strong presence in the Route 128/495 region where they can tap into not only the advanced research carried out in the universities of the Greater Boston area but also highly skilled managerial, engineering and production labor forces and an abundance of venture capital (see Best, 2001, ch. 5). The growth of the region's telecommunications industry, driven by established and start-up companies, in the Merrimack Valley and its surrounding areas (including, most notably, southern New Hampshire) also attracted electronic manufacturing service (EMS) providers such as Celestica, Solectron, Jabil Circuit and Sanmina. These contract manufacturers supply modules and printed circuit board assemblies (PCBAs) to the optical networking equipment companies.[2]

II. SKILL SHORTAGES

As the boom gathered momentum in the late 1990s, companies in the region faced major skill shortages.[3] A survey of Massachusetts technology-intensive companies carried out in May 1998 found a vacancy rate of 10.6 percent for scientists and 8.4 percent for engineers, but only 5.3 percent for technicians, 3.6 percent for managers, and 3.1 percent for skilled production workers (MTC, 1999, p. 15). But the same survey carried out in May 1999 revealed that, at 8.6 percent, the vacancy rate was highest for skilled production workers, followed by managers (8.4 percent), technicians (7.6 percent), and then scientists and engineers (5.4 percent) (MTC, 1999, p. 24). Taken together, skilled production workers and technicians made up 24 percent of the workforces of these companies. The survey was repeated in May 2000, although with somewhat finer occupational classifications; 'web design developers' was included as a distinct category, while the category 'IT technicians' was distinguished from 'all other technicians,' and 'electrical/computer engineers' from 'all other engineers.' In May 2000 the vacancy rate for 'computer scientists/programmers' (who made up 11 percent of the workforce at the surveyed companies) was 15.2 percent and that for 'electrical/computer engineers' (10 percent of the workforce) was 10.0 percent. But the vacancy rate for both skilled production workers (8 percent of the total workforce) and IT technicians (2 percent of the total workforce) remained high at 8.0 percent for each group (MTC, 2000, p. 24).

As summarized in MassInc.'s report, *Opportunity Knocks: Training the Commonwealth's Workers for the New Economy* (Donahue *et al.*, 2000, p. i):

> [O]ne worrisome problem both dims the lustre of the current boom and might even cut it short – inadequate skills. Shortfalls of human capital . . . threaten to inflict major damage on two fronts.
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> First, the state's middle class – the anchor of our commonwealth's economy, culture, and civic life – is under pressure. The income growth of families with one or more high-end professionals or technical workers is far outpacing families with less-skilled breadwinners. The widening economic gap between the have's and have-not's [sic] implies a host of troubling consequences on the social, political, and civic scenes.
>
> Second, Massachusetts businesses are finding their competitive advantages eroding because critical positions are going unfilled. Employers are now faced with a three-fold dilemma: native Massachusetts workers too often lack the skills that new jobs require. Few skilled workers from other states are willing to migrate here. And many companies see their most skilled workers enticed by opportunities in lower-cost locales in the South and West.

During the boom, the shortage of scientists and engineers appeared to have been alleviated somewhat by an increased net inflow of these highly educated personnel to the state (Best, 1999 and 2001, ch. 5; Harrington and Fogg, 2000). Still, as the May 2000 survey of vacancies cited above suggests, by 2000 demand was again overwhelming supply. Some of the excess demand for engineers was met by hiring foreign workers on non-immigrant H-1B visas, for which companies could apply if they could show that they were facing a shortage of such employees within the regular US labor force. According to available data from the US Immigration and Naturalization Service (INS), computer-related and engineering occupations accounted for about 60 percent of all H-1B visas approved in 1998 and 1999. Almost all (98 percent) of those approved to work on these visas had at least a Bachelor's degree when entering the United States (US INS, 2000a and 2000b).

Although skilled production workers and technicians were also in short supply, they were not brought into the United States under the H-1B visa program. Moreover, as the MassInc. report indicates, especially with the technology boom widespread in the United States, skilled production workers and technicians were much less likely than university-educated engineers to migrate to Massachusetts in search of employment. Relatively high housing costs in Northeastern Massachusetts posed a particular barrier to geographic mobility (MTC, 2001, p. 56). The shortage of skilled production workers and technicians, therefore, had to be overcome through indigenous development.

In highlighting the shortage of a skilled workforce as a key weakness of the Massachusetts 'Innovation Economy,' the Massachusetts Technology Collaborative (MTC, 1999, p. 7) argued:

> Slow growth in the state's pool of technically skilled workers may impose an effective limit to growth in the state's key industry clusters . . . Importing more people will not, by itself resolve the state's workforce challenge. The state should intensify its 'grow your own' strategy by better equipping its residents with the skills necessary of jobs in the Innovation Economy.

But how is a 'grow your own' strategy implemented in a rapidly changing high-technology industry such as optical networking? Specifically, what roles do a region's major employers play in the process of skill formation, and what is the relationship between corporate skill-formation systems and the regional support structure of educational and training institutions and relevant government agencies? Can the skill-formation systems that did the job in the 'old economy' meet the challenges of the 'new economy?' More specifically, what are the distinctive industrial and organizational changes that characterize the 'new economy,' and how do these changes affect the system of regional skill formation that characterized the economy in the past? To address these questions, this chapter documents how the Merrimack Valley's largest manufacturing employer, Lucent Technologies, responded both to perceived shortages of skilled production workers when the optical networking was booming from 1998 to 2000 and to the marked slowdown of the industry that occurred in 2001.

III. A 'GROW YOUR OWN' CASE STUDY

Lucent's aptly named Merrimack Valley Works (hereafter referred to as 'the Works') has been located in North Andover, Massachusetts for almost half a century. In October 2000, faced with labor shortages, the Works employed about 5600 people, down substantially from its historic high of almost 10000 employees about three decades earlier when the Works manufactured relatively labor-intensive electro-mechanical based transmission systems. As, during the 1970s, electronic systems, incorporating solid-state technology, replaced electro-mechanical transmission systems, the number of production employees was steadily reduced. In the late 1990s, the Works outsourced production of PCBAs and modules to contract manufacturers, as it focused on high-skill systems-integration processes, which also reduced its demand for production workers.

This chapter will describe how the Works sought to respond to actual and potential skill shortages, and the role of regional educational institutions and government programs in supporting these efforts. We shall argue that the success of the Works in 'growing its own' in the recent boom built on a highly effective skill-formation system that the company, in collaboration with a local community college, already had in place when the burgeoning growth in demand for optical networking products took off in 1998. Indeed, so effective was the Works' system of skill formation that at the height of the boom, two of Lucent's major competitors in optical networking, Cisco Systems and Nortel Networks, set up systems integration operations in close proximity to the Works, and sought to hire its skilled labor.

Unfortunately, however, that is not the end of the story. The euphoric optimism for continued rapid growth in the optical networking industry that had prevailed in the fall of 2000 had, by the winter of 2001, turned to a guarded pessimism. Over the course of 2001 there was a complete reversal of the labor market conditions that prevailed one year before. In the fall of 2000, managers at the Works were scouring New England for people with qualifications to be trained as skilled production workers and were worrying that Cisco, Nortel, and other 'labor competitors' might lure away its existing employees. In the fall of 2001, however, managers at the Works were overseeing the plant's *third* wave of terminations since the previous April.

Responding to the severe business downturn in the optical networking industry, the Works reduced its payroll from 5600 employees to less than 3000. Following what had been the practice at former parent corporation AT&T (see Keefe and Batt, 1997), each of the Works' three waves of layoffs in 2001 included a benefits package that enabled employees who were nearing eligibility for retirement to leave the company voluntarily, thus reducing the number of newly hired and trained employees who would be involuntarily separated from the company. The third wave of layoffs, responding in part to a continued deterioration of market conditions, sought to 'right-size' the employee staff in preparation for the sale of a large portion of the Works capacity to an EMS provider. With this sale, the buyer was expected to transfer most of the remaining Works' employees onto its payroll. Lucent would retain several hundred engineers and highly skilled production workers to staff a Systems Integration Center. [4]

When the optical networking boom took off in 1998, Lucent Technologies Merrimack Valley Works and the region with which it interacted were, as we will show, well positioned for a 'grow your own' strategy. But as the boom in the optical networking industry petered out, both the impetus to 'grow your own' and the existing system of skill formation were in jeopardy.

IV. THE TESTER SHORTAGE IN AN ENVIRONMENT OF CHANGE

In November 1998, J. R. Newland, manufacturing and provisioning vice president for optical networking products at Lucent Technologies, approached the University of Massachusetts Lowell to seek help in the company's attempt to respond to increases, both current and projected, in the demand for skilled labor at the Works. From 1997 to 1998, Lucent's total revenues had grown by over 14 percent from \$26.4 billion to \$30.2 billion.[5] Based on industry sources, the company claimed that the global optical networking market was growing by 19 percent annually, with accelerated growth projected to double the total size of the market from about \$9 billion in 1997 to about \$18 billion in 2001.[6] As Lucent's major manufacturing plant for optical networking switching and transmission systems, the projected growth of the industry confronted the Works with increases in the demand for skilled labor on a scale that it had never before experienced. The problem, moreover, was not just a growth in the quantity of skilled labor demanded but also the new types of knowledge required in a period of rapid technological and market change.

With a long tradition of manufacturing at the North Andover site, the Works has undergone several technological and organizational changes throughout its history. Built in the 1950s by Western Electric, the wholly owned manufacturing subsidiary of AT&T, the plant manufactured transmission equipment based on electro-mechanical technology, predominately for the Bell System companies. In the early 1970s, the Works began the transition to solid-state electronics technology. Between 1972 and 1974, the skill requirements of the new technology led to the retraining of 4000 of the Works' 7000 employees (Adams and Butler, 1999, pp. 189–93; see also Balzer, 1976).

With the breakup of the Bell System in 1984, mandated by the Modified Final Judgment of the US Federal Court, AT&T divested itself of all 22 local telephone companies but retained Bell Labs and Western Electric. Its manufacturing division became AT&T Technologies, with the Works as one of its largest manufacturing plants. Further organizational change occurred in 1996 when AT&T spun off its manufacturing division, along with Bell Labs, as an independent enterprise, Lucent Technologies.

Throughout these organizational changes, the Works engaged in 'continuous improvement,' for which the on-going development of employee skills was fundamental. In the early 1980s, the Works was one of the first US companies to enlist the services of W. Edwards Deming, whose work on statistical quality control had become legendary in Japanese industry since the late 1940s (Walton, 1986, ch. 26). The 'continuous improvement' discipline instilled within the factory was recognized nationally in 1992 when the AT&T Transmission Systems Business Unit (the predecessor to Lucent's Optical Networking Group), of which the Works was a member, won the coveted Malcolm Baldridge National Quality Award in manufacturing.[7]

Throughout most of its history, the Works had been a largely self-sufficient integrated manufacturing unit, often even producing the nuts and bolts for its sophisticated and expensive telecommunications equipment. Even into the second half of the 1990s, the Works was described as producing 'virtually everything used in a fiber-optic network except the fiber lines themselves . . .' (Howe, 2000c). In January 1999, however, the Works began a process of outsourcing its more routine production activities, most notably the manufacture of printed circuit boards, so that it could focus its attention on systems integration as it made the transition from electronic to optical equipment (Crabtree, 1999). Nevertheless, with the demand for its equipment strong and the process of outsourcing incomplete, over the course of 1999 and 2000 the Works maintained its employment level at about 5600 (Fleming, 2000a and 2000b; Metz, 2000).

In June 2000, Lucent announced 'that its Merrimack Valley manufacturing facility, located in North Andover, Mass., would become the manufacturing center of excellence and global systems integration center for Lucent's extensive portfolio of optical networking products.' The intense demand for the Works' products, the proliferation of products that customers were demanding, and the rapid transition to optical technologies had generated enormous pressures on the Works to augment and upgrade its capabilities for systems integration. As Lucent Vice President Newland stated in the announcement:

> The systems integration role fits perfectly with the strategy that we've been deploying at Merrimack Valley for the past couple of years. By emphasizing high-end assembly, integration, testing and new product introduction, Lucent will continue to lead the optical revolution by producing innovative optical products. Merrimack Valley is the premier optical networking manufacturing site in the world and continues to demonstrate its operational excellence through its talented workforce. We will continue to recruit locally, across the country, even worldwide, for the best talent available for the production associates, testers, technicians, engineers, and management professionals committed to serve our customers better than anyone else.[8]

Systems integration is the process of combining PCBAs, wired equipment, optical sub-assemblies and software into a configured optical networking system that is tested and shipped to the customer. The testing function is central to systems integration. Testing verifies acceptable performance of the configured system. Additionally, test analysis provides feedback to the product development organization on design margin robustness.

Once a product is fully assembled and configured according to customer order, the product is 'exercised' using testing software loaded onto specialized equipment called a 'test set,' which is monitored by a skilled production worker called a 'tester.' The tester runs the product through a sequence of steps duplicating use in customer applications. These tests are conducted both at ambient and elevated temperatures. In the event of a failure during the test sequence, the tester is responsible for determining the state of the system at the time of failure, analysing data representing key performance variables, and isolating the condition which caused the failure.

Test engineers develop test routines and supporting software to verify systems performance and perform diagnostic analysis for specific products. When product offerings were long-lived and incorporated relatively stable technologies, as they had been in the two decades before the optical networking revolution of the late 1990s, test engineers had sufficient time to develop sophisticated test software customized for each particular product. Under such conditions, the test set was engineered to enable the product to 'test itself', utilizing the internal system controls integrated into the design. Such a 'product-testing-product' approach enabled a single tester to operate multiple test sets, monitoring the operation of each and responding to failures as they occurred. With the level of 'intelligence' built into the test set, operation of the test function placed fewer demands on the skills of the testers (March, 2000).

Development and prove-in of automated custom test software are not feasible, or cost effective, when the pace of technological change and new product introduction is rapid, as was the case in the optical networking industry beginning in 1997. Under such conditions, the testing function becomes dependent upon both the capabilities of the test set and skills of the tester to sequence through all test steps for the verification of system performance during production. Development of the test routine is the responsibility of a cross-functional team comprised of product design, test and process engineers. The team relies heavily on feedback from shop floor testers experienced in monitoring test equipment. Diagnostic routines required to rectify test failures are developed with the assistance of the most skilled testers – known as 'tester analysts.'

The skill and knowledge base of the tester compensates for the lack of automation incorporated within the test set. A tester in the optical networking industry must be knowledgeable in basic optoelectronics. In addition, each tester must have specific knowledge of the operation of the products that the systems integrator produces and the capability to interpret alarms or warnings generated by the testing system. A proficient tester will possess analytical and reasoning skills that permit the rapid troubleshooting of failures (March, 2000).

At the Works, testers are members of the unionized labor force, represented by the Communications Workers of America. The union agreement contains only one tester job classification, with pay of $20–24 per hour, although with overtime some testers can earn $75 000–$80 000 per year. The formal educational qualification for tester certification consists of seven college-credit courses and preparatory mathematics, which are offered on-site by instructors from nearby Northern Essex Community College (NECC). With these educational requirements in hand, a prospective tester must then pass an internal company examination to gain entry into the position. When, at any point in time, there are more qualified testers than tester positions, seniority at the Works determines which employees fill the available openings.

The Works' management assigns each 'tester' – the single formal job classification specified in the union agreement – to one of three different functional categories: tester, tester analyst, or layout operator. Of the 600 testers employed by the Works in October 2000, about 40 were layout operators, the category that demands the greatest experience and responsibility. The majority of the rest of the tester labor force function as tester analysts. There exists a wide variation in capability among this group because the job demands a high level of tacit knowledge. As Richard Devincentis, the 'alternative shift' Senior Manager put it: 'Some people just have the knack for [test analysis].'[9] Given a shortage of qualified testers that the Works faced in the boom, the company created the category of 'provisional tester' – an employee who was in the process of taking the courses to meet the tester educational requirements and who therefore had yet to take (and pass) the internal company exam.

V. TESTER TRAINING

The current system of tester certification was put in place beginning in 1986.[10] Under the union contract, there were nine different tester grades rather than the one grade currently used. There were no formal academic requirements for entry into the job. After negotiations with the union, the company decided to provide all of the testers with academic training, and invited NECC, Merrimack Community College (MCC), and the University of Lowell (now UMass Lowell) to apply to be providers of this training. NECC was chosen because it would focus exclusively on tester education, whereas UMass Lowell was more concerned with educating engineers. MCC had less experience than NECC, and could not offer the courses at as low a cost. As was its longstanding policy, the company covered the cost of tuition. In addition, however, because certification had become mandatory, in bargaining with the union, the company permitted workers to take these courses on company time.

Through this process, by the beginning of the 1990s the company had enough certified testers to meet its needs. In the mid-1990s, however, shortages appeared as many experienced tester analysts retired (employees at the Works are eligible for a pension after 25 years with the company, provided that they have reached the age of 50). As a response, in 1995 the Works used the services of NECC to train 150 current Works employees to be tester analysts. Most of these employees were between 35 and 45 years of age, and had 15 to 20 years of experience with the company. These employees took the courses on-site at the Works' Learning and Performance Center, but on their own time (courses were offered before each shift), with tuition paid by Lucent. Of the 150 people who began the training, 100 completed the course in about one and a half years. In addition, the company negotiated with the union to create the 'provisional tester' category for people who were in the process of completing the educational requirements. Provisional testers were paid at a rate between that of assemblers and testers, and could become regular testers once they finished the academic course of study. In 1995, 250 people were in the provisional tester category, and by October 2000, 90 of them had become fully qualified testers.

Promotion from assembler to tester is not necessarily a final career move at the Works. Tester analysts and layout operators can apply for promotion to senior technical associate (STA) positions, and make the transition from being an hourly-rated unionized employee to a member of salaried management. The educational requirement for promotion to STA is an Associate's degree, toward which testers can credit the courses that were taken for tester certification. The Works' employees could take all of the courses for an Associate's degree on-site at the Works' Learning and Performance Center, with NECC providing the instruction. Such certification programs were done on the employee's own time, with the company paying for tuition, while job-specific training was done on company time.

In 2000, STAs were paid \$46 500 per year, a salary that could mean a substantial cut in pay since, as a member of management, an STA was no longer eligible for overtime pay.[11] The STA position is designed to be a step toward becoming a test engineer – the formal job classification is Member of Technical Staff, or MTS. To be eligible for promotion to an MTS position, the STA must obtain a Bachelor's degree in engineering, again on his or her own time, but with tuition assistance from Lucent. Given shortages of entry-level engineers at the Works during the boom, the Works' Exceptions Committee promoted some highly experienced STAs to MTS positions, despite the fact that they had not obtained their Bachelor's degrees.[12]

During the boom, Ken Eisenberger, the Director of the Learning and Performance Center at the Works, began working with UMass Lowell to deliver on-site courses toward optical certification and Bachelor's degrees in electrical engineering and computer science. In the spring of 1999, Professor Michael Fiddy, Chair of the UMass Lowell Department of Electrical and Computer Engineering, began teaching graduate electro-optics courses at the Works that could be applied toward UMass Lowell's already existing graduate photonics certificate M.S. optoelectronics option. In addition, a UMass Lowell undergraduate certificate program, also already in existence, was adapted to suit the company's needs. This certificate degree could ultimately be applied to a BSEET degree. Other UMass Lowell engineering faculty members have also taught on-site manufacturing courses, applicable to the University's B.S. or Associate's technology degree programs. These on-site courses continued to be offered every semester through the autumn of 2001. There were discussions between the University and the Works about the possibilities for cooperative education, internships at the Works for students and faculty, and company financing of a University junior faculty position.

The undergraduate classes in the certificate program got off to a difficult start because many of those who wanted to take the program had little of the expected mathematics background. In particular, the occupational workers, some of whom were already certified testers, wanted conceptual courses that would help them to understand the 'optical networking' words and acronyms that they were now hearing every day as well as to appreciate the functions of, and improvements to, the hardware with which they work. As a result, the course material was repackaged so that as much understanding as possible of optical systems and fiber optics could be delivered with a high school mathematics background, to be followed by a mathematics course which was specially designed to provide the necessary skills needed to continue with the certificate. This certificate program, modified specifically for Lucent, attracted the attention of other companies, such as Agilent and LightChip, and appeared to be the most effective way of addressing the employees' and employer's needs in a timely fashion. New skills and understanding would be acquired from day one. It was also agreed that these courses would be migrated into on-line courses in order to provide that additional measure of flexibility needed by employees who were frequently required to work extra hours or travel. A number of managerial employees took the courses in order to upgrade their capabilities; in many cases, they wanted to acquire formal education in a discipline quite different from that in which they had originally obtained their Bachelor's degree.[13] In the autumn of 2000, such upgrading of their knowledge of optical systems was particularly attractive to managers and engineers who wanted to position themselves for offers from Cisco and Nortel, both of which were expanding in the region and, reportedly, were offering salaries some 30 percent higher than Lucent.

VI. LABOR COMPETITION

Coming into the optical networking boom that took off in 1998, therefore, the Merrimack Valley Works had a well-developed in-house training system and had long offered both managerial and occupational employees extensive career ladders, possibilities for continuous learning, and considerable employment security. In these respects, the Works epitomized the best in employment practices, including a system of skill formation, that an 'old economy' US company could offer. During the boom in the optical networking industry, however, the 'new economy' confronted the 'old economy,' with major implications for the employment of labor in the Merrimack Valley region.

The dynamic development of the optical networking industry was an important source of the boom in the regional, as well as national, economy (see Carpenter and Lazonick, 2001 and Carpenter *et al.*, 2002). As a major 'old economy' player in the optical networking industry, Lucent Technologies, with its corporate headquarters in New Jersey and over 120000 employees worldwide at the end of 2000, underwent a major organizational transition. Following the business model developed by Cisco Systems, established telecommunications equipment suppliers such as Lucent, Nortel Networks (formerly Northern Telecom), and Alcatel were using their stock as a currency to acquire Internet and optical technology companies, some of them start-ups, at valuations that were typically in the hundreds of millions, and often in the billions, of dollars. The largest of these acquisitions, such as Nortel's purchase of Bay Networks for $9 billion in 1998, Lucent's purchase of Ascend for $20 billion in 1999, and Alcatel's purchase of Newbridge Networks for $7 billion in 2000, were designed to give the buyers immediate access to already developed data communications products possessed by companies that were already generating substantial revenues. In many other cases, however, the acquisitions were start-ups with only 100–200 employees and products that had not yet passed the market test. Such companies offered only the promise that their technological potential would be transformed into substantial revenue streams when integrated into the operations of the acquirer.

Having made an acquisition, the acquirer generally had to offer stock-option packages to recruit personnel from these acquired companies and then retain their services. Such acquisition and recruitment activity in turn created incentives for many of the 'old economy' companies' long-term employees, whose business and technical skill were in demand at start-ups, to forsake the standard career paths that they had been following and jump ship to 'new economy' companies that offered the potential of huge stock-based rewards. In 'old economy' corporations, stock options were generally available only to top executives, whereas in established 'new economy' companies such as Microsoft, Intel, and Cisco, stock options were much more widely distributed among technical and administrative personnel. With the new confronting the old in optical networking, companies such as Lucent, Nortel and Alcatel were compelled to push the use of stock options deeper into the organization, although generally in an ad hoc fashion as recruitment and retention of key personnel demanded (Carpenter and Lazonick, 2001 and Carpenter *et al.*, 2002).

As a result, Lucent came under intense pressure to maintain the growth of its stock prices so that it could match the acquisition and recruitment currency that the stock market had granted to a 'new economy' competitor such as Cisco. During the boom, these high stock valuations went to those companies that were investing, largely through acquisition, in potentially innovative high-technology capabilities, while avoiding investment in low-margin routine activities. For example, until 2000, Cisco had grown to be the dominant company in the Internet routing industry (on the basis of which, using acquisitions, it entered the optical networking industry) while doing virtually no manufacturing. Even its systems integration activities were carried out at the facilities of EMS providers such as Solectron. For an 'old economy' company such as Lucent, the imperative to maintain high stock valuations accelerated a trend to divestment of components production. Whereas in the old economy, the Works produced virtually all its own components, the new-economy strategy was to outsource as much as possible.

But outsourcing can come at a cost. During 2000 the global electronics boom created intensive components shortages that at times brought production to a stop at the Works as well as elsewhere in optical networking (Hill, 2000). Indeed, if there was one factor that prevented the Works from shipping its products on time during the boom, it was a shortage of components, not a shortage of skilled personnel (since shortages of bodies could be offset by overtime as well as redivision of labour).[14] The Works was not just competing against other optical networking manufacturers for these components; multimillion-dollar telecommunications equipment produced in small numbers can be in competition with inexpensive electronic games, produced in vast quantities, for limited supplies of commodity components.

During 2000, therefore, component shortages became a more limiting factor than labor shortages on output in the optical networking industry. Nevertheless, in the boom, optical networking companies that wanted to innovate and grow needed increased numbers of reliable and skilled employees for both new product development and the timely delivery of high quality products to customers. As Edward March (2000), Director of Circuit Pack Engineering and Manufacturing at the Works, put it:

> [The skill-shortage] problem extends across new products as the older electronic based systems are replaced with new optically based products. In fact, I suspect that this problem extends across the telecommunications industry in general as manufacturers strive to introduce new optical products and supply them in volumes capable of satisfying the enormous demand telecommunication service providers have for these products. Until a large pool of people becomes trained and skilled in optical technology, all companies will need to develop strong educational training programs internally to transform their current work force into one proficient in production of optically based products.

For the Works, skilled production workers, such as testers, tended to come from the regional labor supply. Indeed, from the late 1980s the Works had recruited virtually all its testers internally from its large pool of production workers. Now, however, with persistent shortages, the Works was actively recruiting testers from 'the street,' including from technical colleges as far away as Vermont and Maine where the new employees would have taken some or all of the courses required for tester certification. Whether or not they already had obtained these course credits, many of the new entrants were eager to take advantage of Lucent's tuition assistance program once they entered the Works. Some of them were looking to upgrade their education and skills to make the transition into the engineering ranks.[15]

These new recruits were not necessarily looking to Lucent for careers. They were well aware that there was fierce competition for their labor from a host of 'labor competitors' that had recently moved into the region. Many of these companies were located in southern New Hampshire, where resident employees pay no state income taxes. These companies reportedly offered signing bonuses and relocation packages to recruit into both production and engineering jobs.[16]

Foremost among these labor competitors were Lucent's main rivals in the optical networking industry. During the summer of 2000, just as Lucent was pursuing its strategy of making the Works its center of excellence for systems integration, both Cisco and Nortel launched systems integration facilities in the region, each within about 20 miles of the Works and easily accessible along the interstate highway system. On 24 July 2000, Nortel announced that it would build two major optical networking facilities in the Route 128/495 region. One of the two facilities, in Billerica (the

Massachusetts location of its 1998 Bay Networks acquisition), would employ 1050 people in a new 'optical system house.' The completion of its expansion in Massachusetts, scheduled to take place over the next year and a half, would enable Nortel to double its production of optical networking systems (Bray and Kerber, 2000).

Meanwhile Cisco Systems had taken over an old Digital Equipment Corporation plant in Salem, New Hampshire, where, with operations commencing in October, its plan was ultimately to employ 2500 people to do optical networking systems integration (Howe, 2000a). In August Cisco convinced a federal judge to reject Lucent's attempt to have the court issue an injunction to block ten former managers and engineers who left the Merrimack Valley Works in June from working for Cisco at the New Hampshire plant. Among the Lucent defectors was an employee of 18 years who became the manager of the Cisco optical networking facility (Howe, 2000b).

The opening of the Cisco systems integration plant was particularly significant because heretofore Cisco had not done any of its own manufacturing, and even located its testing operations at contract manufacturers such as Solectron. Carl Redfield, Cisco senior vice-president of manufacturing and logistics, stated publicly that within a year Cisco would begin to consider selling the Salem plant to a contract manufacturer.[17] In the event, in November 2001, it was announced that Celestica would occupy much of Cisco's Salem plant (consolidating its New England operations there) while Cisco would maintain its own workforce of only 150 people.[18] When made a year earlier, Redfield's statement about selling the plant may have been for the benefit of financial analysts who might have downgraded Cisco's prospective stock-price performance if they thought that the 'lean and mean' company was now finding it necessary to engage in lower yielding manufacturing activities. But the fact that Cisco continues to maintain its own capabilities suggests that the company's entry into the production of more complex 'carrier-class' optical networking products has made it necessary for Cisco to be directly involved in the systems integration process.

Thus the interface between investments and divestments among the major North American players was converging around systems integration (see Carpenter *et al.*, 2002). The Route 495 district in north-eastern Massachusetts was becoming a prime site for such activity. In addition, the main attraction of the region, skilled labor, derived from Lucent's longstanding presence there as a leading manufacturer. As the demand for skilled labor by companies that were right at the center of the new economy heated up along Route 495, the business conditions were ideal for business and government to join forces in the region to enhance the Merrimack Valley region's capability to grow its own skilled labor.

VII. FROM TRAINING TO TERMINATION

Labor competition in the Merrimack Valley region was intense during the last half of 2000. Beginning in January 2001, however, it became evident that the demand for optical networking products would not be sustained at anything like the level that had been driving investment decisions over the previous two years. In part the boom had been driven by a massive investment in fiber optic capacity; it is estimated that in 1999 and 2000, 100 million miles of fiber had been laid worldwide (Fedder, 2001). In 2001 service providers cut back capital expenditures, and a number of the newer companies went bankrupt. Huge inventories of networking gear accumulated; in March 2001 Cisco Systems announced that it was taking a record-setting $2.5 billion charge for inventory write-offs. This charge resulted from massive long-term commitments that, in the face of component shortages and with highly optimistic projections for sustained demand for its own products, Cisco had made to purchase gear from suppliers the previous spring. In addition, in order to win new orders and book sales (which in turn helped to boost a company's stock price), equipment suppliers such as Lucent, Nortel and Cisco had extended extremely generous, and highly risky, vendor financing to service providers. With the failure of some of these providers, much of this financing turned into a mountain of bad debt. In 2001 Lucent announced layoffs of 39000 (close to 30 percent of its labor force), Nortel 50000 (over 50 percent), and Cisco 8500 (over 20 percent) (Carpenter *et al.*, 2002).

Between April 1996, when Lucent's stock was first listed on the New York Stock Exchange, and December 1999, when its stock price hit its peak, the company's stock price appreciated by over 750 percent. At the beginning of September 2001, Lucent's stock price had declined to less than 8 percent of its peak value in December 1999. This is not the place to analyse the causes of the financial instability that has beset Lucent over the past two years (for such an analysis, see Carpenter *et al.* 2002). Suffice it to say that the volatility affected most optical networking companies, and the new economy more generally. At Lucent, however, it appears that, at the corporate level, managerial behavior within the company exacerbated the instability. Such behavior included 1) the purchase of revenue-less high-tech start-ups for billions of dollars in the company's stock, some of which have since been entirely written off (the most dramatic example being Chromatis Networks, which was acquired in May 2000 for $4.5 billion in stock); 2) extravagant vendor financing, apparently motivated by the desire to increase the company's reported earnings, and hence boost its stock price; 3) the booking of hundreds of millions of dollars of non-existent earnings (for which the company is now under investigation from the

Securities and Exchange Commission); and 4) opportunistic investments by top Lucent executives in other companies, including one reported case in which Lucent's CEO, Rich McGinn, took a huge personal stake in a competitor founded by the ex-CEO of a start-up that Lucent had recently acquired (Carpenter *et al.*, 2002).

The waves of layoffs at the Works that began in April 2001 were the direct results of the dire financial difficulty in which Lucent as a whole found itself in 2001. Since 1999 the Works had been outsourcing PCBA manufacturing, but the growth of demand for systems-integration activities had sustained the level of employment at the Works at around 5600 during the boom. As a marked slowdown in the industry continued in January 2001, Lucent's corporate office began executing its strategy of selling off 'non-core' manufacturing assets to contract manufacturers. This strategy included selling a large percentage of the Works production capability. Recognizing the importance of retaining the skilled, experienced workforce in building its optical products, an important part of Lucent's plan required the contract manufacturer to employ as many former Works employees as possible when manufacturing transferred to the new owner. The production employees would continue to be represented by the Communications Workers of America. Indeed in the summer of 2001 Celestica took over two of Lucent's manufacturing plants – one in Columbus, Ohio (which it bought) and the other in Oklahoma City (which is leased) – with the workers continuing to be represented by their union, in these cases the International Brotherhood of Electrical Workers.

On 2 April, 2001, Lucent announced that 800 employees at the Merrimack Valley Works would be laid off, of whom 725 would be union members and the other 75 members of management. On 19 April, 2001, Lucent Technologies and the Communications Workers of America entered into a Memorandum of Agreement (MOA) that detailed the 'treatment of employees directly impacted by the Company's decision to subcontract or outsource bargaining unit work'.[19] Among other things, as part of a voluntary retirement package to be offered by the company to employees at risk because of announced layoffs, the MOA increased a lump sum payment for workers made redundant through subcontracting or outsourcing from (as per the terms of the existing agreement) a maximum of $30 500 for those with the most service, to a maximum of $40 000. In the first wave of 2001 downsizings at the works, 440 employees volunteered for the retirement package, while 450 were laid off. In June, more of the Works managerial employees were asked to take voluntary retirement as part of a company-wide reduction that ultimately involved 8500 Lucent managers and engineers. In mid-July the company offered voluntary retirement packages to union employees at the Works in a planned layoff of 275 (of which in fact 239 volunteered for retirement). By the end of July, Lucent announced its intention to sell most of the Works, reducing Lucent employment there by the end of the year to about 600–800 employees doing high-end systems integration. The third wave of layoffs sized the workforce for the sale of the rest of the facilities to a contract manufacturer. The announced number of layoffs was 950, with voluntary retirement packages being offered under the enhanced 19 April 2001 MOA. Of a total of 1250 employees who were eligible for a pension, 1211 volunteered for retirement, and Lucent agreed to provide the retirement package to all of them. Included in this last wave of layoffs were 710 production workers, 132 testers, 156 trades employees and 209 office workers. The departing employees received 117 percent to 134 percent of their normal termination pay, plus career training and outplacement expenses and extended health benefits for one year.[20]

In all, between April and November, Lucent laid off 2376 Works' employees, well over 40 percent of its labor force. In October and November, the company was seeking bids on the plant sale from Celestica, Jabil Circuit, Sanmina and Solectron. As of early December 2001, it was rumored that Solectron would be the buyer, raising fears on the part of employees that they would have to work at the company's existing production facility in Westborough, Mass, some 50 miles from the Works (Murray, 2001). As it turns out, Lucent's agreement with Solectron, announced on 28 March 2002, specifies that the contract manufacturer will employ about 400 former Works employees in the vicinity of North Andover, while Lucent itself will retain about 500 employees, mostly engineers, at a Systems Integration Center, also at a neighboring site. Meanwhile, on 4 January, 2002 the US Department of Labor announced a $3.3 million emergency grant to set up a job search and career counselling center, to be administered by the Lower Merrimack Valley Workforce Investment Board, for the specific purpose of helping displaced Works employees to find new jobs (Murray, 2002).

This program will complement a retraining program already underway. In January 2001, as the business outlook in optical networking dimmed, a new retraining program – the Northeast Skills Training Project (NSTP) – which had its origins in the boom was gearing up at the Works. At the initiative of the CWA union local and with the support of the Massachusetts AFL-CIO (where Education and Training Director Harneen Chernow was the prime mover), the union and management had cooperated in submitting a proposal to the US Department of Labor for an H-1B training grant.[21] Although production workers at Lucent have had a career ladder open to them to rise up internally to the engineering ranks, the main use of H-1B training grants is to upgrade the skills of production workers to enter more highly skilled production jobs. Testers are a prime occupational group for such training. The Works was well positioned to get an H-1B training grant because it had a skill-formation system for testers in place and because Lucent was one of the largest users of H-1B visas in the country (US INS, 2000c).

The grant that funds NSTP is for $2.3 million for two years from November 2000 and is administered by the University of Massachusetts Labor Extension Program. It provides up to 640 training slots for CWA Local 1365 Works' employees and up to 110 training slots for members of the International Union of Electrical Workers (IUE) Local 201 who work at Ametek Aerospace (a subcontractor whose plant is scheduled to be relocated outside the United States).[22] The main purpose of NSTP, when the grant was written and secured in 2000, was to help the Works deal with the need for more testers. NECC teaches the courses on-site at the Works, while Lucent provides an 'in-kind' match in the form of payments for 50 percent of the time that enrollees spend in courses (amounting to $243 000 in the first semester) plus a one-time expenditure of $161 000 for the construction and equipping of a new on-site classroom. In the event, in 2001 the H-1B grant has become important for helping to retrain laid-off Lucent workers to position themselves for re-employment with other companies.

VIII. THE PROSPECTS FOR A NEW 'GROW YOUR OWN' STRATEGY

The attempt at implementing a 'grow your own' strategy at the Works raises many questions about the forms that such a strategy will take, and the processes that will be involved, in the new economy. As an old-economy manufacturing plant, the Works had an exemplary internal skill-formation system in place when Lucent sought to compete and grow in the optical networking boom of the late 1990s. With the downsizing of the Works' labor force that has already occurred and the transfer of some employment to Solectron, that skill-formation system will no longer be in place at the Works. Lucent itself will only continue to employ production workers who have already attained tester certification, and hence will not have an internal pool of assembly workers whose skills can be upgraded over time. Solectron is also likely only to do higher-end systems integration work in Massachusetts; contract manufacturers are adept at moving routine, cost-sensitive work out of the United States, while focusing on high value-added activities in a high-wage area such as Massachusetts. As a result, in contrast to the internal skill-formation system that prevailed at the Works, we should not necessarily expect that Solectron would put a similar skill-formation system in place (but this matter remains to be seen).

There seems little doubt that there will be plenty of high-end work for contract manufacturers to do in the region. Although the growth of the optical networking industry has slowed dramatically, and an abundance of fiber is already in place, there is ample scope for innovation in optical networking over the coming years. The Optical Fiber Conference 2001 broke all records for attendance, with 38 000 participants, up from 17 000 the year before.[23] The April 2001 issue of *Photonics Spectra* argued: 'Layoffs and Wall Street notwithstanding, photonics is booming – and so is the job market' (Johnson, 2001, p. 100). The slowdown was primarily affecting lower-level manufacturing personnel rather than engineers. The boom of 1998–2000 is now being seen as an extraordinary, and atypical, period, with the industry settling back down to business as usual, with enormous technological opportunity. It is not only demand for engineers that is expected to remain strong. The April 2001 issue of *Photonics Spectra* estimated that, over the next four years, the current supply of photonics technicians with Associate's degrees would need to be increased by 32 000, while the September 2001 issue revised this figure upwards to 62 000.[24] Route 128/495 will remain a prime location for employing these people.

But what type of skill-formation system will generate the skilled personnel that the on-going development of the optical networking industry will require? The demise of the 'old economy' model, epitomized by the Works with its internal focus, suggests the need for a more collective response by interests in the region to put in place a new, externally-structured, skill-formation system. Such a system will increase the demands on the regional educational system in the skill-formation process. NECC and other community colleges will need to continue to perform critical training functions on an expanded scale. For UMass Lowell, there will be both an expanded role in providing training to engineers and a new role in mobilizing those actors in the region with an interest in a 'grow your own' strategy. These actors will include unions, educational institutions, training agencies and companies, among which are the contract manufacturers that have increased their presence in the region. Such a coalition of interests in a new system of skill formation will not just happen; there is an important role for a technology-oriented regional university to look for emerging opportunities for skill formation, and through its interaction with companies in the region help to create these opportunities (see Best and Forrant, 2000; Forrant *et al.*, 2001).

As part of this new system of skill formation, it is not just the system of higher education that needs to be expanded and transformed. There is an urgent need to upgrade the quality of education throughout the system, starting with K-12. As an integral part of these efforts to mobilize the University's resources for regional development, the UMass Lowell's College of Engineering has launched a direct-action initiative to encourage the upgrading of the technical capabilities of the Region's labor force. Krishna Vedula, Dean of the UMass Lowell College of Engineering, has been the acknowledged leader in Massachusetts in organizing business, government and academic interests to take actions that broaden and deepen the supply of engineers produced within the state. Reacting to the continued decline in the state's engineering graduates – from about 3900 in 1987 to about 2500 ten years later (MTC, 1999, p. 43) – and electrical engineering graduates in particular, Vedula founded the Engineering in Massachusetts Collaborative (EiMC) in April 1998, and enlisted Ray Stata, chairman of Analog Devices, and Joseph Alviani, president of the Massachusetts Technology Collaborative, to serve as EiMC chairmen. Through EiMC, Analog Devices has since the fall of 1998 offered internships of up to four years at the company to selected regional high-school seniors who pursue a B.S. degree in the UMass Lowell electrical and computer engineering program (Best, 1999; Fiddy *et al.*, 2000; Vedula *et al.*, 2000).

EiMC places great emphasis on the need to transform the quality of science and mathematics offerings in the Region's high schools, and on the need to inform high school students of the importance of analytical skills for their future careers. EiMC has also developed close ties with regional community colleges. The University has been running programs for high school and community college teachers and students during summer and other school breaks to introduce them to the possibilities of engineering careers. Sustained interaction between the University and the Region's high schools is by no means new to UMass Lowell. Lowell State College, which represented the other side of the merger with Lowell Technological Institute that created the University of Lowell in 1975, had its origins as a teacher's college. As a result, UMass Lowell's College of Education has a very strong K-12 teacher-training program, and a close relation with the region's public primary and secondary schooling system. The University also has a very active continuing education program for upgrading the skills of the regional labor force. What is new, reflecting the on-going mission-oriented transformation that UMass Lowell underwent in the 1990s, is the emphasis on integrating the College of Engineering into these activities.

Initiatives that improve the quality and attractiveness of science and mathematics offerings in the region's public high schools not only increase the number of students who are equipped to enter and complete university engineering programs, but also develop an even larger stratum of students who have the abilities and incentives to take up employment in skilled technician jobs. These are jobs for which, as we have argued, the region will have to engage in a 'grow your own' strategy. The fact that high-technology companies in the Merrimack Valley region, as in the United States as a whole, can draw upon a global pool of highly mobile engineering talent (whether they come to the United States as immigrants or on H-1B visas) should not lead these companies to overlook the fact that the region will have to remain an important source of skilled labor if they are to do their work here. With the development of competitive high-tech regions around the world, over the long run, the Merrimack Valley region is unlikely to meet the demands of these companies for skilled labor, in terms of both quality and quantity, unless these companies themselves – both those with a long history in the region and those newcomers that want to tap the region's capabilities – support the building of the new regional skill-formation system that now needs to be put in place.

NOTES

1. The authors acknowledge extensive comments and advice from Edward March, Director of Circuit Pack Engineering and Manufacturing at Lucent Technologies Merrimack Valley Works, as well as comments from Michael Best, Robert Forrant and Mary O'Sullivan. This chapter also draws on research of William Lazonick with Marie Carpenter and Mary O'Sullivan on the optical networking being carried out at INSEAD. We are grateful for the cooperation of a number of people at Lucent Technologies Merrimack Valley Works, including (first and foremost) Ed March as well as Kathie Campbell, Lynn Centariczki, Dick Devincentis, Ken Eisenberger, Natasha Glendon-Crossley, Joe Kanan, Sheila Landers, Neil Murray, Lee Pratt and Milt Taylor. Judy Coughlin of the UMass Lowell Labor Extension Program provided us with information on the H-1B training grant that she administers. An earlier version of this chapter was presented at the International Conference on Approaches to Sustainable Regional Development, University of Massachusetts Lowell, 26–28 October 2000. In its initial stages the University of Massachusetts Lowell Committee on Industrial Theory and Assessment supported the project on which this chapter is based. William Lazonick also acknowledges support from the Russell Sage Foundation, as well as funding for related research from the Targeted Socio-Economic Research Programme of the European Commission and the National Science Foundation.
2. See 'Providers making optical investments despite downturn', *Manufacturing Market Insider*, August 2001, pp. 3–5.
3. For overall assessments of the state of skill formation in the region and Massachusetts, see Forrant and Barry, 2001 and Forrant *et al.*, 2001.
4. On 28 March 2002, Lucent announced the sale of the Works to Solectron, with the deal to close by June 2002.
5. Lucent Technologies, *1998 Annual Report* (http://www.lucent.com/investor/annual/98/revolution6.html).
6. Lucent Technologies, *1999 Annual Report* (http://www.lucent.com/investor/annual/98/optical2.html).
7. The US Department of Commerce's National Institute of Standards and Technology administers the Baldridge Award, which is in effect an American version of Japan's Deming Prize. For the Baldridge Award, see http://www.quality.nist.gov/, and the profile

of AT&T Network Systems Group Transmission Systems Business Unit at http://www.quality.nist.gov/AT&T_NSG.htm.

8. 'Lucent Technologies selects Massachusetts site to become global optical systems integration center', Lucent Technologies press release, 7 June 2000 (http://www.lucent.com/press/0600/00607.nsa.html)
9. Interview with Richard Devincentis, Senior Manager, Lucent Technologies Merrimack Valley Works, 2 October 2000.
10. The following information comes from interviews with Neil Murray, Workforce Relations and Security, Lucent Technologies Merrimack Valley Works, 16 October 2000, Joseph Kanan, President of Local 1365 of the Communications Workers of America, 3 December 2001 and Michael Pelletier, Chair, Department of Electronic Technology, Northern Essex Community College, 30 October 2001.
11. The move can also have an adverse effect on the employee's pension level.
12. Interview with Lynn Centariczki, Technical and Professional Relations Manager, Lucent Technologies Merrimack Valley Works, 2 October 2000.
13. In the Spring 2001 class there were 15 managerial and 11 occupational employees; in the Fall 2001 class ten managerial and ten occupational employees. Several managerial employees dropped out of the class in the Fall because of a delay on the part of Lucent in deciding whether their tuition would be reimbursed (the decision was ultimately positive).
14. Interview with Lee Pratt, Senior Manager, Workforce Relations and Security, Merrimack Valley Works, 27 November 2001.
15. Interviews with Neil Murray and Ken Eisenberger, Lucent Technologies Merrimack Valley Works, 16 October 2000.
16. Interview with Neil Murray, Lucent Technologies Merrimack Valley Works, 16 October 2000.
17. 'Cisco cuts ribbon on N.H. plant', *The Boston Herald*, 4 October 2000.
18. 'Celestica moving work to Salem', *Lawrence Eagle-Tribune*, 21 November 2001.
19. 'Memorandum of Agreement Between Lucent Technologies Inc. and The Communications Workers of America', 19 April 2001, provided to the authors by Joseph Kanan, President of CWA Local 1365.
20. Information made available to the authors by Joseph Kanan. See also articles in the *Lawrence Eagle-Tribune* from 12 December 1999; 24 January 2001; 15 February 2001; 2 April 2001; 8 April 2001; 18 April 2001; 8 May 2001; 13 July 2001; 17 July 2001; 28 July 2001; 26 September 2001; 11 October 2001.
21. Companies pay $1100 for an H-1B visa, of which $1000 goes into a fund to retrain US workers, ostensibly for the types of positions that are currently being filled by foreign workers through the H-1B program. In fact, as we have seen, the H-1B visas go to those with at least a Bachelor's degree.
22. We are grateful to Judith Coughlin, Director of NSTP for supplying a copy of the project contract with the US Department of Labor as well as the Director's Reports of August 2001 and October 2001. She also presented details of the project at the CIC-RESD Seminar, UMass Lowell, 5 November 2001. The on-site coordinators of NSTP are Milt Taylor at the Works and Paul Babin at Ametek, a Massachusetts-based aerospace subcontractor that is also involved in NSTP.
23. *Optics and Photonic News*, May 2001, p. 48.
24. See http://www.workingoptics.com.

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