Enhancing the Yamacraw Cluster

Prepared for:
Yamacraw

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Executive Summary

Yamacraw is a state technology development initiative launched by Governor Roy Barnes in 1999. The program seeks to make Georgia a world leader in the design and commercialization of high-capacity broadband communications systems, devices, and chips. Key programmatic elements of Yamacraw include applied research, education, corporate membership, seed funding, marketing, and a design center facility.

Announced in 1999 as a five-year project, Yamacraw is nearing completion of its third year as of the writing of this report. Yamacraw has met or exceeded most of its initial targets, including 25 company members, 25 percent growth in research funding, and an increase in the number of faculty and graduates in relevant degree programs.

Now that a foundation has been created, what should the state do next to build out the Yamacraw cluster? That is the question that the Georgia Department of Industry, Trade, and Tourism (GDITT) and the Yamacraw Initiative asked Georgia Tech and SRI International to investigate in the second half of 2001 and first half of 2002. A team from Georgia Tech's Economic Development Institute, School of Public Policy, and City Planning Program along with SRI International conducted the cluster study.

The objective of the study was to find out what Georgia should do to advance development of the Yamacraw cluster. The study aimed to understand the dynamics and benefits of developing high-technology clusters. It also sought to identify how firms geographically cluster, how clusters changed over time, and whether vertical supplier-customer linkages were geographically important to the development of a Yamacraw cluster. There was additional interest in understanding how clusters in other parts of the U.S. and across the globe developed and what role research played in this development.

Because of the nature of the Yamacraw cluster, which is a new and dynamic industry, the team employed triangulation of several different methods to develop findings and recommendations. A huge amount of data was obtained to examine development directions for the Yamacraw cluster: 13 articles, six member case studies, 7.9 million geographically-defined employment records, 10,337 publications, 720 patent records, and eight case studies of cities with concentrations of Yamacraw-related industries.

The importance of research in sustaining and enhancing successful technology clusters was clearly demonstrated in this study. Therefore, it is recommended that Georgia should focus on enhancing its highly successful academic research posture by attracting both commercial research-and-development (R&D) units and federally funded research institutes. Scenarios for enhancing the state's research activity, which could be pursued individually or simultaneously on several different fronts, include (1) developing multiple university, government, and corporate research institutes; (2) attracting a large anchor research corporation; and (3) creating or attracting an intermediary organization to link corporate and university researchers. Development of additional research nodes should be considered a major follow-on activity in the Yamacraw area.

The study also recommends that GDITT use R&D activity as a primary screening tool for attracting prospective companies (particularly their corporate R&D units) to Georgia. Based on a firm's research activity, the state can decide whether and how special research relationships can be developed. A preliminary list of prospective firms is furnished in this report. Some of the firms on the list are relatively smaller-niche companies that may be interested in special relationships with researchers outside the Yamacraw faculty. There are large domestic and international firms as well that may desire research observatory/landing party offerings as part of a total package.

Section 1. Introduction

In the summer of 2001, the Georgia Department of Industry, Trade, and Tourism (GDITT) and the Yamacraw Initiative requested Georgia Tech and SRI International to investigate opportunities for development of the Yamacraw cluster. The emphasis was not on the attraction of high-tech chip design firms, which was already progressing well, but rather on the prospects for recruiting and developing related manufacturing, support, and supply-chain jobs that would fill out the cluster.

Study Context

Yamacraw is a state research initiative sponsored by Georgia Governor Roy Barnes. Launched as a five-year project in 1999, its goal is to make Georgia a world leader in the design and commercialization of high-capacity broadband communications systems, devices, and chips. Yamacraw focuses on three areas: broadband devices, embedded systems, and prototyping. The basic elements of the initiative are: (1) corporate membership in the Yamacraw design center; (2) an industry-relevant research program; (3) a large and growing pool of graduates in relevant degree programs, based on the recruitment of new university system faculty and state-of-the-art curriculum development; (4) an early-stage seed fund for investing in chip design start-ups; (5) a marketing program to build Georgia's high-tech image in the area; and (6) a new building to house the program.

The program has met or exceeded most of its initial targets. Yamacraw has recruited 25 companies to take memberships (an additional three companies have not yet been announced). Job commitments have been made for 3,200 positions, and 1,400 of these have been filled. More than 85 faculty have been recruited, and curricula have been developed at eight universities. The number of trained students has increased beyond the 400-per-year standard at the end of the 1990s. Research dollars have risen by 25 percent to $5 million. The state created a $5 million venture fund (administered by the Advanced Technology Development Center) which has invested in six incubator start-ups. A marketing and public relations campaign, Web site, newsletter, and other efforts have been developed to enhance the state's high-tech image. Groundbreaking occurred November 13, 2001 for a 200,000-square-foot design-center building in Midtown Atlanta to serve as a meeting place for researchers, industry, students, and venture capitalists. The state allocated $100 million over a five-year period for the initiative.

Study Objectives

This study's objective is to assist Yamacraw in its strategy to build out from the foundations of the existing design-company cluster. There are five main questions that this study seeks to answer to fulfill its objective:

1. What are the benefits of clusters, and factors are important in the development of high-technology clusters?

2. What spatial patterns do clusters of firms in broadband communications industries exhibit? How have these clusters changed over time? To what extent are supplier or customer firms geographically linked to the core broadband communications cluster?
3. How have similar clusters, located in other parts of the United States and abroad, developed and what are their critical characteristics?
4. What is the relationship between research and design firms and firms engaged in other aspects of the industry (e.g., manufacturing, sales, and service)?
5. What should Georgia do to further develop its broadband communications cluster? What types of firms should the state target to enhance the Yamacraw cluster?

Study Approach and Overview of Report

Yamacraw is focused on a dynamic and new industry area. To research such an area, the Georgia Tech/SRI team selected a mix of methods—both quantitative and qualitative—to build a rich information base for addressing these questions. Five key tasks were involved.

1. We conducted a literature review, summarized in Section 2, to better understand the state of practice in cluster-based economic development.
2. We conducted case studies with key executives of six Yamacraw core member/prospective member companies to obtain an in-depth understanding of relationships between the design center and supplier and customer firms along the value chain. Section 3 contains a write-up of these interviews, along with a cross-case analysis and implications for development of the Yamacraw cluster.
3. Section 4 focuses on Yamacraw-like clusters within the United States. A geographic information systems (GIS) analysis has been used to show where these clusters are located, what they look like over time, and how they link with input and output firms. Based in part on these GIS, five high-tech clusters have been described and assessed for lessons learned for Georgia analyses. These cases are presented in Section 5.
4. A technology opportunity analysis (TOA) was completed to capture the research-intensive nature of the Yamacraw cluster. The TOA analyzed bibliometric data to assess the R&D context for the Yamacraw program and to measure geographic concentrations of research in the broadband communications sector.
5. The results of this analysis led to more detailed profiles of three leading international broadband communications clusters—Kanagawa, Japan; Bavaria, Germany; and Eastern Scotland. Section 6 summarizes the results of the TOA and cluster profiles.

We combined these measurements with our judgments to arrive at insights for further development of the Yamacraw cluster. Our overall recommendations appear in Section 7.

Georgia Tech's Economic Development Institute was responsible for overall project management and report production and for the formation of case studies of Yamacraw member companies. The Georgia Tech School of Public Policy conducted the TOA of publications in Yamacraw-related research fields, developed profiles of three international clusters, and contributed to a review of the literature on technology-based clustering. Georgia Tech's City Planning Program developed and analyzed an extensive historical GIS database for the United States. SRI was responsible for developing case studies of Yamacraw-like clusters in other part of the country, and also contributed to the literature review, input/ouput analysis, and interpretation of GIS results.

Throughout the process, weekly meetings were held with Yamacraw and GDITT managers. Monthly briefings were submitted to Yamacraw. A preliminary presentation of findings was delivered in December 2001. In addition, several documents related to the Yamacraw initiative were reviewed.

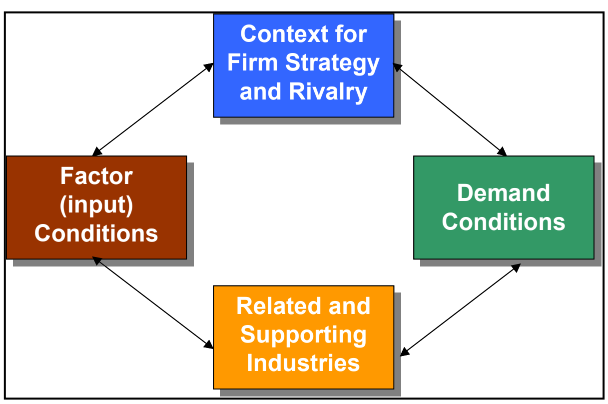
Section 2. Lessons from the Literature

Why Cluster?

Clusters are accepted in many business circles to describe how technology development occurs. Some observers consider clustering to be a natural business process. Businesses concentrate in certain locations that are near valued resources, be they raw materials, expert labor, or research infrastructure. The geographic concentration of many firms in similar industries produces a scale that is greater than any one individual firm. But clustering is more than a number of firms concentrated in a single region. The type of interaction among firms in the region has been found to be as important as the sheer number of proximate firms. Firms in a cluster may both compete and cooperate. They can share resources, spin out new firms, and generate demand for other firms to move to the cluster. (Rosenfeld 1997)

Michael Porter (1990) is among the most well-known proponents of clustering. He finds that firms locate in clusters because it gives them a competitive advantage. Porter conducted a series of case studies, from which he developed a "diamond" to describe four major drivers of competitiveness accruing to firms located in clusters (see Figure 2.1): (1) context for firm strategy and rivalry (i.e., regional business climate); (2) conditions such as natural resources and availability of skilled labor; (3) demand conditions such as the degree to which there is a sophisticated local market for goods and services; and (4) related and supporting industries, including local suppliers, customers, specialized services, and competitors.

Figure 2.1. Porter's Diamond of Competitive Advantage



Porter's notion that cluster firms are more competitive draws on a long history of theories about economic growth. It can be considered a revival of 19th century agglomeration theories, which say that lower costs go to a firm locating in a region where there is a concentration of other firms, or it could reflect a rediscovery of the "growth pole" analytical concept of the 1950s and 1960s, in which dominant or innovative firms draw and focus economic resources to a region given that certain infrastructure and other prerequisites are available. Other researchers rediscovered clustering as they examined the textile industries in northern Italy (Piore and Sabel 1984) and the information technology industry in Silicon Valley (Saxenian 1994), to name a couple examples.

Clusters and Technology-based Economic Development

Strategies for technology-led growth rest on a complex and uncertain route to development. Technological innovation and change are sometimes thought of in a simplistic manner: (1) resources such as knowledge, ideas, money, and facilities go into a "black box," and new products and processes come out of it, and (2) the black box works like a "pipeline" in which basic research is supported and stuffed into one end and new products are expected to emerge at the other. In reality, processes of technological innovation are messy, risky, and unpredictable. A sound business plan, efficient production, talented marketing, sound financing, and generating demand for the new product are essential. (SRI International 2000)

Studies of cluster-based approaches have found that clusters can facilitate this process. Clustering can create an environment that encourages innovation and learning among these firms through the informal exchange of knowledge and information. (Bergman and Feser 1996) Picking up this theme, states have sought to rejuvenate their existing economies by investing in new strategies that variously focused on creating science and technology clusters. States have tried to establish their own version of California's Silicon Valley, Massachusetts Route 128, or North Carolina's Research Triangle Park. An array of economic development tools emerged, emphasizing the creation of new firms and jobs in high-tech industries over the recruitment of firms through relocation subsidies. Venture capital funds, incubators, research parks, and centers of advanced technology became staples of state economic development policies. Technological change was seen as the key to economic development in the future. (SRI International 2000)

Why Do Some Clusters Work?

High-tech firms do not just emerge randomly. They require a particular environment in which to grow and flourish. As the many disappointed creators of failed research parks have learned, it takes far more than an attractive setting and tax incentives to create a self-sustaining high-tech cluster of firms. Nearly two decades of experience and research on the successes and failures of these new, high-tech strategies have produced some important lessons. (Eiseinger 1988, Malecki 1991, Glasmeier 1988, Saxenian 1994) These are summarized below.

(1) Place matters. Many cities are unlikely to ever meet the requirements of technology-based growth. Some failures have resulted when economic development agencies overtly picked small, outlying communities to locate industry clusters without paying enough attention to whether the targeted firms would actually move to locations that lacked the prerequisites for high-technology firms to thrive. In other cases, agencies automatically assumed that linkages to suppliers, customers, and other related firms would be created without any purposeful effort. (Held 1996) Yet another set of failures did have a concentration of specialized firms (e.g., Bethlehem, Pennsylvania's steel industry), but the clusters were based on a narrow set of firms, inwardly focused, and lacked a learning network that would support adaptation in the face of economic restructuring. (Rosenfeld 1997) Technology-based cluster development occurs only where a number of elements already exist. The process is too complex to specify necessary and sufficient conditions. It is clear that necessary elements include the amenities associated with an urban setting, a skilled labor force, availability of risk capital, proximity to a major research university, and an existing industrial base within which some research is conducted. (Bergman and Feser 1996)

(2) Research exchange is necessary. Technological innovation requires ideas and knowledge. Sometimes the knowledge already exists, but often it does not and research must be undertaken to find it. However, research alone often yields nothing but knowledge expansion. The challenge of successful technological innovation involves transforming research ideas into new products that can be successfully commercialized, and into new processes that can be successfully implemented. Private firms, universities, and other organizations may conduct research, but the mere presence of these organizations in a given locale is not enough to ensure innovation. Innovation and competitiveness require the sharing of research and sufficient interactions among innovative firms, research universities, and specialized service providers to transform research into commercial applications. (Baptista et al 1998)

(3) Entrepreneurship and small-business activity is important. Self-sustaining, technology-based development involves entrepreneurship and new business formation. Many communities have based their technology cluster on landing big high-tech employers. While this strategy sometimes has succeeded, more often it has proven risky, as was demonstrated in a case study of Virginia's efforts to attract three wafer fabrication facilities. Virginia's wafer fabrication-led strategy to create a "Silicon Dominion" did not pan out when cyclical changes in the industry halted construction indefinitely. This less-than-expected outcome occurred despite the state offering more than $85 million in incentives to attract a Motorola wafer fabrication facility, which prompted other local industries to request comparable support. Similarly, as the proponents of North Carolina's Research Triangle Park discovered, it is not sufficient to attract and retain large high-tech businesses – you must also develop an environment that fosters the creation and growth of new firms. (Buchholz 1999)

(4) There must be critical mass/focus. Both experience and research have shown that some fairly demanding requirements must be met if self-sustained growth of high-technology firms will occur. These include local sources of entrepreneurs, new knowledge, highly technically trained professionals (often via a research university), skilled workers, risk capital, business support services, job shops, convenient transportation, a good education system, and at least some amenities. And they must be focused to the extent that a critical mass of clustered research capabilities, interrelated technology-based firms, and high-technology investment is developed. (Eisinger 1988)

Critiques of Cluster-based Strategies

Although cluster-based technology development strategies are in vogue, they have been subject to criticism. Clusters have been found to resist innovation, become overspecialized in an industry, and collapse in economic downturns (e.g., Bethlehem, Pennsylvania and the steel industry). In addition, strong vertical linkages with large companies have been found to create more innovation than have firms concentrated in a similar industry that do not collaborate. (Hudson 1999, Rosenfeld 1997, Glasmeier and

Harrison 1997). These criticisms highlight the fact that cluster-based strategies can make firms and regions more competitive and stimulate technology-based economic development given the right mix of inter-firm relationships and economic conditions.

Section 3. Case Studies

Can Yamacraw create and extend a broadband device cluster in Georgia? To identify opportunities for attracting suppliers, customers, and other firms that serve Yamacraw industries, researchers began by interviewing Yamacraw core members. This section discusses the findings that resulted from these interviews. Each interview was developed in a formal case study. Capsule results from the company case studies are presented, after a brief discussion of the methodology used to develop and conduct them. The section closes with a cross-case analysis summarizing key findings from the case studies.

Case Study Design

The case studies of selected Yamacraw companies were designed to obtain expert opinion about opportunities for cluster development. In particular, the case studies were to investigate four key topics. First, researchers explored the importance of geographic proximity in the relationships between the company, its parent organization (if applicable), its customers, and its suppliers. Second, the case studies sought to identify and understand the significance of other elements—e.g., knowledge workers or research—besides traditional supplier-customer chains. Third, researchers aimed to understand how Georgia (primarily metro Atlanta) could grow its cluster compared to strategies that other cities have taken. And fourth, any opportunities for a role in cities outside metro Atlanta were explored.

Ideally, input from all Yamacraw members would have been obtained. However, scheduling and accessibility issues dictated that a sample of members be interviewed. Six Yamacraw member companies were selected as case study subjects. Selections were based on a desire to cover the main research areas under the Yamacraw umbrella—broadband access devices, embedded systems, system prototyping—and reflect the fact that most Yamacraw members focus on hardware devices. There was also a desire to interview large as well as very small members. Scheduling and accessibility of executives at the company were important considerations as well. The companies selected, and their reasons for selection, are shown in Table 3.1.

Case Study Implementation

The case studies were conducted from September to December 2001. The interviews took place at the company facility with at least one chief executive. In two cases, three executives and managers participated, and in one case, four executives and managers attended the case interview. Interviews lasted at least one hour.

A protocol was developed to guide the interviews. The protocol included questions about company characteristics, relationships with headquarters locations, supplier-buyer interactions and the importance of geographic proximity, talent attributes and other knowledge-related elements, strategic opportunities for cluster development in Georgia, and possible roles for cities outside metro Atlanta in the Yamacraw cluster. Because these case studies were primarily exploratory and sought expert advice, researchers used the protocol as a guideline for interviews but did not strictly adhere to it. Two cases offered a better approach for learning and obtaining advice about cluster development because the interview consisted of Yamacraw company executives delivering a presentation that focused on recommendations for cluster development. In one case, the company spent a significant amount of time giving the interviewers a tour of its facility.

Table 3.1: Why Case Study Firms Were Selected

Company	Selection Rationale
Company A	Broadband access devices area (chip design for telecommunications industry); headquartered in Silicon Valley; one of the first design centers in Georgia; full Yamacraw member
Company B	Broadband access devices area (high-value coatings); full Yamacraw member and former ATDC incubator firm
Company C	System prototyping area; is a large multinational corporation, and potential Yamacraw member
Company D	Broadband access devices area (display units); is part of a foreign-owned company; full Yamacraw member
Company E	Embedded systems area; is located outside Atlanta; full Yamacraw member
Company F	Broadband access devices area (fabless chip design); emerging Yamacraw member

Case Study Summaries

The following sections summarize, in capsule form, the key findings from the cases.

Company A

Company A is a $1 billion manufacturer of integrated circuits (IC) headquartered in Santa Clara, California. The telecommunications industry is Company A's primary customer. Company A's traditional static random access memory (SRAM) products are purchased by such firms as Cisco, Nortel, Lucent, Nokia, and Alcatel. Company A's first design center outside Silicon Valley is the generalized design center in Atlanta. The Atlanta Design Center is now the largest design unit in Company A with 44 employees, most of whom have masters' degrees and PhDs in electrical engineering. The most critical and challenging aspect of the Atlanta Design Center is finding designers who can learn new specialties quickly. Significant access to university faculty and the best students is also critical for a mid-sized company such as Company A (and particularly the design center).

Company A does not make many purchases. Although there would be some benefit to geographic proximity with the developers of integrated circuit (IC) design software (e.g., Tality/Cadence), locating such a design services company would mean only a small number of jobs for Georgia. The Atlanta design center's customer is other Company A units; however, the Atlanta design center would be more valuable to Company A if it had geographic proximity to product line engineers for Company A's end users (e.g., Siena, Nortel, Cisco).

Critical success factors for cluster development include (1) geographic proximity to university researchers and students, (2) concentrating university research in a single location, (3) entrepreneurial development, and (4) building a high-tech image more than professional association and technology parks per se. Company A's executive recommended not only to look at cities with successful clusters (e.g., Silicon Valley, Austin/San Antonio) but also at cities that have not been as successful due to (1) an inability to focus research resources, (2) develop an entrepreneurial climate around a large recruitment model, or (3) target a single wafer fabrication facility. For smaller communities, the executive recommended focusing on software applications in fields not well-served by information technology.

Company B

Company B has developed a process for depositing high-value thin-film coatings on wafers that competes with chemical vapor deposition. The company focuses on early-stage production, and its volumes are small. Company B was founded in 1994 as a member of ATDC. It currently employs 120 people at a single location with another 10 consultants it uses as needed. Most of its employees are chemical engineers, electro-chemical engineers, and material scientists mainly from Georgia Tech.

Company B's customers are in the radio frequency (RF) devices, fuel cells, and photonics markets. Because of the small size and high value of Company B's parts, geographic proximity is not important. Nevertheless, one of Company B's customers, Shipley Electronics (a $1 billion subsidiary of Philadelphia-based Rohm and Haas, which supplies chemicals and photoresists for the electronics industry) closed an office in California and opened a facility in Atlanta to be near Company B. Suppliers are not that important because Company B uses basic chemicals and glass. Company B would like to attract major partnerships with Micron, ADC , Peregrine Semiconductor, JDS Uniphase, or Intel. However, Company B cannot afford to compete for such partnerships, which require upfront investment in equipment in new fabrication facilities, so it differentiates its product on more customized applications.

Company B noted that firms are not building new products in Silicon Valley because of the business climate. Atlanta has some of the ingredients that Silicon Valley has, excepting some weakness in supporting services. Company B cautions that Georgia not spread its money too far outside Atlanta.

Company C

Company C. sells and services manufacturing equipment for a broad range of products to electronics manufacturers worldwide. Company C, which sells and services placement machines for printed circuit board component manufacturing in Atlanta, is developing a new Atlanta-based laboratory to commercialize and prototype new manufacturing process technologies. The laboratory offers line design, reliability and qualifications testing, characterization and analysis, and failure analysis and surface preparation. Company C plans to sell its prototyping and testing services to its large customers and smaller Yamacraw members.

This prototyping and testing capability could be an asset for the city in attracting electronics firms because not many cities, besides Silicon Valley, have this type of capability. Also, Company C executives recommended that Atlanta not try to replicate Silicon Valley. Instead, the city should compete for southeastern sales offices, which could eventually attract to Atlanta more of the value-added portion of the supply chain (e.g., prototyping firms, small-volume board manufacturers in the optics circuit board arena) that is located in other cities. Former or shrinking Atlanta high-tech firms (e.g., Lucent) could also produce new start-up engineering companies. Company C was less optimistic about going after equipment manufacturers (currently a mature market), electronics manufacturing service (EMS) firms (while the outsourcing trend is growing, EMS firms favor lower-cost, offshore markets), and software (work being outsourced abroad).

Company D

Belgium-headquartered Company D designs and manufactures displays, display controllers, radar scan converters and video products for command and control, air traffic control, avionics and medical diagnostic imaging industries. The 80,000-square-foot facility in Duluth, the only facility owned by Barco in the United States, conducts engineering, manufacturing, operations, and shipping activities. This facility generates about 80 percent of total revenues of the Company D division. Company D claims to invest twice as much of its revenues in R&D than the average company in this industry and looks to Yamacraw for basic research.

Company D doesn't see much advantage to having nearby suppliers unless it involves custom work such as metal shaping or painting/coating. However, the firm does see a need to have customers close by for collaborating on solutions that Company D can meet. Also, partners are important to have close at hand to facilitate coordination and sharing of ideas and solutions. ·Potential cluster industries include microcircuit design and/or manufacturing e.g., custom application specific integrated circuits (ASICS), very large scale integration (VLSI), sensor technology companies, application software, environmental stress screening service companies, analytical lab/diagnostic services, distribution and service/support firms for key manufacturing equipment lines (e.g., Philips, Company C). It was recommended that Atlanta improve the industry exposure of semi-skilled workers as well as skilled professionals, and develop more cathode ray tube (CRT) display recyclers.

Company E

Company E develops customer care, billing, and management systems for the wireless industry. Its products run on client servers and handle billing and other activities based on information passed from the device (cell phone) to the server. The company, which is headquartered in New York, employs nearly 300 workers in Savannah, about 106 of whom are software engineers. Many of the firm's employees are graphic design, Web development and design, marketing graduates from Savannah College of Art and Design (SCAD).

Partnerships are particularly important to Company E, much more so than traditional supplier relationships. The firm has several partners such as IBM, RateIntegration, Output Technology Solutions, Compaq, Macromedia, Oracle, Tax Partners, CCH, Praeos, Empower Geographics, Zortec, WebLogic, BCG, and GiantBear.com. These partnerships enable Company E to offer cutting-edge technology to its clients and take advantage of its partners' influence within the industry. Close geographic proximity is very advantageous. For example, there is an IBM field office in Savannah, with which the company works extensively.

Critical factors to developing a cluster in Savannah include SCAD, the historic district, the development of tax incentives for technology firms, and the ability to economically affect the local community.

Company F

Company F is a start-up fabless semiconductor design firm specializing in integrated circuits for high-speed optical communications. Company F plans to subcontract the fabrication of chips based on its designs to several fabrication plants to mitigate the risk of downtime. The company has about two dozen employees, most of whom are highly skilled engineers with PhDs.

Physical supplies do not figure prominently in Company F's business. Its most important input is highly skilled labor. Likewise, geographic proximity of customers is not critical because designs can be electronically transferred to customers worldwide. However, geographic proximity of competitors (e.g., Company A) is significant to Company F's ability to recruit certain types of engineers with semiconductor design experience.

Cross-Case Analysis

Tables 3.2 and 3.3 summarize the cluster descriptions and insights we obtained from the interviews. These insights are as follows:

Physical proximity benefits do not follow conventional supplier-customer relationships. Most cases indicate that companies in chip design and embedded systems find some advantage to geographic proximity. This advantage is not like traditional supplier-customer chains. Physical suppliers were not important to the businesses profiled in these cases and the value of proximity to customers was mixed. For some of the firms profiled, geographic proximity to customers would be beneficial to collaborative design. For others, geographic proximity was not crucial because of factors such as electronic transfer or low shipping costs.

Proximity to business partners and competitors is important. Many of the case study respondents used the language of business partners and competitors to describe highly valued interrelationships with other firms rather than traditional supplier-customer descriptors. Business partnerships were valued because they held influence in the industry, offered access to cutting-edge technology, and provided sales opportunities. In addition to the appeal of partners, a few case respondents would also like to see more competitors in the Atlanta area. A concentration of competitors would enable local companies to more easily attract and retain knowledge workers.

Access to research and talent is critical. The cases showed that knowledge-related inputs were as important in cluster development as were linkages with other companies. Ability to recruit and retain specialized talent was critical to all case study firms. Several respondents also emphasized the importance of access to university research. For at least one company, Yamacraw research activities constituted the lion's share of its basic research requirements. Many of the interviewees expressed caution about spreading research investments too thinly across a range of institutions. Testing and prototyping facilities, a high-tech image, entrepreneurial activities, and support services were also mentioned as key elements in cluster development.

Focus investments. Most respondents felt that Atlanta's concentration of chip design and embedded systems firms was not yet established enough to spread such efforts to other cities. Focus was a significant theme in case study respondents' assessment of Atlanta's cluster development opportunities.

Don't go after the entire value chain. While one interviewee mentioned the desire for a proximate wafer fabrications facility, most of the executives believed that smaller targets would be more effective. These interviewees warned against pursuing the entire vertical chain, including large manufacturing and assembly facilities. Instead, they recommended recruiting sales offices with some applications and sales engineering functions, promoting testing and prototyping capabilities, and building entrepreneurial start-ups.

Table 3.2. Yamacraw Member Company Characteristics

Elements	Company A	Company B	Company C	Company D	Company E	Company F
Products	ICs (SRAMS, FIFO)	High-value thin-film coatings	Placement machines for printed-circuit board-component manufacturing	Display-related products	Fabless semiconductor design firm	Wireless customer care and billing systems, knowledge management systems, consulting
Business unit in Georgia	Branch general design center in Atlanta; manufacturing in California, Oregon	Headquarters	U.S. headquarters	Only U.S. division owned by Barco	Start-up	Branch
Customer types	Telecom industry	RF devices, fuel cells, photonics	Company C's large customers, small Yamacraw members	Avionics, command and control (civil aviation authorities, defense), medical imaging	High-speed optical communications	Wireless industry
Knowledge requirements	Masters, PhDs in electrical engineering	Chemical engineers, electro-chemical engineers, material scientists	Service engineers	Semi-skilled/ blue-collar workers as well as skilled workers (jobs network, graduates with more industry exposure)	Two dozen employers, most are engineers with PhDs (may change with growth of company)	Software engineers graphic design, Web development and design, marketing graduates from SCAD
Yamacraw's attraction	Access to top university researchers and best students	Public relations, government relations, major partnerships (not supplier-customer connections)	Potential customer base	Potential for collaboration, sharing with other Yamacraw companies		
Suppliers	Not much -IC design software -Workstations	Basic chemicals, glass		Not much need for local suppliers	Not many physical supplies used	Not important
Partner Issues		Partnerships with wafer fabrication				Enable Company F to offer cutting edge

Elements	Company A	Company B	Company C	Company D	Company E	Company F
		facilities are desirable, but expensive because they require upfront investments				technology to clients and take advantage of partners' industry influence

Source: Case Studies with Selected Yamacraw Members, 2001.

Table 3.3 Yamacraw Member Company Assessment of Cluster Potential

Assessment	Company A	Company B	Company C	Company D	Company E	Company F
Benefits of cluster	Ability of design engineers to discuss product details with customers would make his unit more valuable			No advantage for supplier proximity unless custom work required; There is advantage for customer proximity to collaborate on solutions	-Testing facility nearby would be beneficial, -Customers do not have to be nearby (designs electronically shipped) -Would like to have competitors nearby (IDT, Broadcom, Cypress) because easier to recruit talent	Proximity to partner, e.g., an IBM field office in Savannah, which her company works with extensively.
Cluster elements	-Concentration of research resources -High-tech image		-Laboratory to prototype new manufacturing process technologies -Design and applications engineers -High-tech image			-SCAD and historic district -Tax incentives -Ability to work with the community to impact technology orientation
Competitor cities	Raleigh-Durham – large high-tech recruitment			Silicon Valley: Atlanta should not try to compete with		

Assessment	Company A	Company B	Company C	Company D	Company E	Company F
	New York – young software developers Boston – off/on Austin – big corporate, now entrepreneurial Oregon, Colorado, Virginia – big fabrication model, didn't work well when the fabrication facility shut down or wasn't built Mississippi – failure, because spread research			Silicon Valley		
Opports for Atlanta			-Southeastern sales offices, which have applications and sales engineers (go after applications) -Entrepreneurial activities of former or shrinking Atlanta high-tech firms (e.g., Lucent), -Do not go after the whole value chain because of outsourcing trend -Not EMS firms, which are closing domestic facilities -Not much opportunity in	Microcircuit design and/or manufacturing (e.g., custom ASICS, VLSI) Sensor technology companies Application software (e.g., UNIX/NT), Recruiting companies who specialize in key outplacement of graduates (and/or intern programs with students) Environmental Stress Screening		

Assessment	Company A	Company B	Company C	Company D	Company E	Company F
			equipment manufacturing until optics changes the market	service companies "ESS" Analytical lab/diagnostic services Distribution, service/support for key manufacturing equipment lines (e.g., Philips, Company C)		
Opports outside Atlanta	Software applications in areas not well served by software		Not software: U.S. firms are outsourcing software jobs to programmers in Russia, India	Recyclers of CRT displays		

Source: Case Studies with Selected Yamacraw Members, 2001.

Section 4. What Yamacraw-like Clusters Look Like: A U.S. Perspective

The objective of this section is to identify how Yamacraw industry clusters have developed in the United States. Geographic concentrations in Yamacraw core and related industries are examined through a geographic information system (GIS) analysis. The GIS mapping shows how concentrations of employment in Yamacraw core industries have changed over time, and how suppliers (also known as input firms) and customers (also known as output firms) are spatially coordinated with these core industry employment concentrations.

The GIS analysis shows how Yamacraw and related industries are distributed in space and how they developed over time. The analysis involved several steps: (1) defining the Yamacraw industries; (2) developing a database of county-level employment data, including estimating data suppressions, and smoothing the data; (3) GIS analysis of the core Yamacraw industries; and (4) identifying and mapping upstream and downstream industries.

Defining Yamacraw Core Industries

Defining Yamacraw industries presents a challenge because the broadband communications industry is relatively new and undergoing almost constant technological and business transformation. In contrast, publicly available data for U.S. counties employs conventional industry coding schemes—Standard Industrial Classification (SIC) and North American Industrial Classification System (NAICS) codes—which are very broad. These coding schemes cannot pinpoint Yamacraw-specific product lines. They represent the broad sectors within which Yamacraw firms operate.

Because the county-level data was based on SIC codes, Yamacraw company members had to be matched with these codes. Multiple approaches were triangulated to arrive at the appropriate coding scheme. First, a profile of each Yamacraw member firm was developed. Second, each firm was located in the Dun and Bradstreet MarketPlace database, and the corresponding industry classification—both SICs and NAICs codes—was recorded. Third, researchers conducted interviews with three Yamacraw program managers and each member company's classification was reviewed against program managers' knowledge of the company.

Based on this approach, the following core cluster definition was developed.

Yamacraw Core Industries Definition

SIC	Industry Description
3661	Telephone and Telegraph Apparatus
3663	Radio and Television Broadcasting and Communications Equipment
3674	Semiconductors and Related Devices
3825	Instruments for Measuring and Testing of Electricity and Electrical Signals
3812	Search, Detection, Navigation, Guidance, Aeronautical, Nautical Systems Instruments
7371	Computer Programming Services
7373	Computer Integrated Systems Design

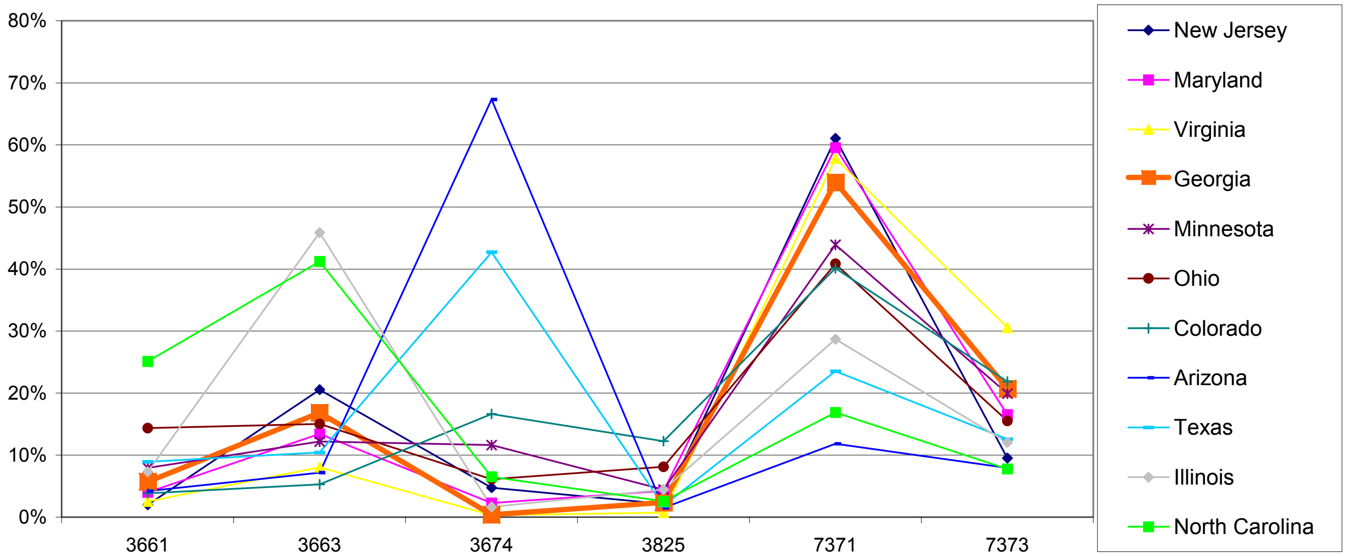
Employment in the above industries was added together to create a "Yamacraw" core industry group. There were nine states with total employment of more than 30,000 in this industry group: California, New York, Massachusetts, Texas, New Jersey, Virginia, Illinois, Pennsylvania, and Florida. A second set of nine states had employment in the 15,000 to 30,000 range—Georgia, Maryland, Minnesota, Ohio, Colorado, Washington, Oregon, North Carolina, and Arizona. States in the same size category as Georgia could be viewed as comparable, whereas larger states could be viewed as further developed.

In addition to examining the overall size of employment in Yamacraw industries, researchers looked at employment patterns in each of the component industries. In some states, Yamacraw employment might be concentrated in only one of these industries, whereas in others, it might be more evenly balanced across all industries.

Figure 4.1 shows a group of states with Yamacraw-related employment concentrated in one industry. Virginia, Maryland, New Jersey, and Minnesota were similar to Georgia in that their Yamacraw clusters grew around the computer programming services industry (SIC 7371). Yamacraw clusters in Texas and Arizona grew around semiconductor manufacturing (SIC 3674). Illinois and North Carolina had a significant percentage of employment in radio and broadcasting equipment industries (SIC 3663). Semiconductor manufacturing (SIC 3674) was prominent in Texas.

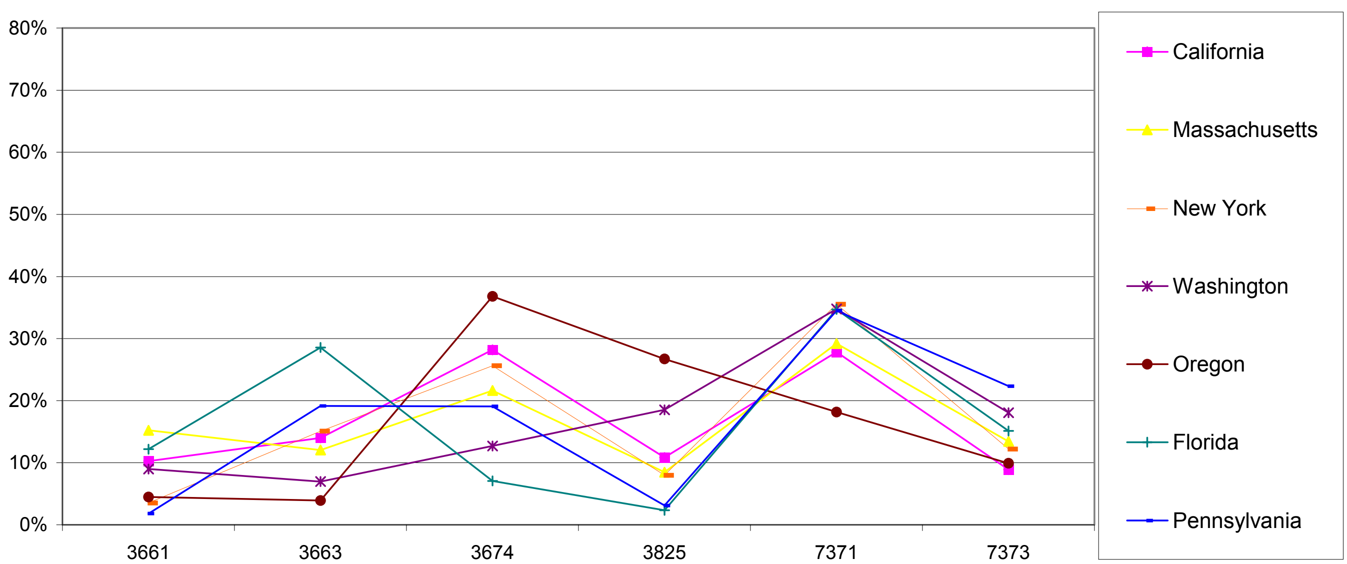
In contrast, Massachusetts and California did not have significantly high percentages of Yamacraw employment in any particular industry. Their Yamacraw-related employment is relatively evenly balanced across all industry classifications.

Figure 4.1 For Some States, Including Georgia, Employment in Yamacraw



3661 Telephone and Telegraph Apparatus
3663 Radio and Television Broadcasting and Communications Equipment
3674 Semiconductors and Related Devices
3812 Search, Detection, Navigation, Guidance, Aeronautical, Nautical Systems, Instruments
3825 Instruments for Measuring and Testing of Electricity and Electrical Signals
7371 Computer Programming Services
7373 Computer Integrated Systems Design

Industries Is Concentrated in One Sector, Whereas Others Are More Balanced.



3661 Telephone and Telegraph Apparatus
3663 Radio and Television Broadcasting and Communications Equipment
3674 Semiconductors and Related Devices
3812 Search, Detection, Navigation, Guidance, Aeronautical, Nautical Systems, Instruments
3825 Instruments for Measuring and Testing of Electricity and Electrical Signals
7371 Computer Programming Services
7373 Computer Integrated Systems Design

County-level Historical Data

The GIS was based on the U.S. Census Bureau's County Business Patterns database. County Business Patterns is a U.S. Census Bureau database that extracts records from multiple government sources—various surveys conducted by the Census Bureau (e.g., Annual Company Organizational Survey, Economic Censuses), and administrative records of the Internal Revenue Service, the Social Security Administration, and the Bureau of Labor Statistics. County Business Patterns yields numbers of establishments, employment, and average wages by industry classification for all counties in the United States Publication of County Business Patterns data typically follows a two-to-three year time lag. The GIS analysis combined data from County Business Patterns over the 1986 to 1997 period. More than 3,100 counties were represented in this database of nearly 7.9 million employment records.

It should be noted that the Census Bureau suppresses county-level employment records to prevent disclosure of information about a single employer. Roughly two-thirds of the records had some data suppression, reporting an employment size range rather than the actual number of employees. Researchers filled in suppressed data using state-specific or national averages (on occasion, the national data was suppressed at the four-digit SIC level, so three-digit level data was used). Error checks substitute the maximum or minimum of the suppression code range in cases where the calculated data fell outside the range.

Spatial smoothing was used to address random fluctuations, for example the employment change in the Atlanta area related to the 1996 Olympics. For much of the analysis, a three-year moving average was used to smooth fluctuations (or a two-year moving average for the 1996 to 1997 timeframe). Also, employment per square mile within 25 miles of county centers was aggregated to account for Georgia's counties being smaller than those of other states.

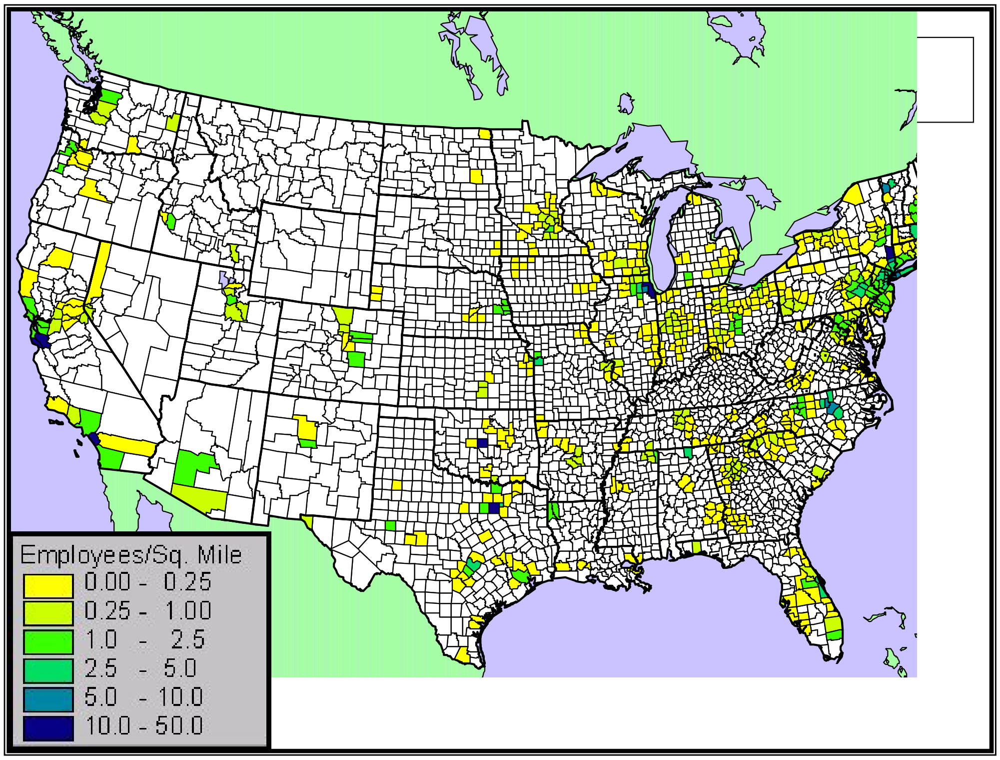
Mapping Yamacraw Core Industries

The GIS created a series of maps of Yamacraw industry employment per square mile for each year from 1986 to 1997. Figure 4.2 shows the 1986 and 1997 maps. A striking feature of the maps is the extraordinary growth of employment in the core Yamacraw industries during this time. This growth mirrors the overall expansion of the telecommunications/information technology industry for the period.

Geographic concentrations in employment in Yamacraw core industries are evident. The growth pattern of these clusters is consistent with what is known about industry cluster dynamics. In 1986, a handful of major Yamacraw industry clusters existed. (See Table 4.1. below). New geographic cluster concentrations emerged later as the cluster expanded overall throughout the United States. Yamacraw industry clusters were most prominent on the East Coast, West Coast, and Central/East regions. The metropolitan Atlanta cluster reflects this trend. Atlanta moved up very quickly, from not being observed as an emerging cluster in 1986 to representing a major cluster by 1992.

Figure 4.2. Yamacraw Employment Within 25 Miles of County Centers, 1986 and 1997 (Data from County Business Patterns Was Smoothed Using Three year Moving Average)

1986



1997

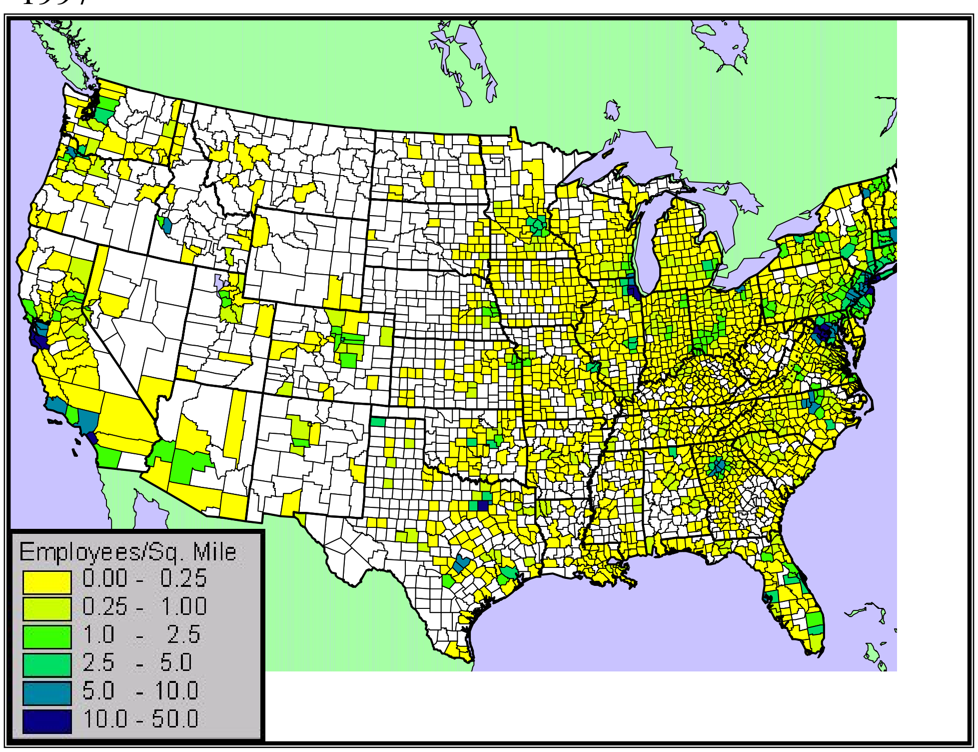


Table 4.1. Chronology of Major/Emerging Yamacraw Industry Clusters*

Metro Region		1986	1992	1997
I.	**Major Clusters**	New York City	New York City	New York City
		San Francisco/ Silicon Valley (SV)	San Francisco/SV	San Francisco/SV
		Boston	Boston	Boston
		Chicago	Chicago	Chicago
			Seattle	Seattle
			San Diego	San Diego
			Dallas/Fort Worth	Dallas/Fort Worth
			Research Triangle	Research Triangle
			South/Central Florida	South/Central Florida
			Washington, D.C.	Washington, D.C.
			Atlanta	Atlanta
				Minneapolis
				Phoenix
				Denver
				Austin/Houston
II.	**Emerging Clusters**	Seattle		
		San Diego		
		Dallas/Fort Worth		
		Research Triangle		
		South/Central Florida		
		Washington, D.C.	Minneapolis	
			Phoenix	
			Denver	
			Austin/Houston	
			Salt Lake City	Salt Lake City
				Upstate New York
				Western Pennsylvania
				Boise
				Detroit
				Burlington, Vermont
				Huntsville, Alabama

*In almost all cases, clusters should be identified geographically as "*greater* (city)" or "*metro* (city)," although these identifiers have not been added for presentation purposes.

The drivers of Yamacraw industry growth in certain cities or regions vary. Some growth appears to be driven primarily by a major customer base (e.g., New York City, Chicago), some primarily by software industries (e.g., Seattle, Salt Lake City), some by hardware industries (e.g., Florida, Pennsylvania), and many by various combinations (e.g., hardware/software-Silicon Valley, software/customer base-Washington, D.C.).

The spatial patterns of clusters wax and wane with cyclical changes in the local or global economy. For example, “declustering” or reductions in employment concentration in select regions was observed. Cities such as Phoenix had relatively high employment concentrations until the early 1990s, which can probably be explained by the 1991-1992 recession. Some counties in these regions, which were on the margin in terms of employment concentration categories that the GIS analysis used, dropped back into a lower-employment concentration category during this period.

Table 4.1 uses visual analysis to identify “major” and “emerging” Yamacraw industry clusters in three periods. It is significant that some emerging clusters such as Atlanta have grown (or “graduated”) into major clusters, whereas other emerging clusters have not.

Upstream and Downstream Firms

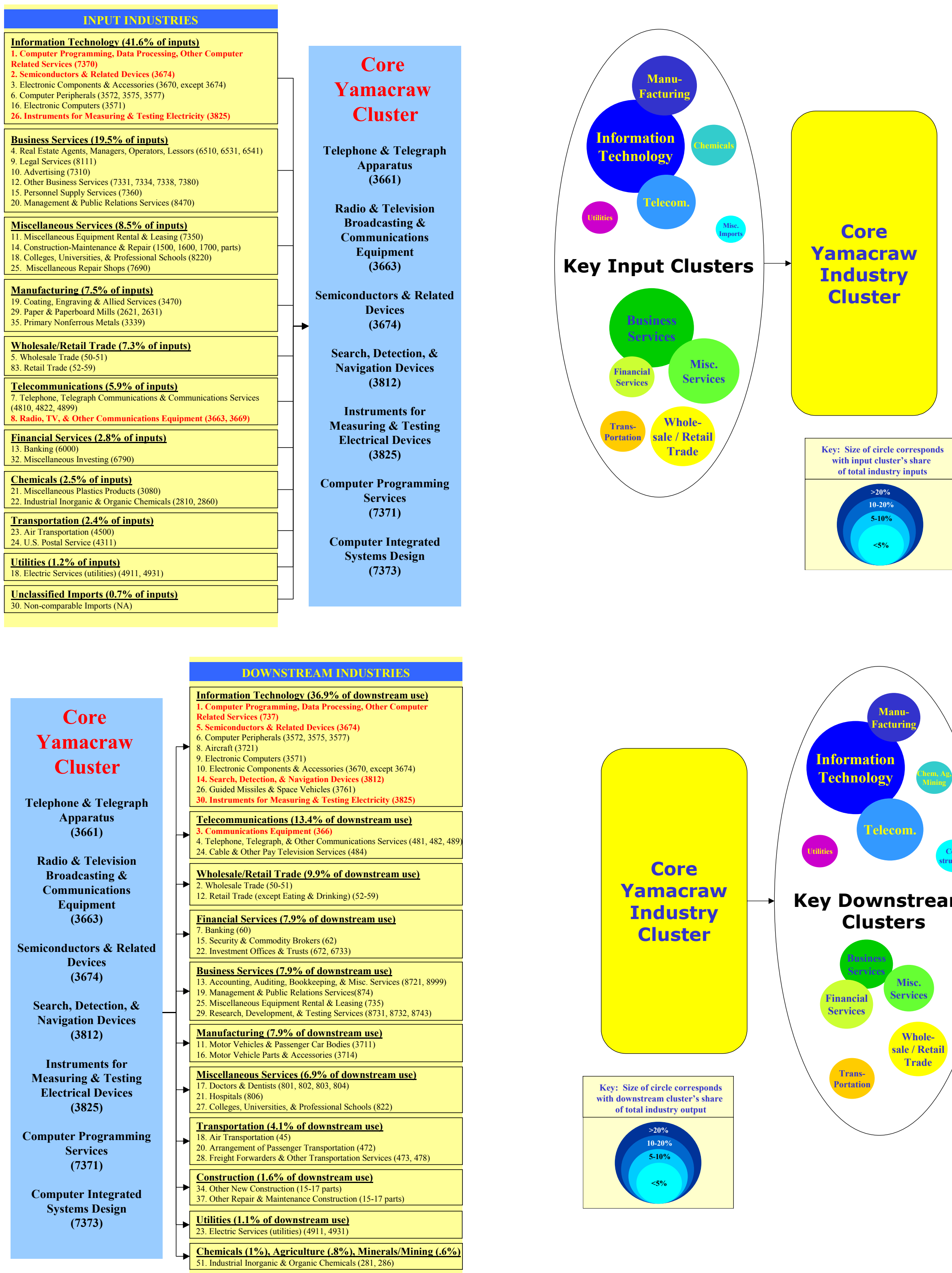
SRI developed a list of supplier and customer industries based on input/output tables published by the U.S. Bureau of Economic Analysis (http://www.bea.doc.gov/bea/dn2/i-o.htm). The analysis ranked inputs—also known as upstream or supplier industries—and outputs—also known as output or customer industries—based on the level of purchases or sales by the Yamacraw SIC-based industries. Figure 4.3 shows the results of the upstream and downstream firm analyses. The results of the input-output analysis indicate that some of the Yamacraw core industries also act as input and output firms.

The GIS analysis presented the upstream firms as a ratio of input employees to Yamacraw employees, normalized to the national ratio and averaged for the 1995 to 1997 time period. In instances where Yamacraw core industries also act as input and output firms, the same numbers of employees were included in both the numerator and denominator. The national ratios are calculated separately for total input employment and each of the five input sectors. (See Table 4.2 for these ratios.)

Table 4.2. National Ratios of Input Employment to Total Yamacraw Core Industry Employment

Industry	Ratio
All	3.03
BS (business services)	0.41
CH (chemicals)	0.13
IT (information technology)	0.99
MN (manufacturing)	0.60
MS (miscellaneous)	0.93

Figure 4.3. Input and Output Industries to Core Yamacraw Industry Cluster



Source: U.S. Bureau of Economic Analysis and SRI, 2001.

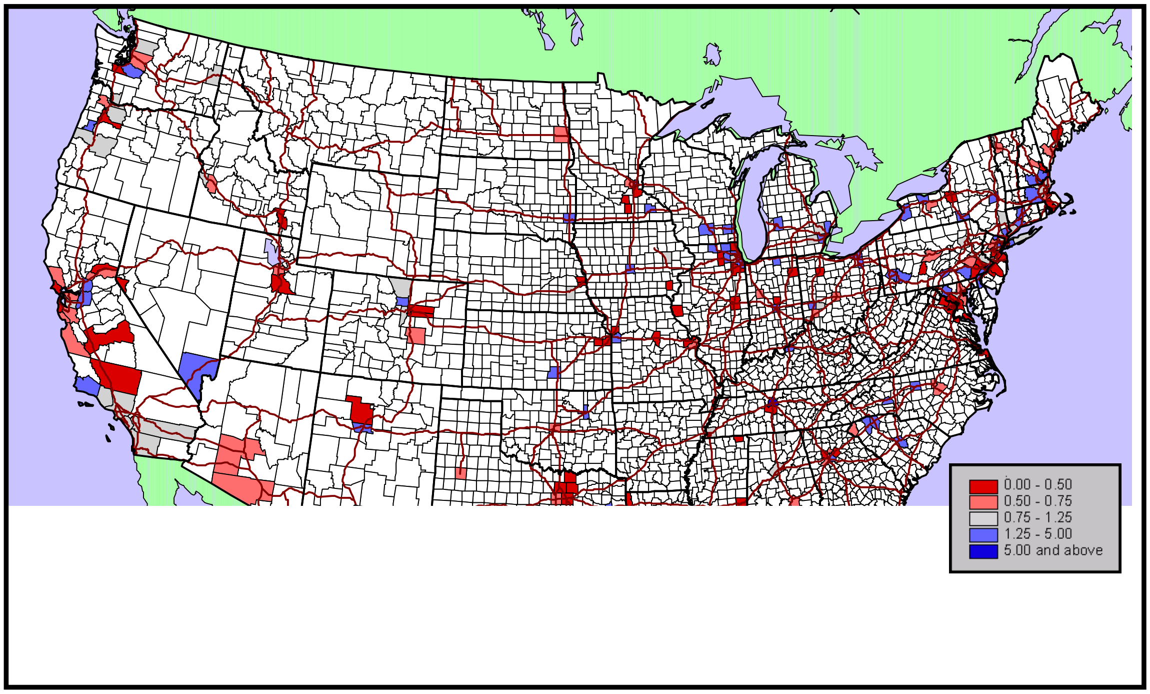
What do these ratios mean? An example: There are 951,227 Yamacraw-type employees in the United States, and 2,882,278 input employees. The national input/Yamacraw ratio is 3.03. If a county has 6,000 input employees and 1,000 Yamacraw employees, the county's raw ratio would be 6000/1000 or 6.0. Because the national ratio is 3.0, the county's normalized ratio is 6.0 / 3.0, or 2.0. This means that the county has twice as many input employees as one might expect. It is “rich” in input employees. If a county has 2000 input employees and 1000 Yamacraw employees, its raw ratio is 2.0, and its normalized ratio is 2.0 / 3.0, or 0.67. It only has 67 percent of the input employees that one might expect, so it is “poor” in input employees. In other words, the ratios show the percentage by which a county exceeds or falls short of the national ratio of input employees to Yamacraw employees.

The input maps show this normalized ratio by county for 1995-1997 average employment, only shading counties with over 500 Yamacraw employees. Red areas are poor in input employees, gray areas are normal, and blue areas are rich. The more blue on a map, the higher the level of observed co-agglomeration of those input industries with Yamacraw industries. The more red on a map, the less likely those industries are to collocate with Yamacraw industries. There are separate maps for total input, and the separate sectors of business services, chemicals, information technology, manufacturing, and miscellaneous. Figure 4.4 contains the total input map.

The input map shows that supplier industries have some presence among Yamacraw clusters cities, but it is small and spotty. Atlanta and other metropolitan areas with a substantial concentration of Yamacraw industries have a county or two with above average employment in input industries. However, these industries do not necessarily form in a consistent spatial pattern. Some are concentrated at the periphery of the metropolitan area, others are clustered in the central county of the city, and others are not located near core industry clusters. Atlanta has some co-agglomeration of chemicals and generic manufacturing, but it is rather weak in concentrations of business services and information technology services and manufacturing.

Figure 4.4

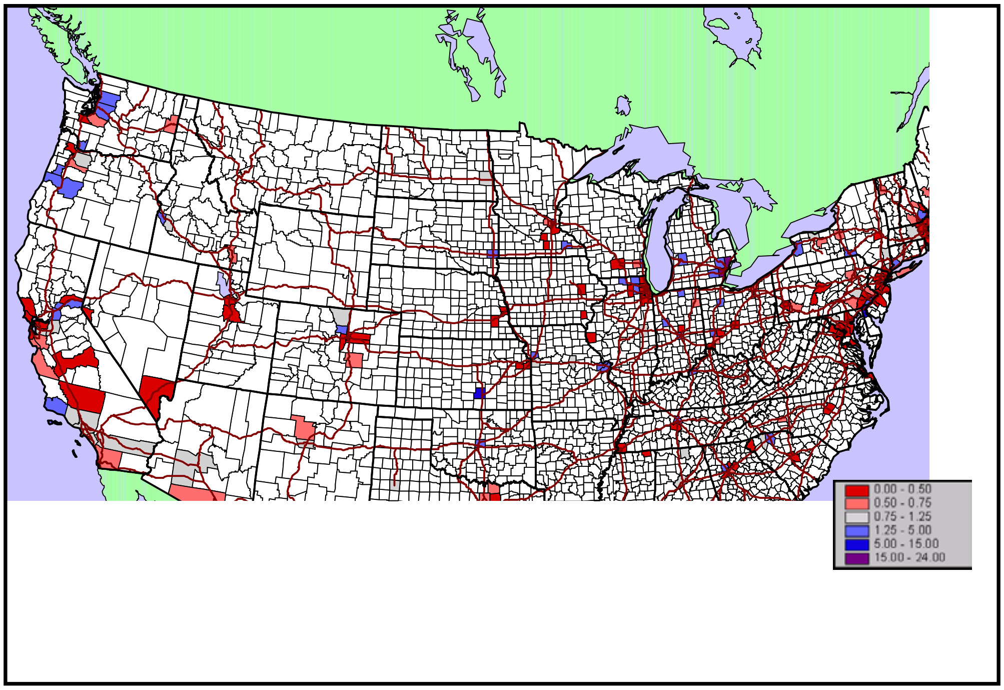
Ratio of Total Input Employees to Yamacraw Employees
Normalized to 1:1 from National Ratio
Average 1995-1997 Employment
All Counties with over 500 Yamacraw Employees



Output analyses also involved developing normalized ratios of output employees to Yamacraw employees in the same way as the input ratios were developed. For 1995-1997, the national average was 1.59 output employees for each Yamacraw-type employee. Figure 4.5 maps the normalized ratios for all counties with more than 500 Yamacraw-type employees. This emphasis on counties with large Yamacraw-type industry employment avoids the possibility of high percentages of output employment among counties with little Yamacraw industry employment. Visual inspection of the map again suggests small and spotty output co-agglomeration. Where there is co-agglomeration, counties with concentrations of output employment tend to be on the periphery of the cluster, although in many instances, above average output employment is not located near a core cluster.

Figure 4.5

Ratio of Total Output Employees to Yamacraw Employees
Normalized to 1:1 from National Ratio
Average 1995-1997 Employment
All Counties with over 500 Yamacraw Employees



Summary

GIS analysis was used to investigate whether there were geographic concentrations of Yamacraw-related companies across the nation. Although there are weaknesses in defining Yamacraw industries with traditional industrial classifications, these data were used to examine employment concentrations by county over time.

The GIS analysis shows evidence of clustering in industries that encompass Yamacraw activities. These clusters are associated with major metropolitan areas. Clusters in Yamacraw-related industries show marked expansions and contractions depending on economic cycles. Newer emerging clusters tend to be small geographically, encompassing one or two counties, whereas other more mature clusters on the East and West Coast include broader geographical regions. Additionally, mature clusters tend to include a more balanced composition of industries. In contrast, newer emerging clusters revolve around the strength of one industry sector.

The GIS analysis did not show reliable evidence of supplier or customer co-agglomeration. Counties with concentrations of supplier or customer employment were not consistently located in the same places as the core cluster.

Georgia, through the metro Atlanta area, has grown from an almost nonexistent player to a major national cluster. Its growth around IT programming service industries makes it most similar to the Washington D.C.-Maryland-Virginia area. At the same time, Georgia does not have the industry balance of more mature clusters in California and Massachusetts.

Section 5. Lessons Learned from Leading U.S. Technology Clusters: Case Study Profiles

Introduction

The following section presents case studies of five regions – Silicon Valley, San Diego, Austin, Phoenix, and Research Triangle – that have cluster-development strategies targeted to information technology and/or telecommunications. These five regions all have a notable level of information technology/telecommunications development. Silicon Valley is the model for successful cluster development. Austin has also successfully created a concentration of firms in the industry. San Diego, Research Triangle, and Phoenix probably fall into a secondary category of emerging information technology/telecommunications centers. They are presented in this section to offer insights and support learning. The case studies bring out both important similarities and striking differences in the experiences of these five regions.

Each case study begins with a section describing the scope and development path of its industry cluster. This is followed by an assessment of the region's assets, the role of government, and other key factors in the region. The case studies conclude with a review of insights and lessons learned from the cases.

- Silicon Valley's success was built upon a foundation of entrepreneurship emanating from Stanford and other regional universities. Federal government support and procurement, which led to the development of major research facilities and large-scale IT firms, also were important elements of the cluster.

- Austin represents an example of collaboration among regional government and university stakeholders. Through a series of initiatives, the region was able to attract industry consortia and core IT companies, which combined to serve as a magnet for other firms.

- Like Silicon Valley, San Diego benefited from major federal government procurement, particularly telecommunications equipment and services for defense purposes. Several university-spawned companies with state-of-the-art technologies helped propel the region, although it has not reached the level of Silicon Valley or Austin.

- Research Triangle serves as an example of a region that comprehensively planned and implemented an industry cluster strategy. The early emphasis went to inter-university cooperation and the development of a major high-technology industrial park. Gradually, anchor firms were attracted and provided a nucleus for continued growth.

- Phoenix represents a case of state/regional cooperation, the creation of public/private partnerships, the use of traditional industrial attraction strategies, and a workforce development initiative.

Selecting the Case Studies

The GIS analysis presented in Section 4 was used to select cities/regions for national case studies. The matrix in Table 5.1 indicates differentiating factors among different cities/regions based on the GIS analysis and available information at SRI. Figured into the selection was the desire to include a relatively diverse mix of case studies. An additional factor was the greater availability of information and analysis for the "mature" clusters, because they have had time to develop. The differentiating categories for case study selection were as follows:

- **Cluster Growth Status:** The relative maturity (within the past 15 years) of the cluster in temporal/scale terms.
- **Regional Assets**: The local availability of human resources, R&D centers, research universities, capital, and other assets.
- **Demand or Supply Driven:** The extent to which cluster growth was stimulated by regional supply (capabilities, large anchor firms, etc.) or by demand for ICT goods/services.
- **Available Information or Analysis:** An initial assessment of the availability of general information on the nature and characteristics of cluster growth in the city/region.

Based on these factors, Yamacraw program managers selected five from the list below for in-depth profiling. These five are indicated in italics.

Silicon Valley

Cluster Scope and Development Path

Silicon Valley in California is without doubt ***the*** paradigm for New Economy growth. This region, geographically defined as the area lying between greater San Francisco on the north and greater San Jose on the south, is the principal model other regions seek to emulate to achieve high-technology development.[1] Silicon Valley is particularly known for the fact that it is well-endowed with all facets of IT activities – including semiconductors, computer hardware, software, communication equipment, and data storage.

A combination of regional advantages and historical accidents combined to produce perhaps the greatest "regional science park" in the world. The regional advantages that Silicon Valley possesses include world-class academic institutions, brilliant scientists, an extremely entrepreneurial environment, an active venture capital community, massive procurements of semiconductors, and the pleasant climate of Northern California.

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[1] Ironically, some Silicon Valley observers suggest that everyone seeks to emulate Silicon Valley except people living there.

Table 5.1 U.S. Case Study Selection Criteria

Cluster City or Region	Cluster Growth Status	Regional Assets	Demand or Supply Driven	Available Information or Analysis
Silicon Valley	***Mature***	***Strong, Available***	***Supply and Demand***	***Good***
Chicago	Mature	Strong, Available	Demand	Good
Research Triangle	***Mature***	***Strong, Created***	***Supply***	***Good***
Washington DC	Less Mature	Moderate	Demand	Fairly Good
South/Central Florida	Less Mature	Weak	Demand	Fair
Boston	Mature	Strong, Available	Supply and Demand	Fairly Good
Pittsburgh	New	Weak	*Unknown*	Poor
Huntsville	New	Weak	*Unknown*	Poor
Austin	***Less Mature***	***Initially Weak***	***Supply***	***Fair***
Phoenix	***Less Mature***	***Weak***	***Unknown***	***Fairly Good***
San Diego	***Mature***	***Moderate***	***Supply***	***Fairly Good***
Seattle	Mature	Strong, Created	Supply	Fairly Good
New York	Mature	Strong, Available	Supply and Demand	Poor

Narrowly defined, Silicon Valley is a 30-mile by 10-mile strip of land between San Francisco and San Jose. Some argue that the region is geographically broader, consisting of nine counties that border the San Francisco Bay, spanning 7,100 square miles of cities, towns, coastline, forests, mountains and open space. While the actual facilities for research, education, and production are spread throughout the region, all are located within a two-hour drive of one another, and most are considerably closer.

With a population of about 7 million people, the region includes the major cities of San Francisco, Oakland, and San Jose as well as heavily populated areas between them. The region produces $200 billion worth of goods and services every year. If Silicon Valley were a country, its economy would rank 21st in size among all the economies of the world, greater than those of Austria or Sweden. The region attracts over one-quarter of total available U.S. venture capital despite the fact that it accounts for only 2 percent of the nation's population. About 4,000 IT-related companies are located along the Highway 101 corridor (the backbone of Silicon Valley) from San Francisco to San Jose.

Silicon Valley's Origins and Development

Until the mid-1900s, this region was better known for its agricultural richness. At the end of World War II, the predominant industry around San Jose was small-scale food processing and distribution. One can say that the modern Silicon Valley was perhaps the first New Economy region that emerged due to forces other than those (e.g., resource base, labor availability, transportation hub, etc.) associated with traditional industry location. Nevertheless, the "engineering" of Silicon Valley was not carried out under any grand design; rather, the region transformed as a consequence of a set of serendipitous but related events.

Depending on one's viewpoint, Silicon Valley has several sires.

- Some trace the genesis of Silicon Valley to the invention of the vacuum tube triode by Lee de Forest in 1916 in Palo Alto. His Audion tube performed as an amplifier, thus opening the door for the development of radio, television, radar, tape recorders, and computers. William Hewlett, among others, therefore named de Forest the "father" of Silicon Valley.[2]

- Others cite the new audio-oscillator enterprise incubated in a garage in 1938 by David Packard and William Hewlett. After selling their first oscillators to Walt Disney, they reinvested their earnings and expanded both their products and their range of customers. Thus Hewlett and Packard are dubbed the "founding fathers" of the Valley.[3] Their garage at 367 Addison Avenue in Palo Alto bears a plaque proclaiming it the "Birthplace of Silicon Valley."

- Still others trace Silicon Valley's origins to the creation of the Stanford Industrial Park in the early 1950s. Stanford University needed money to expand, but was prohibited from selling some of its plentiful 8,000 acres. However, there was nothing to prevent long-term leasing of land. Varian Associates became the first tenant of Stanford Park, moving into the park in 1953. Eastman Kodak, General Electric, Admiral Corporation, Shockley Transistor Laboratory of Beckman Instruments, Lockheed, Hewlett-Packard and others followed soon thereafter. Frederick Terman, an entrepreneurial Stanford engineering professor, pushed for the initiative. He also served as a mentor to Hewlett and Packard in their dream of starting an electronics company. Thus, Terman also is often called the "father" of Silicon Valley.

Market Magnets and Critical Assets

Silicon Valley has amassed what is probably the world's strongest "magnet" to attract IT/telecom companies. The region offers all the assets needed to nurture high-technology industry. In fact, the magnet's drawing power, which has yielded such success over time,

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[2] See *Fred Terman, the Father of Silicon Valley*, Carolyn Tajnai, 1995.
[3] See "Founding Fathers," *Stanford Magazine*, July/August 1998.

has generated its own problems that now plague the area – overcrowding, high wages, excessive housing costs, and crippling highway traffic.[4]

Core Companies. Through a combination of serendipity, new starts led by university graduates and professors, and gradual attraction of investments, Silicon Valley has become the leading global center of IT firms, both large and small. These companies encompass the entire technical scope of the IT industry cluster, broadly defined. The mere presence of companies such as those listed in the following table has been sufficient to attract new and expanded enterprises in the region. (See Table 5.2.)

Table 5.2. Selected Core IT Companies Located in Silicon Valley

Industry Segment	Company
Hardware	Hewlett-Packard Apple Computer Sun Microsystems Seagate
Software	Oracle Netscape (part of AOL-Time Warner) Silicon Graphics Inktomi Cypress
Semiconductors	Intel AMD National Semiconductor
Internet Enabling Technology	Cisco
Service Providers	Yahoo! AboveNet Mpath
E-Tailors	E*Trade Beyond.com
Access Providers	Excite@Home

Many of these and other companies were or remain world leaders in their respective fields, and have contributed to the overall development of Silicon Valley.

- Hewlett-Packard, for example, pioneered the formation of a distinctive Silicon Valley management style, treating employees as family members. Hewlett-Packard accepted an offer to lease part of Stanford Research Park for its operations. This initiated the clustering of industries in Palo Alto.

- Shockley Industries, established by a CalTech-trained engineer, William Shockley, and 20 East Coast scholars, revolutionized electronics by developing the transistor to magnify electronic images and replace the much bulkier and energy-wasting vacuum

[4] Many of these problems have subsided, at least temporarily, following the substantial downturn in the IT sector that began in 1999.

tubes. Some of Shockley's colleagues later defected and started their own firm, Fairchild Semiconductors, the first company to manufacture exclusively in silicon and eventually becoming one of the largest firms in the California electronics industry.

- Xerox PARC assembled the key technologies for personal computing, and entrepreneurial Apple "finessed" the technologies away from Xerox to generate the first practical PC.

- Intel has led the global race for more powerful and speedier computer processors.

- Cisco has become the world leader "backbone" of the Internet, and Yahoo has developed one of the most popular portals and search engines.

Unparalleled R&D Infrastructure. By all accounts, Silicon Valley's dominant R&D infrastructure is the key anchor for the region's IT industry cluster. At the core of this infrastructure are premier research universities. Spinning out from these entrepreneurial research centers are several world-renowned research institutions – both national laboratories and private organizations – that maintain vital links to the academic community. The region's infrastructure can be visualized as a triangle consisting of research universities, federal and private laboratories, and private industry R&D.

- The region's leading research universities – Stanford University and University of California (Berkeley) – are renowned for their work in many IT fields.

- Five major federal laboratories collectively employ over 15,000 people in the region, and receive about $2 billion in federal funds.

- The presence of several major private-sector research facilities in the region demonstrates how federal and state investments are leveraged to create a total investment of far greater value.

World Class Research Universities. Silicon Valley's knowledge-based economy is centered around academic institutions known worldwide for their superior research and educational programs, including those in information technology. These universities – Stanford, Berkeley, and University of California (San Jose) – continue to play a defining role in the region's major IT industries. In addition to these core universities, the San Francisco Bay region is also home to several major private and federal research laboratories. Collectively, these institutions have long been the focus of activity for the IT cluster.

> **Stanford University.** Founded more than 100 years ago, Stanford University is considered one of the world's foremost centers of higher education and research. Today, the university has 14,000 undergraduate and graduate students and 10,000 faculty and staff members, and programs in engineering, humanities and sciences, medicine, business, and law. Stanford features one of America's most

active offices of technology licensing. *Fortune* magazine has referred to Stanford as "the intellectual incubator of the digital age."

Stanford's Office of Technology Licensing (OTL) was founded in 1970 to promote the transfer of Stanford technology for society's use while generating unrestricted income to support research and education. The OTL receives three to four new technology disclosures per week, 10 to 15 percent of which are eventually licensed. In 2000, the university received $49 million in royalty income from 272 different licensed technologies. With a charter to create new connections between inventors and industry, the OTL offers a key link between the university and the IT industry.

University of California (Berkeley). Established in 1868, Berkeley is one of the country's most prestigious universities and a worldwide leader in research, science, and engineering. It receives more awards for R&D funding than any other national university without a medical school. In 1996-1997, for example, the university's faculty was granted $336 million in research project awards, and had 3,800 projects under way. Berkeley's five colleges and nine professional schools enroll approximately 30,000 students in more than 100 academic departments and interdepartmental programs. The school's technology transfer office manages a growing portfolio of patents and licensing activity, and its faculty and students have founded numerous spin-off companies.

Many forget that until the 1930s, the "great" universities of California, including Stanford, Berkeley and the California Institute of Technology (Caltech), were ranked far below the best East Coast institutions. In a rush to develop excellent universities in California, with the support of various parts of the U.S. Department of Defense, these institutions spent the years before World War II playing catch up. Ernest Lawrence, a Caltech graduate, as a junior professor at Berkeley applied enormous talents and drive to gather talented people, money, and investments to explore the possibility that energy could be derived from the splitting of the atom. Professor Frederick Terman at Stanford applied the same form of entrepreneurship to help William Hewlett and David Packard find money to start Hewlett-Packard.

Core Federal Laboratories. Silicon Valley has been "endowed" with an extraordinary array of scientific research facilities by the federal government, due to a combination of brilliant scientists, pressure by politicians, and the Cold War. These facilities grew to give the region an unmatched critical mass of research assets, many of which are directly relevant to the IT industry.

NASA Ames Research Center is one of the 10 field installations of the National Aeronautics and Space Administration (NASA). It conducts key R&D activities and develops the enabling technologies that support all NASA missions. Several technologies created at Ames have been spun off for the IT and other industries. Located in the heart of Silicon Valley, Ames is at the very core of the research cluster of high-tech companies, universities, and laboratories that define the region. The facility features $2 billion in capital equipment, 3,500 on-site research personnel and a $600 million annual budget. These resources are devoted to Ames' mission to pioneer the identification, development, verification, transfer, application, and commercialization of high-payoff aeronautical technologies.

Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab), located next to the University, is a research facility that employs 3,550 staff, 600 of whom are students. For over 65 years, this multi-program national laboratory has served the region with advanced research and technologies in the fields of computational science, advanced materials, environmental science, energy efficiency, biosciences, and high-energy/nuclear physics. Each year, the lab hosts more than 2,000 participating guests. It is the oldest U.S. National Laboratory, founded in 1931 by Ernest Lawrence, one of the lab's nine Nobel Prize winners.

Lawrence Livermore National Laboratory is administered by the University of California for the U.S. Department of Energy. Built in 1952 on an abandoned naval airfield 40 miles from San Francisco, it is one of the world's largest R&D labs, employing about 7,000 with an annual budget exceeding $1 billion. The lab was traditionally focused on its core mission of national security through nuclear weapons research. With the end of the Cold War, the lab's research areas have been expanded. The lab's contributions are increasingly growing out of partnerships with private industry. For example, the lab has formed more than 200 research partnerships with companies and provided free technical assistance to 290 small businesses. About 65 companies licensed technologies from the lab in 2000, and several start-up companies have been founded by lab employees-turned-entrepreneurs.

Sandia National Laboratories began in 1945 in Alburquerque, New Mexico, in support of the U.S. atomic bomb development effort in World War II. It was managed by AT&T for 44 years, until the U.S. Department of Energy awarded its management contract to Lockheed Martin's Sandia Corporation in 1993. Since its inception, an additional facility was added in Livermore, California. This facility employs 1,000 people for a variety of R&D activities. Unlike many of the other National Research Laboratories, Sandia's technical staff targets specific goals rather than pursuing knowledge for its own sake. Currently, Sandia focuses on research related to national security as well as energy, the environment, and manufacturing technologies. Discoveries made at Sandia are shared with the private sector, and have created new avenues of growth for the regional economy. It was at Sandia, for example, that "clean room" technology was first developed, thereby enabling the production of large-scale integrated circuits by private corporations.

Stanford Linear Accelerator Center (SLAC) was created in 1962 on 400 acres west of Stanford University. SLAC was established to design, construct, and operate state-of-the-art electron accelerators for use in high-energy physics and synchontron research. SLAC is home to about 2,000 researchers, many of whom come from other universities and laboratories in the United States, as well as from industrial concerns and foreign countries. The variety of physics programs at the lab has resulted in the award of over 600 doctoral degrees and the publication of more than 3,000 scientific and technical papers. One of the major contributions to emerge from SLAC is studies of the cleanliness of silicon chips that form the backbone of the region's semiconductor industry.

Private Research Facilities. A group of private research institutions emerged in Silicon Valley around the middle of the 1900s. These facilities acted as a transmission belt between academic/government-sponsored research and industry applications and growth.

Stanford Research Park was founded in 1951 on 700 developed acres in the city of Palo Alto, adjacent to the university campus. It now forms the cornerstone of Silicon Valley, attracting some of the most successful technology companies in the world. The complex houses 150 companies and 23,000 employees engaged in predominantly scientific, technical, and research-oriented activities in electronics, computer hardware, software, biotechnology, and space. The park offers both a standard and a unique set of benefits. Like other industrial parks, Stanford has no payroll or business taxes, low-cost utilities, and a well-maintained infrastructure. Its affiliation with the University enables resident companies to take advantage of myriad other opportunities, including the ability to form close working relationships with university faculty and students, recruit Stanford graduates, access the university library systems, retain faculty as consultants, interact frequently with Stanford's Office of Technology Licensing, and participate in seminars and workshops that encourage the exchange of technical information.

SRI International (formerly Stanford Research Institute) is recognized as a leading independent, nonprofit organization focused on technical, business and policy innovation. SRI invented the computer mouse, two-way computer video conferencing, the precursor to the Internet, and computer networking. An R&D partner to government agencies, global corporations, start-up companies, industry consortia, and nonprofit organizations, SRI concentrates on creating, applying, and bringing new technologies to market. So far, 28 spin-off companies have been created to leverage SRI's core technologies, one of which is information technology, in commercial applications.

Xerox PARC, an advanced research offshoot of the leader of xerography, played a key role in Silicon Valley's development. PARC scientists laid the foundations for personal computers, workstations, graphical user interface, abstract elements of programming, networking, e-mail, and other IT applications now commonly used. In its heyday, PARC was as important to Silicon Valley as any area university. However, the Xerox leadership failed to see the promise of personal computing, and PARC's role has diminished significantly.

Close University-Industry Linkages. The relationship of companies in the cluster to the "core facilities" described above is one of the defining characteristics of Silicon Valley. The university and public research communities enjoy a variety of close relationships with regional firms – as company founders, licensors of technology, consultants, research partners, providers of student interns, and cultivators of new talent. The resulting environment has been described as one which contains an unparalleled "critical mass of human talent," and as one in which the lines between research institutions and private companies is blurred.

Private IT companies also interact heavily with one another within Silicon Valley. Many small companies have emerged to provide goods and services to the major IT firms. These suppliers include producers of software, instrumentation, lab equipment, and components, as well as firms that provide contract research and manufacturing services.

Technology Transfer Networks. Silicon Valley possesses an enormous array of technology transfer systems, both formal (e.g., university technology licensing offices and federal laboratory commercialization offices) and informal. The deep, almost seamless exchange of people, information, and other resources among these institutions has cultivated a unique culture of innovation that in turn attracts even more of the world's best entrepreneurial and research talent.

Local Venture Capital and Other Funding Sources. No other region in the country attracts more venture capital than Silicon Valley, which accounts for more than one fourth of all venture capital invested in the United States (28 percent in 1998, according to PricewaterhouseCoopers' *Money Tree™ Report, 1998)*). Venture capitalists tap personal Silicon Valley networks management talent, tech-savvy lawyers, technical experts, and potential business partners to fortify new business ventures.

Catalytic Government Activities

The role of government in the development of Silicon Valley should not be underestimated. However, the key government role was played by the federal government rather than state and local governments, and this role was not one of economic planning, as in Research Triangle, but rather as a funder of research and as a procurer of equipment and services.

The importance of the federal laboratories was discussed above. In addition, the relocation of a major military contractor, Lockheed, to California in 1956 brought considerable federal defense dollars to the area. Semiconductor procurements by the defense agencies amounted to approximately two-fifths of total production of those goods. Many Silicon Valley companies remain heavily dependent on federal contracts.

Although federal government spending on Silicon Valley R&D amounts to about $2 billion annually, state and local governments also play an important role in creating an environment conductive to IT entrepreneurship and innovation. While government incentives are not typically the most important factors attracting companies to Silicon Valley, they can have a marginal impact on a company's selection of sites.

Incentives

The state of California provides the following incentives to attract new companies or retain existing firms.

Tax Incentives

- **Net Operating Loss Carryover** allows businesses that experience losses for the year (as do many research-intensive companies) to carry this loss forward to the next year to offset income in the following years.

- **Manufacturers Investment Credit (MIC)** of 6 percent is available to manufacturers operating in California. This credit can be applied toward the purchase of manufacturing equipment and special purpose buildings.

- **California's R&D Tax Credit** for 8 percent of qualified research expenses (research conducted in-house) or 12 percent for basic research payments (to an outside company) is the nation's highest. This incentive is designed to encourage companies to increase their R&D activities in California.

- **Child Care Tax Credits** of up to $50,000 per year are available to employers who establish an employee child care program.

Financing Incentives

- **Local Financing Redevelopment Agencies** provide various forms of financial assistance throughout California. Businesses may benefit from direct financial assistance for manufactured products, capital financing, or long-term operating leases, or indirect assistance such as fee reductions, land cost write-downs, mortgage interest write-downs, and utility tax rebates.

- **Local Revolving Loan Funds** are available throughout the state. They provide capital to eligible small businesses that provide jobs for Californians.

Local/Regional Incentives

- **New Jobs Tax Credit** is available for any business that creates permanent new jobs in San Francisco or relocates existing jobs to San Francisco. Businesses receive a credit against their city payroll expense tax or business tax liability for four years.

- **Enterprise Zones** provide special state and local incentives in 39 designated areas throughout the state. Incentives include tax credits for sales or use taxes paid on qualified machinery, hiring credits, a 15-year carryover of up to 100 percent of net operating losses, and expensing of certain depreciable property.

Other Key Players and Initiatives

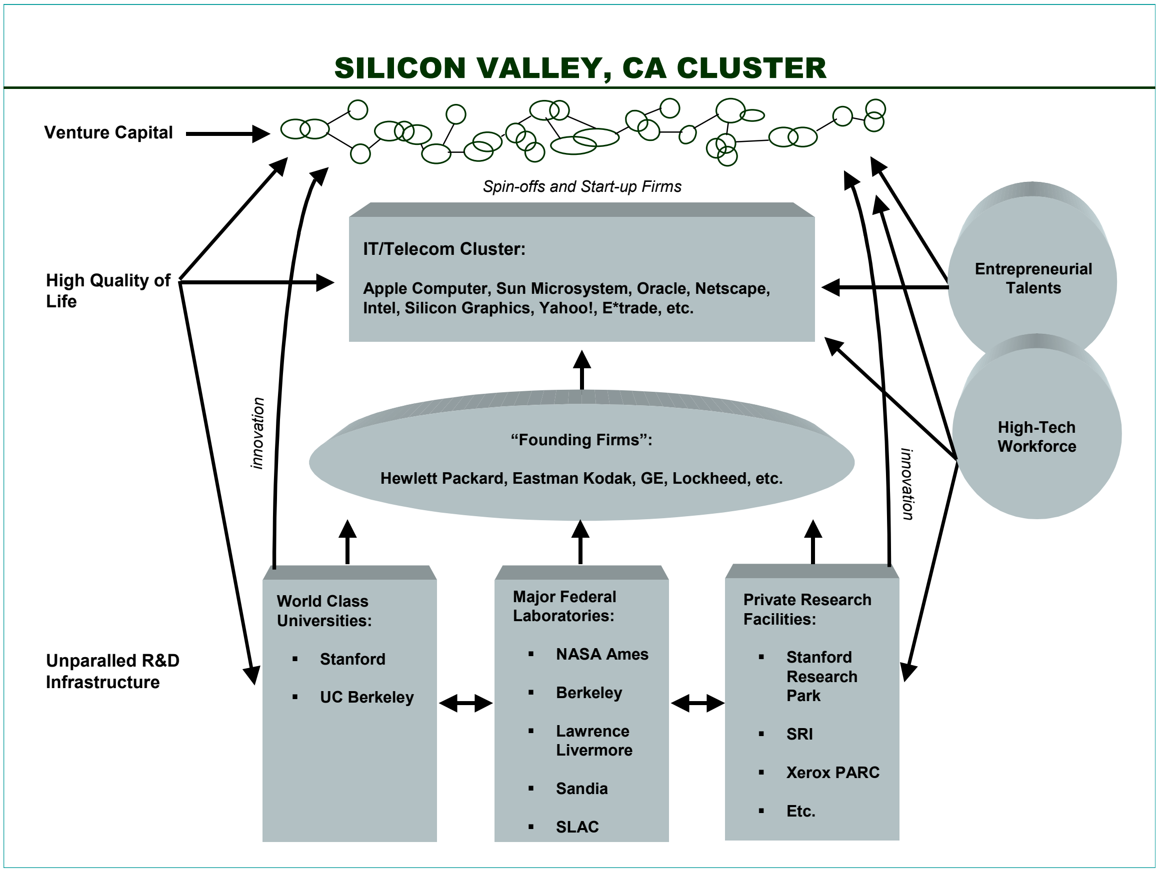
Joint Venture: Silicon Valley Network is a regional catalyst for solutions to problems that affect all sectors of the community. Joint Venture brings together leaders from business, labor, government, education, and community organizations to build a sustainable community that competes globally. The organization's scope of work is based on 17 goals that fall into one of the four following areas: innovative economy, livable environment, inclusive society, and regional stewardship.

BAYTRADE is a vigorous, public/private collaborative effort to promote international trade by helping hundreds of small and medium-sized businesses penetrate global markets.

Insights and Lessons Learned

The emergence of Silicon Valley as the paradigm of IT cluster development was in part based on chance, but more so on a long sequence of strategic decisions and investments stretching over 50 years. The IT industry is a direct consequence of research carried out at the region's core universities, and in many cases the creation of entire companies can be directly linked to a particular university as well. (See Figure 5.1 for a depiction of the Silicon Valley cluster.) Beyond the unparalleled knowledge base the region offers to IT companies, both established and new starts, firms are attracted to the region for a number of reasons:

Figure 5.1



- Overall, the region offers the culture and resources of a rich entrepreneurial environment.
- Silicon Valley possesses the nation's largest aggregation of world-class research universities and federal research laboratories.
- The region is home to a highly-educated talent pool, accounting for the country's largest share of workers with college and advanced degrees. Some 85 percent of Silicon Valley IT executives cite access to technical talent as a factor in determining the location of their companies. This is a significantly higher percentage than the national average.
- Silicon Valley's highly trained and motivated work force yields the nation's highest productivity growth rates.
- The region features extensive cultural and recreational resources, as well as natural beauty and an outstanding climate. This quality of life is a major draw for knowledge workers.
- Silicon Valley houses other internationally competitive clusters that have strong synergies with IT, including biotechnology, multimedia, aerospace, banking, finance and venture capital, and environmental technology.
- The are boasts the highest Internet penetration of any U.S. region.
- Silicon Valley attracts the largest percentage of available venture capital among all regions in the United States.

The critical mass enjoyed by the IT industry in Silicon Valley is itself a draw for cluster growth – creating a self-reinforcing circle. Geographic proximity has played a critical role in retaining talent. The heavy concentration of a large number of technology-based firms has enabled people to change employers without altering other aspects of their lives (other than their commutes). When a person leaves one job for another, there is no need to move one's residence or take one's children out of a particular school district to enter a different firm and region. If a small group of employees becomes dissatisfied with their firm, they gather together after work to tinker with their own ideas, develop a business plan, acquire funds from venture capitalists, and seek advice from local academic sources. If they succeed, they are heroes, and if they fail, they can be reabsorbed into some of the many local firms looking for talent.

As people in the region became occupationally mobile, their roles became interchangeable. Employers become employees and co-workers become competitors. Engineers develop loyalties to technologies and fellow engineers/scientists rather than to their firms. In this context, competition demands continuous innovation, which requires cooperation among companies. Rapid flows of information and knowledge have become the currency of value. This system promotes collective learning and flexible adjustment among companies that make specialty products within a broad range of related technologies. Silicon Valley's dense social networks and relatively open labor markets encourage innovation and experimentation.[5]

A number of lessons can be drawn from Silicon Valley's experience. These can provide insights and strategic guidance to other regions.

Build/support world-class research programs. Without doubt, Silicon Valley would not have achieved its success in the absence of highly advanced research institutions. Although other regions cannot expect to replicate the unprecedented range of federal labs in Silicon Valley, efforts to stimulate advanced research programs at regional universities can help draw highly qualified researchers, which in turn will yield highly educated technical personnel and spin-off companies.

Aggressively pursue federal procurements of technology. There is nothing like large-scale federal contracts to build critical mass. States and localities have always fought for "traditional" federal facilities (military bases, agency headquarters, etc.). To develop IT capabilities, they should also vie for technology procurements.

Infuse entrepreneurship in educational programs. Underlying nearly all facets of Silicon Valley's success are two interrelated characteristics – technological experimentation and entrepreneurship. The researchers who began or joined Silicon Valley institutions or companies have historically viewed themselves as technological trailblazers, comparable in some ways to the 19th century pioneers who settled the West. As modern-day pioneers, they began as technology entrepreneurs and transformed this trait into business entrepreneurship. The "heroes" of Silicon Valley are thus the

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[5] Saxenian, A.L., *Regional Advantage: Culture and Competition in Silicon Valley and Route 128,* Harvard University Press (Cambridge, MA), 1994.

successful entrepreneurs who have taken aggressive professional and technical risks. They are the garage tinkerers who have created successful companies.[6]

States and regions vary significantly in the level of entrepreneurship displayed in their university and other related institutions. Efforts to encourage entrepreneurship through whatever means possible – research funding with commercialization selection criteria, identification of faculty or student "champions" of entrepreneurship, formal or informal programs, etc. – can yield considerable success.

Austin

Cluster Scope and Development Path

Forty years ago, Austin was known largely for being the state capital of Texas and the site of the University of Texas (Austin). Today, Austin is touted in technology circles as "the second Silicon Valley." Consider that Austin is rated one of the top five most wired cities in the United States,[7] is home to one of the top 10 engineering schools in the country,[8] and reads like a *Who's Who* of high-tech computer, semiconductor, and electronic component companies. Tables 5.3 shows that Motorola, Advanced Micro Devices, Applied Materials, and Samsung, four of the country's largest semiconductor and semiconductor equipment manufacturers, are located in Austin, as are Dell, IBM and Apple, three of the country's leading personal computer manufacturers, and the software company, Tivoli Systems.

Table 5.3. Major Technology Employers in Austin

Company	Technology Area	Number of Employees
Dell Computer Corp.	Computers, peripherals	17,000
Motorola, Inc.	Semiconductors	9,000
IBM Corp.	Computers, peripherals, software	7,000
Advanced Micro Devices	Semiconductors	4,200
SBC/Southwestern Bell	Telecommunications	3,000
Applied Materials	Semiconductor equipment supplier	2,600
Tivoli Systems	Software	1,949
National Instruments	Semiconductors	1,798
Solectron Texas	Semiconductors, electronic components	1,700
3M Corp.	Manufacturing and R&D	1,550
WorldCom	Telecommunications	1,500

Source: Greater Austin Chamber of Commerce. http://www.austinchamber.org/, winter 2002.

[6] Saxenian, *Ibid.*

[7] Austin ranked third in *Yahoo! Internet Life* magazine's annual ranking of the 50 Most Wired Cities and Towns in the U.S.

[8] University of Texas at Austin ranked tenth in the Top Engineering Schools category in the U.S. News & World Report's *Best Graduate Schools 2002*. http://wwwusnews.com/usnews/rankguide/rghome.htm

According to the Greater Austin Chamber of Commerce, Austin's IT employment represents 15 percent of total nonagricultural employment in Texas. The recent downturn in the IT sector has resulted in significant layoffs, but the fundamental driver of Austin's economy over the past decade has been the growth of the technology sector. Throughout the 1990s, the Greater Austin-San Marcos MSA added jobs at an average rate of 5.4 percent per annum, or 29,000 jobs per annum.[9] Per capita income nearly doubled over the same 10-year period from an average $16,663 to $31,794 per person, pushing Austin's per capita income ranking from 155th to 39th in the country.[10] Austin achieved this growth in per capita income (an average rate of 6.7 percent per annum) despite the fact that the Greater Austin-San Marcos area's population also grew rapidly during this period (an average rate of 3.9 percent per annum).[11] Greater Austin's population has leapt from 200,000 people in 1960 to 1.2 million in 2000.

Three IT industry clusters now exist where previously there was none (semiconductors, computers, and software). How did Austin transform itself from a city based on government and university jobs to a city driven by R&D and high-tech industries?

The story of Austin's successful transformation revolves around a few critical assets that Austin already possessed and could leverage effectively. It is also attributable to a handful of key catalytic initiatives pursued by the government, the Greater Austin Chamber of Commerce, and the University of Texas. However, as tech-based economic development occurred, the initiative of other key players reinforced and enhanced Austin's tech-based economic growth.

The result is a 21st century city whose key industries are semiconductors, computers and peripherals, software, biomedicine, multimedia, logistics and distribution, music, and film.[12] The number of technology-based companies located in the Austin-San Marcos MSA currently exceeds 2,500, directly employing more than 95,000 people.

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[9] Calculated with Austin-San Marcos MSA data (1990-2000) compiled by the U.S. Bureau of Economic Analysis. http://www.bea.doc.gov

[10] http://www.bea.doc.gov/bea/regional/bearfacts/

[11] Calculated with Austin-San Marcos MSA data (1989-1999) compiled by the U.S. Bureau of Economic Analysis. http://www.bea.doc.gov

[12] Greater Austin Chamber of Commerce. http://www.austinchamber.org/Do_Business/What_s_Hot_Here/Key_Industries

The Road to High-tech: Timeline of Key Junctures in Austin's Economic Development

1957	Austin Chamber of Commerce hires University of Texas (Austin) Bureau of Business Research to identify how Austin could diversify its economy. The Bureau recommends that Austin develop its light manufacturing industry with a focus on the electronics industry.
1963	IBM opens a plant to manufacture Selectric typewriters.
1966	Texas Instruments opens a plant to manufacture handheld calculators.
1974	Motorola establishes semiconductor operation.
1979	Advanced Micro Devices (AMD) opens semiconductor facility.
1982	Dell Computer Corporation founded by Michael Dell, a freshman at University of Texas (Austin).
1983	Creation of thirty-two $1 million endowed chairs in engineering and natural sciences at University of Texas (Austin) as part of incentive package to woo MCC.)
1983	Microelectronics & Computer Technology Corporation (MCC), a consortium of the world's leading computer, semiconductor, and electronics manufacturers, selects Austin over 57 other cities in 27 states.
1984	Austin Chamber of Commerce commissions SRI International to develop a long-term economic plan for Austin. SRI's report stresses the development of three science and technology-related sectors: (1) research and development, (2) technology manufacturing, and (3) technology-based information. The report also highlights the linkage between quality of life and high-tech economic development.
1988	International SEMATECH, a national consortium of semiconductor manufacturers, chooses to locate in Austin.
1990	Applied Materials locates its manufacturing facility in Austin.
1995	Austin Community College establishes a Semiconductor Technology Program to address a shortage of high-tech technicians. The program was designed in partnership with AMD, Applied Materials, Motorola, SEMATECH, and Texas Instruments and offers two-year associate degrees and one-year certificates.

Market Magnets and Critical Assets

Two of Austin's most important assets 40 years ago, which are still important today, are its strong higher education system and its relatively affordable high quality of life, especially when compared to other high-tech-economy cities. A more recent development and a critical asset to Austin in the 1990s has been the emergence of a sizable venture capital industry.

Higher Education System. A primary concern to companies deciding where to relocate technology-intensive design and production facilities is the quality and availability of technicians, engineers, and scientists. The Austin metropolitan area has seven colleges and universities. Notable among these are the flagship of the Texas education system, the University of Texas (Austin), which turns out a large number of high-quality engineers and computer scientists, and Austin Community College, which trains technicians for the semiconductor, computer and electronics industries.

> **University of Texas (Austin).** University of Texas (Austin) is the largest single-campus institution in the United States, with an annual enrollment of 48,000 students. The university leads the country in the number of master's and doctoral degrees awarded and boasts more than 10,000 students actively pursuing graduate degrees. The university has combined undergraduate and graduate enrollments of

6,600 engineering students and 2,700 computer science students per year. Austin has grown to become a premier national university and is the academic flagship of the state's higher education system. In 2000, the University enrolled 245 National Merit Scholars in its freshman class, tying Austin with the Berkeley as having the largest number of National Merit Scholars of any university in the country.

Austin recruits and retains an outstanding faculty through endowed chairs, endowed professorships, and endowed faculty fellowships supported by companies and individuals. The more than 2,000 faculty of the university include Nobel laureates and Pulitzer Prize winners, as well as members of the National Academy of Sciences, the National Academy of Engineering, and the American Academy of Arts and Sciences. The creation of these endowed chairs, which now exceed 40, has its origin in an effort to attract a national research consortium (Microelectronics and Computer Technology Corporation) of leading computer, semiconductor, and electronics manufacturers to Austin in the 1980s. (See discussion under "Other Key Players and Initiatives.")

Austin Community College. The annual undergraduate enrollment at Austin Community College (ACC) is nearly 27,000 students. The college offers a two-year Associate of Applied Science (A.A.S.) degree and a one-year certificate program with specializations in Visual Communication Design, Computer Information Systems, Semiconductor Manufacturing Technology, Electronic Technology, Computer Electronics/Telecommunications, Engineering Technology, and Medical Laboratory Technology, among several others.[13] The Semiconductor Manufacturing Technology program is a new program that originated in 1995 through a joint collaborative effort between Austin Community College, International SEMATECH, and local semiconductor manufacturers. (See discussion under "Other Key Players and Initiatives.")

Venture Capital. The sustained growth of Austin's high-tech sector has been fueled, in part, by the rapid expansion of the pool of venture capital available to local firms. Austin's premier venture capital firm is Austin Ventures. Founded in 1979, it is the third largest venture capital firm in the United States with $1.6 billion under management. Approximately half of its capital is invested in Austin-based companies. Austin Ventures estimates $85 million in venture capital was invested in Austin-based information technology companies in 1996, $250 million in 1998, and $700 million in 1999.[14]

Catalytic Government Activities

In Austin, the key catalytic activities underpinning the development of IT clusters have been the successful attraction of two, high-tech R&D consortia. The unanticipated, long-term benefit of attracting these R&D consortia was the subsequent relocation of very big players in the semiconductor industry, who were member companies of the consortia.

[13] Austin Community College. http://www3.austin.cc.tx.us/catalog/dtypindx.htm#AAS
[14] Raik-Allen, Georgie. "Austin Ventures Raises Record Fund for Southwest," *Red Herring*, 2 December 1999.

The Greater Austin Chamber of Commerce orchestrated both marketing efforts with tremendous support from all levels of government and the University of Texas at Austin.

Attraction of the Microelectronics & Computer Technology Corporation (MCC) and International SEMATECH (ISMT). MCC is a consortium of the world's leading computer, semiconductor, and electronics manufacturers, and users and producers of information technology. Created in 1982, it was the first high-tech R&D consortium in the United States financed by private industry.[15] In 1983, MCC was looking for a place to locate and Austin made it into the final four (down from 53 cities in 27 states), competing against Atlanta, San Diego, and Raleigh-Durham. The city marketed its strong partnership between business, education, and government and its seriousness about turning Austin into a technology-driven economy. The state and city government contributed financial incentives, and a business-friendly environment, as well as providing the requisite statesmanship by the governor and the mayor.[16] The University of Texas (Austin), supported by the private sector, offered the following incentives:

- The creation of 32 endowed chairs (with support from private donors and the state government) at the University of Texas (Austin) to recruit some of the world's best science and engineering faculty.

- A 40,000-square-foot laboratory financed by the University of Texas and leased to MCC at minimal cost.

- Fellowships and teaching positions at the University of Texas for MCC employees.

Endowed Chairs in Engineering and Sciences at the University of Texas at Austin

The creation of thirty-two $1 million-endowed chairs at the University of Texas at Austin was a pivotal part of the incentive package offered to MCC. The endowment was raised through an $8 million private gift and subsequent matching funds. Since 1984, more than forty $1 million-endowed chairs have been created to recruit internationally recognized faculty to accelerate research programs in engineering and science. This infusion has strengthened the university's ability to attract both top-ranked graduate students, as well as quality incoming undergraduates.

In 1984, utilizing the same business, education, and government partnerships, Austin successfully enticed 3M to relocate five of its R&D and administrative divisions from

[15] In June 2000, MCC announced a major restructuring of its business model. Under the new model, MCC is investigating the spin-off of all or part of its major projects as separately funded start-ups. The plan is to transform the R&D consortium into a company that will administer the stock and intellectual property assets of MCC on behalf of the MCC shareholders. The restructuring is said to be driven by the need to explore the most effective ways to invest in promising technologies.

[16] Miller, Jonathon. "Regional Case Study: Austin, Texas, or 'How to Create a Knowledge Economy'" for the European Commission's *The Stories Behind Jobs and Growth: U.S. Regional Economic Development* study.

Minnesota. Then, in 1988 Austin attracted SEMATECH. Originally created as a public-private partnership to reinvigorate the U.S. semiconductor industry, SEMATECH has evolved into the world's premiere research consortium on semiconductor technology. The consortium currently consists of 13 semiconductor manufacturing companies from seven countries striving to accelerate development of the advanced manufacturing technologies that will be needed to build tomorrow's most powerful semiconductors. SEMATECH currently employs 600 researchers.

Other Key Players and Initiatives

The previous section examined the direct actions taken by the Greater Austin Chamber of Commerce, the government, and University of Texas at Austin to attract specific R&D consortia and companies to Austin. However, several other indirect initiatives have also shaped Austin's economic development. For example, once established in Austin, MCC and International SEMATECH came to be key players in Austin's economic development via their own initiatives, which reflected the needs and market demands of Austin's semiconductor and computer/electronics industries. Austin Community College and the University of Texas (Austin) have remained quintessential partners in Austin's development, because these institutions provide the key input in new economy industries—skilled workers. Finally, Austin's entrepreneurs have also had an important impact on the region's developmental growth path.

Spillover Effects from MCC. MCC's critical role in Austin's economic development involved bringing researchers from premier technology-based companies, such as 3M, Hewlett-Packard, Eastman Kodak, Nortel Networks, Motorola, Texas Instruments, and Raytheon to conduct R&D in Austin over several years. After research projects ended, a few of the more entrepreneurial researchers decided to stay in Austin and start their own companies. In other cases, the member company decided to open an Austin operation. This was the case for Crystal Semiconductor and Silicon Laboratories.[17]

The Semiconductor Manufacturing Technology (SMT) program resulted from a partnership between ACC, Applied Micro Devices, Applied Materials, Motorola, SEMATECH, and Texas Instruments. This program was offered for the first time in 1995. The SMT program offers a two-year Associate of Applied Science degree through the Electronic Technology Department and a one-year certificate. Fifty-eight students were enrolled in SMT program classes in the fall semester of 1995.

The program has not been without problems. One was that the chronic shortage of trained technicians led to employers hiring students enrolled in the SMT program before they had completed the academic work. Consequently, the number of graduates of the SMT program, which are aggregated into the larger Electronic Technology Department graduate numbers, has remained relatively low. The first class of SMT students to graduate was in the summer of 1997. The impact of SMT graduates on overall Electronic Technology graduates can be seen in the large increase in the number of certificate recipients in 1997-98, but with a much smaller number of degree recipients. (See Table

[17] Greater Austin Chamber of Commerce. "Austin's Evolution: University Town to High-tech Center."

5.4.) Many students who are hired by companies before completing the program continue to take classes part-time, but may never complete enough hours to graduate.

Table 5.4. Number of Degrees and Certificates Awarded Annually by the Austin Community College Electronic Technology Department

	Associate of Applied Science Degree	Certificate Recipients
1995-96	35	17
1996-97	53	38
1997-98*	59	56
1998-99*	86	41
1999-00*	67	33

Source: Office of Admissions and Records, *ACC 2000-2001 Fact Book.*
*Semiconductor Manufacturing Technology graduates were included in the totals for these three years.

Another issue has been the low SMT program enrollment, which remained at half of capacity (550 students) at the end of the first two years. Following strong criticism by the business community, ACC and a new president, Richard Fonte, stepped up marketing efforts to increase enrollment and succeeded in enrolling 500 students in the SMT program in 1998-99.

University of Texas at Austin. The university continues to underpin Austin's IT sector through the high-quality education of future engineers, scientists, and entrepreneurs; large amounts of R&D spending; incubation and commercialization activities; and participation in basic research, which will lead to the next generation of fundamental technological advances.

National Partnership for Advanced Computational Infrastructure

There are a number of important research centers associated with the University of Texas at Austin. Of particular note are the Texas Advanced Computing Center (TACC) and the Texas Institute for Computational & Applied Mathematics (TICAM). Through these two centers, UT Austin participates in the National Science Foundation (NSF) sponsored National Partnership for Advanced Computational Infrastructure (NPACI). The mission of the (NPACI) is to advance science by creating a ubiquitous, continuous, and pervasive national computational infrastructure: "the Grid." In the NPACI vision, researchers will be able to collect data from experiments and digital libraries, analyze the data with models run on a computing grid, visualize and share those data over the Web, and publish the results for the scientific community in digital libraries. Participation in this national project should position Austin favorably in the future for the next stage of technology in the IT and informatics area.

Austin's Entrepreneurs. Austin has benefited from an entrepreneurial culture, enabling individuals, who possess innovative ideas, think strategically, and are willing to take calculated risks, to succeed. Most well known among these is Michael Dell, founder of Dell Computer Corporation. In 1984, while an undergraduate, Dell launched his firm from his dorm room at the University of Texas (Austin). Today, Dell is the second largest manufacturer of computers in the world and the leading direct computer systems company. Much earlier, in 1955, Dr. Frank McBee, a University of Texas (Austin) engineering professor, founded Tracor, Inc., a small R&D and manufacturing company targeting the defense industry. At the height of this company's history in the late 1970s and early 1980s, Tracor employed 2,000 people and was Austin's only Fortune 500 company.

A further example of Austin's entrepreneurial talent is Dr. George Kozmetsky, who came to Austin from Teledyne Corp. in California in 1966 to become Dean of the Graduate School of Business at the University of Texas at Austin. Dr. Kozmetsky went on to be a key promoter of public/private initiatives focused on growing the pool of technology-based entrepreneurs in Austin. In 1979, he founded the IC2 Institute, an international, multi-disciplinary research and education institute at the University of Texas at Austin that links technology, entrepreneurship, and education to foster economic development. One of its programs is the Austin Technology Incubator (ATI), which supports promising high-growth companies in various technology-based industries with strategic advice, access to financing, marketing and public relations support, employee benefits programs, mentoring, and turnkey physical infrastructure. Between 1989 and 2001, ATI graduated more than 62 technology-based companies, generating over 2,500 jobs in the Austin region. ATI companies have raised more than $600 million in capital and reported revenues exceeding $1 billion.[18]

Public Relations Campaign. The public relations effort launched by the Greater Austin Chamber of Commerce, local government, and private sector should not be discounted. The local press was enlisted to write positive articles about Austin's success story. These stories, which first appeared in local newspapers and periodicals, such as the *Austin American Statesman*, later were picked up by *Fortune*, *Business Week*, the *Economist*, *Time*, *U.S. News & World Report,* and *Newsweek*. Such visibility greatly aided the chamber in attracting other high-tech companies to Austin.

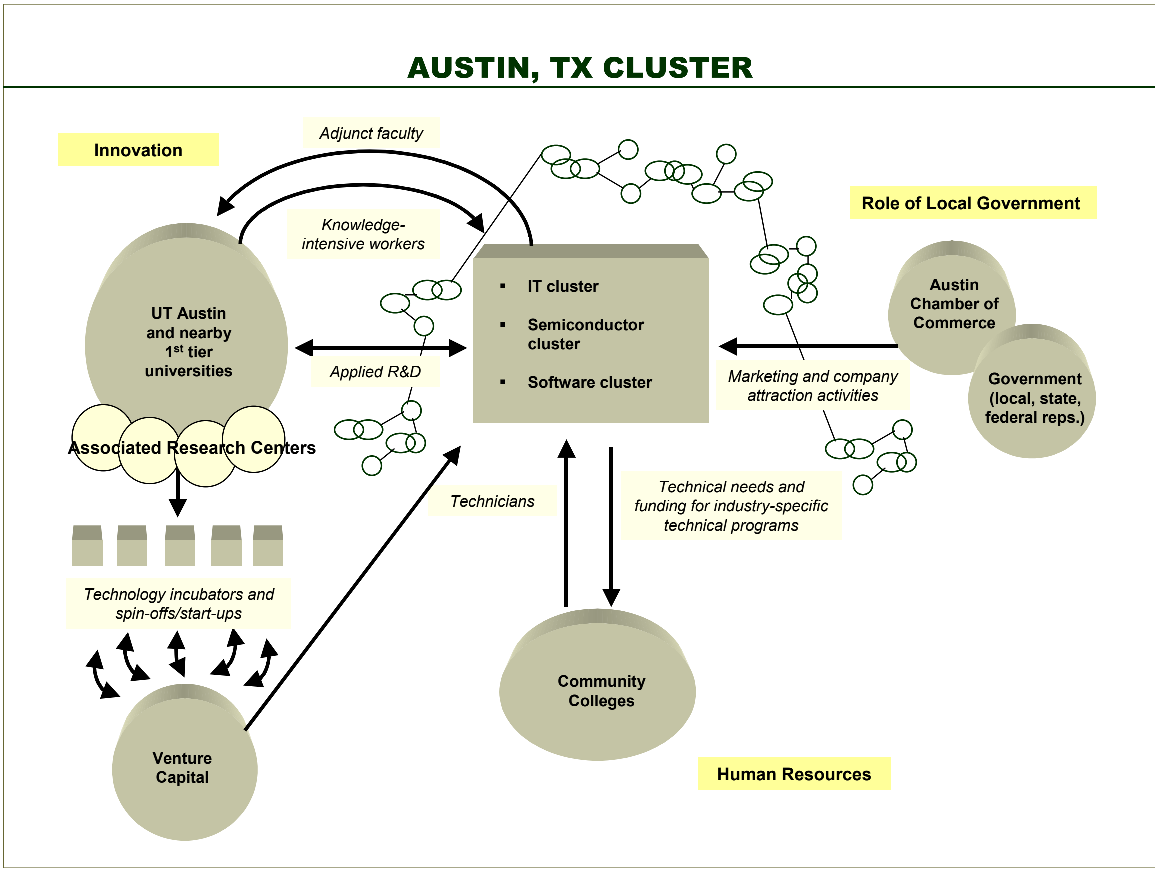
Insights and Lessons Learned

The emergence of Austin as an IT cluster was based on strategic decisions, investments, collaboration with UT, and marketing efforts that took place in the 1980s. The location and growth of the semiconductor industry in Austin—including Motorola, Advanced Micro Devices, Samsung, Cyprus Semiconductor, and Applied Materials—was a key driver of Austin's high-tech sector. The successful establishment of the semiconductor industry in Austin came about largely because of direct efforts taken by the Greater Austin Chamber of Commerce, the state government and the University of Texas at Austin to attract MCC and International SEMATECH. However, there were other key players, including MCC and International SEMATECH, whose own initiatives reinforced and enhanced the effort to attract technology-intensive companies to Austin. These synergies have not stopped, indeed they continue to support the growth of newer high-

[18] "Austin Technology Incubator Launches Eight New Companies; Enterprising Bill Bock of Verity Ventures to be Keynote Speaker," Business Wire, 17 May 2001.

tech industries in Austin, such as software development, biotechnology, and multi-media. Figure 5.2 depicts this cluster.

Figure 5.2



- Overall, the Austin the cluster has a rich entrepreneurial environment.
- Austin possesses a world-class research university and cutting-edge semiconductor research facilities. The city built these institutions rather rapidly through a combination of good marketing and offering endowed chairs to recruit world-class faculty,
- The region is home to a highly educated talent pool. Private companies, especially in collaboration, have been an important source of funding for training and workforce development. Private-sector involvement can help ensure that education and training are aligned with real industry needs and job opportunities
- Austin houses a variety of other internationally competitive clusters that have strong synergies with IT, including biotechnology, software, semiconductors, multi-media, and venture capital.

Austin has shown that high-tech clusters can actually be built in a region through a concerted effort. The combination of good marketing, investment in brainpower, and a focus on improving quality of life helped construct one of the most powerful IT clusters in the United States.

Several lessons can be drawn from Austin's experience, which can provide insights and strategic guidance to other regions.

Build world-class university programs in key fields. Austin would not have achieved its success in the absence of highly advanced research institutions. The key turning points were the endowment of 32 chairs at the University of Texas (Austin) in science and engineering programs. The endowment of these chairs allowed the university to attract world-class professors in these fields. These professors, in turn, attracted top-level students and companies anxious to benefit from the research being undertaken and from the students that began to graduate from these top-level science and engineering programs.

Attract top-level research consortia. Another key catalytic activity underpinning the development of Austin's IT cluster was the attraction of two outstanding R&D consortia. The unanticipated, long-term benefit of attracting these consortia was the subsequent relocation of very big players in the semiconductor industry, who were member companies of the consortia. The Greater Austin Chamber of Commerce orchestrated both marketing efforts with tremendous support from all levels of government and the University of Texas at Austin.

Link companies with educational programs. Private companies, especially in collaboration, can be an important source of funding for training and workforce development. Private-sector involvement can help ensure that education and training are aligned with real industry needs and job opportunities.

Seed startups through venture capital and a well-focused technology incubator. The active local venture capital community played a key role in financing new start-ups in the IT sector. In addition, Austin created a well-functioning technology incubator staffed with people who worked for technology companies in the private sector. The venture capital and the incubator have been crucial enablers in establishing technology-based start-up companies.

San Diego

Cluster Scope and Development Path

In recent years, San Diego's IT/telecom industry has emerged as the region's fastest growing sectors and the city is now the center for wireless communications. San Diego's telecommunications cluster is composed of firms primarily engaged in R&D and manufacturing of telecom equipment including, cellular, satellite, analog, and digital products. Included in the cluster are companies that provide point-to-point communications services such as cellular phones and paging services. San Diego, sometimes called "Telecom Town," boasts the third largest concentration of telecommunications firms in the country, with 600 companies supported with a workforce of approximately 24,874 in 2000. The area's number of IT/telecom companies is expected to grow at an annual rate of 7 percent over the next decade. Although San Diego is the home of major telecommunications firms, most of these businesses are small, with an average employment of less than 50.

The current success of San Diego's economy, in particular its telecommunications industry, did not come overnight, but rather it was the result of the decades-long process that began with the development of a strong core of military activities. Since the 1940s, San Diego has been the center for development of communications technology that has largely been driven by the U.S. Navy's demand for sophisticated wireless communication technologies. Through the support of considerable federal funding, institutions and technologies grew in response to the military's needs.

In the early 1980s, San Diego was still relatively unknown as a major center for communications technology. Many of the new firms focused primarily on defense contracts. The region had no major engineering school, no civilian research center, nor any firms that focused on the development of wireless communications technology for commercial applications.

However, in the late 1980s and early 1990s, San Diego experienced several economic losses as a result of defense downsizing. The reductions in defense industries provided the impetus for new, small, high-technology firms in communications as well as other related high-tech firms to grow from a defense-dependent to a diversified economy. One of the earliest pioneers credited with the development of the region's telecommunications, digital, and wireless industries was Linkabit Corporation, created in 1971 by two university professors, Dr. Irwin Jacobs at University of California (San Diego) and Dr. Andrew Viterbi at University of California (Los Angeles). The pivotal point when the cluster began to take off came during the late 1980s. In 1989, Qualcomm, a Linkabit spin-off, developed a revolutionary technology for cellular communications. With its successful IPO, Qualcomm put San Diego on the international communications map, motivating other regional entrepreneurs, and attracting capital from outside the region. The industry now includes a constellation of large, internationally competitive companies such as Kyocera America, Ericsson, 3Com, Conexant Systems, and Nokia Mobile Phones.

The success of the San Diego region's ability to create and expand its technology firms is due to multiple factors. Some of the factors that contributed to the start-up and growth of technology firms in the San Diego region were much the same as factors that have stimulated the growth in other technology regions. These factors include:

- An R&D base supported by a major research university
- Leadership from individuals in economic development organizations, universities, and the private sector
- A local government that promoted and adopted business-friendly policies
- Attraction of investment capital
- A cohesive private sector that was committed to stay and grow in the region and to help other technology firms get started.

The following sections detail some of the ingredients of market magnets and the regions' assets, catalytic government activities, and initiatives and key players that combined to make San Diego's high-tech region a success.

Market Magnets and Critical Assets

Cutting-Edge Research Institutions. The endowment of research resources has provided much of the thrust behind San Diego's telecommunications cluster. Several of the region's colleges and universities have excellent engineering programs at both the undergraduate and graduate levels. In recent years, these schools have improved their academic curricula and training infrastructure to support specialized research in communications-related fields.

> **University of California (San Diego).** University of California (San Diego) is one the major teaching and research universities in the United States. Founded in 1960, University of California (San Diego) has risen rapidly to its status as one of the top institutions in the nation for higher education and scientific exploration. A member of the prestigious Association of American Universities since 1982, University of California (San Diego) has consistently ranked among the top 10 universities in the country in terms of federal research awards. The university received $461.7 million in research funding in 1999 – 2000, which placed it sixth in the nation and first in the University of California system in federal R&D funding, according to the National Science Foundation's most recent report.
>
> Its faculty includes five Nobel Laureates, it ranks seventh in the country in the number of National Academy of Science members, and it has one of the nation's highest percentages of faculty elected to the prestigious national academies.
>
> University of California (San Diego) is home to one of the nation's two national supercomputing centers sponsored by the National Science Foundation, and leads a consortium of 46 universities in 19 states and five countries focused on developing computational technologies of the future.
>
> The university's core research facilities include the California Institute for Telecommunications, Cal-(IT)², and Information Technology and the Center for Wireless Communications, CWC. Cal-(IT)², a partnership between University of California (San Diego) and University of California (Irvine), has as its purpose to ensure that California maintains its leadership in the telecommunications and information technology marketplace. The institute's mission is simple: Extend the reach of the current information infrastructure throughout the physical world to enable anytime/anywhere access. This, complemented by research and development in related information technologies, will help the state (1) provide new capabilities to important market segments poised for transformation by the Internet and (2) prototype ways to monitor and manage growth anticipated in the coming years.

The CWC of the University of California (San Diego) offers a cross-disciplinary program of research and education targeted at the emerging needs of the cellular and wireless communications industry. Founded in February 1995, the center is a joint effort of the university and a local consortium that is committed to developing a strong university-industry partnership needed for producing a relevant program of systems and technology-oriented research. The CWC places high priority on strategic planning, collaboration, technology transfer, and generation of highly trained graduates at all degree levels to meet industrial human resources needs.

Another aspect above and beyond the impressive facilities at University of California (San Diego) is the leadership behind the institution. Chancellor Richard Atkinson's leadership of the university was a significant factor in promoting university-industry relations that underpinned San Diego's technology development. Dr. Atkinson believed that a research university, in addition to striving for teaching excellence, should play a role in developing a technology-based economy, and he viewed the university as a source of basic and applied research upon which technology firms could build upon. Under his guidance, the University was granted increased funding for R&D, established a top-notch engineering school, developed the CONNECT program (discussed in a later section), and was granted the site for one of the national Supercomputer Centers.

California State University (San Diego). San Diego hosts one of the major campuses of the California State University system, California State University, San Diego (San Diego). Founded in 1897, California State University (San Diego) is a teaching and research university which has more than $65 million in funded research each year.

Technology Transfer Networks. The region's universities, technical schools, and research institutions provide not only a steady pool of highly skilled workers but also tremendous opportunities for joint ventures and spin-off firms. Each of the area's universities has a highly successful industry liaison office that works to commercialize the results of academic research. Research partnerships between industry, academia, and government are a driving force behind San Diego's innovation economy. In addition, the region is home to several high-technology associations and agencies that support their member firms through networking, advocacy, information exchange, and education.

- **Center for Applied Competitive Technologies**—The Center for Applied Competitive Technologies-San Diego, located at San Diego City College, is one of 12 regional advanced technology centers designated by the state of California to assist regional manufacturers in modernizing manufacturing and production technologies, thus enhancing their competitiveness in the global economy.

- **Technology Transfer and Intellectual Property Services**—The Technology Transfer and Intellectual Property Services at University of California (San Diego) was created to promote and facilitate the transfer of technology to the private sector, to help protect commercially valuable intellectual property, and to provide a resource to the UCSD community for intellectual property questions.

- **San Diego Technology Incubator**—Created in partnership with the city and operated by the San Diego Community College District on the City College campus, the technology incubator provides business incubator space and services for emerging high-technology businesses that have been in operation for at least a year.

- **Southwest Regional Technology Transfer Center**—Under a technology transfer grant from NASA, the center assists businesses in using new technologies developed through defense and space programs.

- **Specialized Talent Pool**—San Diego has a large number of highly educated and skilled labor force in the telecommunications cluster. According to the Bureau of Labor and Statistics, 5,400 electrical or electronic engineers and more than 6,500 electrical or electronic engineering technicians lived in the region in 1998, well above the national average.

Local Venture Capital and Other Funding Sources. Because of its large pool of entrepreneurial talent, and the capital and services this talent thrives on, San Diego has developed into a significant entrepreneurial and venture center. According to the PricewaterhouseCoopers' Money Tree data, San Diego regional communications raised $326 million in venture capital funds from 1995 to 1999, representing 3 percent of the national total over that period.

Recently, despite tough economic conditions, venture capitalists continue to show committed resolve. Most are spending the majority of their time and capital resources on existing portfolio companies, as demonstrated by the fact that 81 percent of total venture investment in the third quarter went to follow-on investments. However, venture capital firms are still finding promising new opportunities in a wide range of high-tech sectors of which telecommunications is one.

Outside the realm of venture capital sources, there are many other financial resources for small firms engaged in high-tech business in San Diego that work in conjunction with the city. A program that has been instrumental in providing financial resources to emerging high-technology companies is the **Emerging Technologies (EmTek) Loan Program**.

- **EMTEK (Emerging Technologies) Loan Program** – The EmTek Fund is a public revolving loan fund funded by both the city and the county of San Diego that helps finance promising small businesses' efforts to raise working capital to accelerate growth. EmTek addresses financial needs among the region's smaller growth companies that may not yet possess the transaction size or market potential necessary to attract venture capital. Also, these companies often cannot obtain conventional loans because they lack historical debt service ability and/or collateral.

- EmTek's primary product is working capital financing. This is provided in amounts of less than $250,000, with flexible terms up to five years and at below-market initial interest rates. Subsequent participation/success fees are structured to attain a target internal rate of return of approximately 25 percent on committed funds.

- The EmTek Fund is operated by the city's Economic Development Division with assistance from the Jacobs Center for Nonprofit Innovation and an advisory board composed of private-sector volunteers with broad expertise in early-stage growth company finance. With funding from the city, the federal Economic Development Administration, the county of San Diego, and a consortium of area banks, EmTek's capitalization currently stands at approximately $2.5 million. EmTek seeks a target internal rate of return of 25 percent, composed of: (1) fixed current interest rate (currently 8 percent) and (2) upside participation as negotiated (royalties, warrants, or other success fees). Since its founding in 1985, EmTek has helped more than a dozen entrepreneurial high-tech firms with funding needs.

Catalytic Government Activities

The state has numerous incentives in place to encourage investments in starting and operating a business in California. During the 1990s, state government enacted legislation that provided incentives targeted toward high-technology businesses.

- **Research and Development Tax Credit.** An R&D tax credit for corporations, covering a portion of in-house research and research contracted to universities. It is designed to encourage companies to increase their basic R&D activities in California. The research tax credit allows companies to receive a credit of 11 percent (highest in the nation) for qualifying research expenses (research done in-house), and 24 percent for basic research payments (payments to an outside company).

- **Manufacturers' Investment Credit.** In general, the manufacturers' investment credit is unlimited. It can be used to offset income or franchise taxes based on the purchase or lease of manufacturing and related equipment, which is depreciable under certain federal regulations and has California sales or use tax paid on the purchase. The credit also includes certain capitalized labor costs. In addition, "special purpose buildings and foundations," (e.g., clean rooms) for certain electronic manufacturers, semiconductor equipment manufacturers, commercial space satellite manufacturers, and property related to specified pharmaceutical activities are eligible for this credit.

- **Employment Training Panel.** The Employment Training Panel (ETP) assists businesses in acquiring and retraining a highly skilled work force with expertise in very specific fields to increase competitiveness and productivity. It is supported by California employers through a small contribution to the California Employment Training Fund through the Employment Training Tax.

- **Industrial Development Bonds.** California cities, counties and state government have the authority to offer low-interest financing to manufacturers and other businesses locating in their communities through the use of tax-exempt industrial revenue bonds. An eligible bond project can be the construction of a new plant or replacement of all or part of an existing plant. Industrial activities eligible for financing include assembly, fabrication, manufacturing, and processing. The primary advantage of industrial development bonds is that the financing provided bears an interest rate significantly lower than conventional methods (the lower interest rate is the result of the tax-exempt status of the securities). The bonds are long term, 15 to 30 years maturity, and are assumable.

- **California Technology Investment Partnership Program.** The California Technology Investment Partnership Program (CalTIP) provides matching grants and technical assistance to California-based businesses, consortia, nonprofit organizations, and public agencies for projects qualifying for federal funds through cost-share technology-based projects from various federal agencies. The mission of CalTIP is to accelerate the development of new, globally competitive, technology-based commercial products and services from California firms and consortia. Proposals are evaluated based on immediate and measurable ability to create jobs, clearly identified product line and market, inclusion of a training component for workers associated with the project, demonstrated links with other applicable programs, and whether the proposers and partners are small businesses.

- **Net Operating Loss Carryover.** California's net operating loss carryover ranges from five to 15 years and includes either 50 or 100 percent of the loss, depending on how long the business has operated in California and the location of the business.

The city of San Diego instituted public policy changes and investments in infrastructure that would contribute to a more business-friendly environment. An Economic Development Task Force was created in 1992 to assess the business climate of San Diego. It issued recommendations aimed at improving the business climate through eliminating burdensome regulations, as well as streamlining the bureaucratic process. The task force's recommendations were supported and implemented by incoming Mayor Susan Golding, who was elected in 1992. Under Mayor Golding's leadership, the local government supported the technology environment by increasing tax credits on business investments in university research and provided other direct incentives for technology industries such as reducing business taxes by 80 percent.

The city also established two enterprise zones to attract business—one in southeast San Diego and one near the Mexican border. The city offered businesses located in the zone sales and usage tax credits on certain machinery purchased for use in the zones, employee wage tax credit, business expense deductions, and carryover from net operating losses.

The Business Cooperating Program enacted by the city in 1996 provided businesses and nonprofit corporations with cash rebates or business tax/development fee tax credits for reporting and filing their business sales tax to the State using a method that allows the city to claim a share of locally generated revenues. In 1999, the program was used as an incentive package to attract a giant Swiss pharmaceutical company into making a major investment in San Diego.

Other Key Players and Initiatives

Community-based organizations also have played an important role in developing a supportive environment in the industry. The **San Diego Regional Economic Development Corporation (EDC)** led the development initiatives in the 1980s by encouraging participation from universities and the private sector. The San Diego chapter of the **Massachusetts's Institute of Technology (MIT) Enterprise Forum**, started in the early 1980s, has provided advice and education services to the region's growing companies. **University of San Diego's CONNECT program**, started a few months after the Enterprise Forum, has helped technology start-ups and small companies through business assistance, venture capital, and networking. **The San Diego Regional Technology Alliance** also has implemented programs aimed at promoting science and technology in schools and in disseminating technological know-how. The San Diego Manufacturing Extension Center, through the support of federal and state funds, has helped small manufacturers with upgrading their technologies.

San Diego Regional Economic Development Corporation (EDC). Founded in 1965, the EDC played a leading role in the development of small, high-technology businesses in San Diego. During the 1980s, the EDC's efforts centered on the attraction of industries and major research centers, such as the Microelectronics and Computer Consortium. Although the EDC was unsuccessful in winning the major research centers, its efforts brought together the public, private, and academic sectors to bid for these centers. Its efforts helped to bridge the gap between these three sectors and instilled a sense of community cohesiveness.

In its effort to promote high-technology industries, the EDC led the way in establishing UCSD's CONNECT program. The EDC convened members of the collegiate community and community leaders to form the organization as means of coordinating the public and private sectors and thus to use CONNECT as a vehicle that would enable entrepreneurs to take advantage of UCSD's research.

Some other notable achievements by the EDC include its effort to combat the downturn of the San Diego economy following defense cuts in the early 1990s. The EDC, along with local government and private industry, launched a strategic five-year plan that called for the creation of 15,000 direct jobs in manufacturing and high-technology industries and generating 25,000 indirect additional jobs in the service industries. The plan focused on promoting the growth of the *maquiladora* industries; increasing trade with the Pacific Rim; and promoting the formation of high-technology industries.

San Diego MIT Enterprise Forum. The MIT Forum was created to promote and support emerging technology companies. The first chapter was established by the MIT

Alumni Association over 20 years ago in Cambridge, Massachusetts. It has since grown to 22 chapters worldwide, including the San Diego chapter.

The San Diego MIT Enterprise Forum meets monthly to address business challenges faced by San Diego entrepreneurs. It offers advice, support, and education services for local emerging technology-based companies. Programs include professional seminars, start-up clinics, business plan workshops, and case presentations in which CEOs of early-stage and growing companies present their most pressing issues to a panel of their peers. The most valuable uses of Forum activities are the opportunities provided for entrepreneurs to network with venture capitalists and industry experts as well as private investors who offer strategies, tactics, and advise on funding, marketing, and growth.

The San Diego MIT Enterprise Forum has been credited for attracting millions of venture capital dollars to budding entrepreneurial companies.

CONNECT. University of California (San Diego) CONNECT was created in 1985 to contribute to San Diego's economic development by nurturing high-tech entrepreneurship, facilitating interaction between the university and the business community, and further developing San Diego's infrastructure. The organization is a division of the university's Extended Studies and Public Programs Entirely self-supporting, CONNECT receives no funding from the university or the state. CONNECT is supported entirely by membership dues, course fees, grants, and corporate underwriting for specific programs.

CONNECT has grown rapidly since its founding in 1985 and is credited as one of the major forces in San Diego's rapid high-technology growth. Originally starting with 17 company sponsors, CONNECT saw the number of sponsors grow to over 720 by the end of 2001. CONNECT draws heavily on its active community of corporate leaders, many of whom conduct various activities such as reviewing business plans, critiquing business presentations, conducting seminars, and promoting public policy programs.

CONNECT offers a wide range of programs to serve different needs and venues. The most common entrepreneurial development and investment activities forums are:

> **Springboard Program.** The Springboard Program was started to assist high-tech and biotech entrepreneurs in the very early stages of developing a concept and strategy for a business. Entrepreneurs accepted into the program spend four to eight weeks in coaching sessions with experienced business people who help them develop their business plan. Upon completion of the program, the entrepreneurs are invited to make a presentation of their ideas to a select group of CONNECT sponsors and members. This group usually includes a venture capitalist, accountant, corporate and patent attorneys, marketing professional, and an executive from a successful company in the same industry.
>
> Since Springboards' inception, it has helped more than 150 companies, with investments ranging from $500,000 to $2 million per company.

Technology Financial Forum. The Technology Financial Forum is a major annual event that brings together entrepreneurs, high-technology firms, and potential investors. Started in 1988, the Forum has become one of CONNECT's most successful activities.

Through the Forum, about 40 to 50 firms each year make presentations to potential investors and corporate partners. The Forum lasts two days – one day is devoted to life sciences firms, the other to technology firms.

The 1999 Forum showcased 31 companies presenting to over 300 attendees, including approximately 150 venture capitalists and investment bankers.

Meet the Researchers. The "Meet the Researchers" series brings together scientists and business people from various sectors to learn more about technologies, technological developments,and technology transfer. The program pairs together a researcher from UCSD with a researcher from industry to discuss scientific and engineering issues of mutual interest.

"Most Innovative New Products" Award. The MIP is an annual competition sponsored by CONNECT to select the most innovative new product in five categories: General Technology, Hardware/Physical Device, Life Sciences, Software, Telecommunications/Wireless. The MEP Award is in its 14th year. CONNECT received over 110 product nominations for the 2001 competition, and approximately 900 people attended the sold-out awards ceremony on December 5. MIP remains one of the San Diego's largest and most prestigious business events.

San Diego Manufacturing Extension Center (SanMEC). The SanMEC is a private, nonprofit organization established to provide technical and business consulting services to small and medium sized manufacturing firms.

SanMEC was founded in 1996 as part of the Manufacturing Extension Partnership (MEP) program, under a cooperative agreement with the National Institute for Standards and Technology (NIST) and is governed by an independent, voluntary board of directors from business, industry, government, and academia. SanMEC's budget comes from NIST, state matching funds, and fees for services. SanMEC serves firms in the telecommunications, electronics, biotechnology/healthcare, and software industries. Its services range from technical support in manufacturing modernization, business planning, finance, and capital acquisition to workforce development. It also provides services in new product development, marketing, and distribution planning and development. SanMEC uses business specialists to provide small manufacturers with engineering and other assistance tailored specifically to the client. Since its formation, SanMEC has helped more than 100 companies with manufacturing solutions.

San Diego Regional Technology Alliance (RTA). The RTA is a public/private partnership that provides information to high-technology businesses. The RTA serves as a catalyst for the San Diego educational and business communities for community economic development by:

- Equipping entrepreneurs with the tools to develop their technology businesses
- Creating partnerships between the private and public sectors to bridge the "digital divide" and create a skilled workforce for the region's future
- Conducting research to educate the region on its technology strength.

The RTA was legislatively established in 1993 under the California Trade & Commerce Agency in response to the 1990s defense downsizing and base closures. The RTA, a nonprofit corporation, now focuses on general technology development through the following programs:

Entrepreneur Services. The RTA provides business assistance and efficient access to the network of private and public resources that exist to aid entrepreneurs and growing companies through educational workshops, networking events, referrals, and one-on-one assistance.

Seed Capital. The RTA manages a $1 million seed capital grant program, the California Technology Investment Partnership (CalTIP), which provides up to $250,000 to San Diego technology companies that win federal technology awards, such as SBIR awards. This award provides companies rapid access to capital to support the innovation and commercialization process.

Community Development Program. The mission of the RTA's Community Development Program is to investigate and analyze the extent of the digital divide locally. Through partnerships with business, community leaders, and educators, the RTA strives to bridge the digital divide by working with community centers to assist in the development of technology resources for their constituencies. These partnerships lay the groundwork for meeting the needs of the region's growing high-tech workforce.

Research. The RTA partners with various private, local, state, and federal organizations to analyze the region's technology-driven economic growth and educate policymakers on technology issues. The RTA also helps businesses access federal research and development programs, especially the Small Business Innovative Research (SBIR) and Small Business Technology Transfer (SBTT) programs.

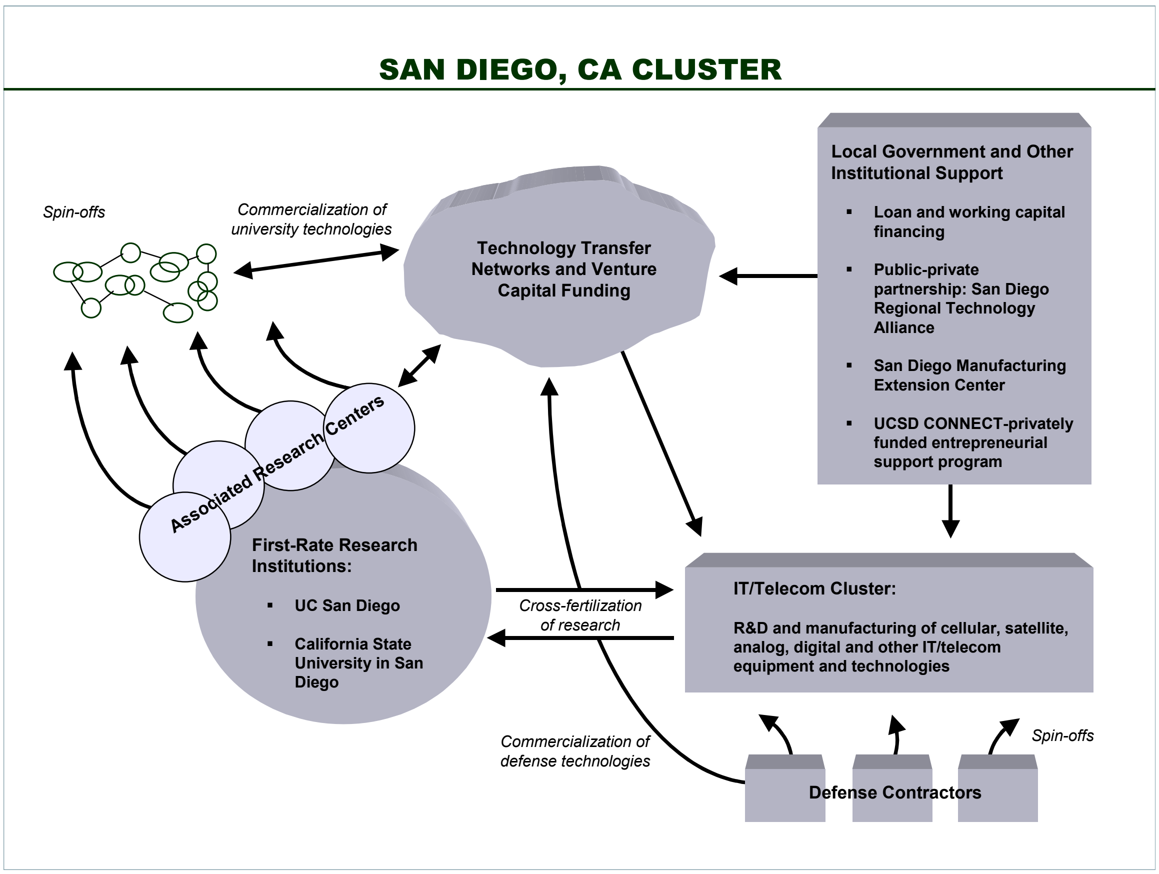
Insights and Lessons Learned

The current success of San Diego's telecommunications industry did not come overnight, but was the result of the decades-long process that began with the development of a strong core of military activities. Since the 1940s, San Diego has been the center for development of communications technology that has largely been driven by U.S. Navy demand for sophisticated wireless communication technologies. Through the support of considerable federal funding, institutions and technologies grew in response to the military's needs.

In the early 1980s, San Diego was still relatively unknown as a major center for communications technology. Many of the new firms focused primarily on defense contracts. However, in the late 1980s and early 1990s, San Diego experienced several economic losses as a result of defense downsizing.

The pivotal point for the cluster's acceleration came during the late 1980s. In 1989, Qualcomm, a Linkabit spin-off, developed a revolutionary technology for cellular communications. With its successful IPO, Qualcomm put San Diego on the international communications map, motivating other regional entrepreneurs, and attracting capital from outside the region. The industry now includes a constellation of large, internationally competitive companies such as Kyocera America, Ericsson, 3Com, Conexant Systems, and Nokia Mobile Phones. (Figure 5.3 portrays this cluster.)

Figure 5.3



Insights from the San Diego case include:

- A defense-oriented R&D base supported by a rising research university.
- Leadership from individuals in economic development organizations, universities, and the private sector.
- A local government that promoted and adopted business-friendly policies.

- Good attraction of investment capital.
- A cohesive private sector that was committed to stay and grow in the region and to help other technology firms get started.
- An excellent natural climate that makes San Diego a very good place to live and work.

San Diego's accomplishments and the process by which the city has encouraged development and growth in the telecommunications cluster offers lessons for other cities. Key factors that enabled San Diego to achieve its success include:

Build strong collaborative partnerships. San Diego built close networks and partnerships among businesses, government, and research institutions. These partnerships have been the glue that keeps the telecommunications industry cluster together.

Local government should provide strong support for business. Over the past two decades, San Diego has received considerable national recognition as a city that has lowered its crime rate, improved its image, cleaned its environment, and created substantial numbers of new jobs.

Develop technology transfer networks. The region's universities, technical schools, and research institutions provide tremendous opportunities for joint ventures and spin-off firms. Each of the area's universities has a highly successful industry liaison office that works to commercialize the results of academic research. Research partnerships between industry, academia, and government are a driving force behind San Diego's innovation economy.

Leverage your R&D base. University of California (San Diego) has risen rapidly to its status as one of the top institutions in the nation for higher education and scientific exploration. UCSD has consistently ranked among the top 10 universities in the country in terms of federal research awards. In 2000, the university placed sixth in the nation and first in the University of California System in federal R&D funding, according to the National Science Foundation's most recent report. The excellent research base has attracted telecommunications industry companies.

Research Triangle

Cluster Scope and Development Path

The Research Triangle in North Carolina is one of the oldest technology clusters in North America. It provides a prime case study where a world-class research and industrial park and industry cluster were created "from scratch." The Research Triangle development is a product of deliberate planning by the region's visionaries. The philanthropic activities of early entrepreneurs such as Dr. Bartlett Durham, Erwin Mills, and Washington Duke provided the foundation for the region's transition from agriculture to manufacturing to a knowledge-based economy. Land and monetary grants provided the underpinnings for the region's institutions.

Research Triangle Park (RTP) serves as the key infrastructure foundation for the region. The 6,900-acre RTP—one of the nation's premier research and development talent pools—nurtures a symbiotic relationship with three internationally known research universities and its high-tech business tenants.

Established by the state legislature to attract high-value economic growth to North Carolina, RTP was built in 1959 around the three universities located in Raleigh (North Carolina State University), Durham (Duke University), and Chapel Hill (University of North Carolina). The initiative has been extremely successful, and today, over 50,000 people work at 136 R&D, office, and high-tech manufacturing facilities in the RTP. RTP has become an international research and development center, bringing high-paying jobs and attracting other industries and facilities to the region. The result is booming growth and urbanization, particularly around Raleigh in Wake County. The area's population grew from 700,000 in 1990 to nearly 1 million in 2000.

Information technology has played a major role in the RTP's development and success since IBM first moved into RTP in 1966. Today, the Raleigh-Durham area is ranked 20th in the country for its concentration of high-tech personnel, who make up almost 9 percent of the RTP workforce. With one-third of its 25-or-older population holding a bachelor's degree or higher, the area (including Durham and Chapel Hill) was recently ranked as the top region for knowledge workers in *Fortune* magazine. RTP is also home to the nation's richest company in terms of stock market capitalization—Cisco Systems, which operates a major R&D facility that is currently adding more workers. Roughly 80 percent of the state's approximately 200,000 IT workers live and work in the Raleigh-Durham area. The Research Triangle is home to some of the nation's most prestigious telecommunications, electronics, and computer firms, and continues to attract additional prominent firms.

Market Magnets and Critical Assets

Cutting-Edge Research Institutions. Three educational institutions form the pillars of the region's knowledge-based economy, providing world-class research facilities as well as a critical mass of scientists, researchers, and technicians.

> **Duke University.** Duke University is regarded as one of Research Triangle's most valuable assets. Known for the quality of its faculty as well as its academic and research programs, Duke University is one of the South's premier private research institutions. In the past several years, the university has witnessed dramatic expansion of research activity on campus that resulted in a 55 percent increase in research expenditures from 1990 to 1995. In 1994-1995, sponsored research expenditures totaled $203 million of which roughly 73 percent ($148 million) was federally funded.
>
> Located at Duke University is the Fitzpatrick Center for Photonics and Communications Systems. The new $100 million center is part of the University's Pratt School of Engineering and was established in December 2000

through a $25 million gift to the University. The center aims to pursue R&D in photonics in hopes of creating technological advances and growth that rival California's Silicon Valley.

North Carolina State University (NCSU). NCSU is the largest university in the University of North Carolina System. Since its founding in 1887, NCSU has become one of the nation's leading institutions for science, engineering, and technology. The U.S. National Science Foundation ranks NCSU in the top ten for industry-sponsored research and 17th nationally for licensing revenues and patents. NCSU is fourth in the nation for spinning off start-up companies, and in 2000 IBM recognized NCSU as the university from which the prestigious computer company hired more students than any other.

Located adjacent to the campus is the famed 1,334-acre research park known as the Centennial Campus, a research and advanced technology community where university, industry, and government partners interact in multidisciplinary programs for solving contemporary problems. Centennial Campus is a "technopolis" of corporate, government and academic R&D facilities and business incubators. Its major feature is the intensive partnership among industry, government and university residents, all of whom receive full University Affiliate Status.

University of North Carolina-Chapel Hill. Founded in 1793, the University of North Carolina at Chapel Hill is the nation's first state university. The university ranks among the top U.S. research institutions. The University comprises of 13 colleges and schools with curricula representing over 100 major fields.

University and Federal Research Centers

Microelectronics Center of North Carolina (MCNC). MCNC is a private, nonprofit corporation in partnership with North Carolina's universities, businesses, and state government that supports research and education in microelectronics, advanced communications, supercomputing and visualization. MCNC is one of the country's first state-supported microelectronics research centers and houses a 10,000-square-foot, Class 1 clean room to fabricate "proof of concept" integrated circuits. MCNC is also the home of North Carolina Supercomputing Center.

Center for Advanced Computing and Communications (CACC). CACC was originally founded at NCSU in 1982 but merged with Duke University in 1994. CACC pursues cutting-edge research in five primary areas: high-speed networking, fault-tolerant systems, image processing, distributed algorithms and systems, and digital communications and optimization.

Anchor Firms. The cluster is anchored by communications powerhouses. IBM was the first to establish a major research facility in RTP. Other big IT players, such as Nortel

Networks and Cisco Systems followed suit. In the early 1990s, the Research Triangle Park increasingly became associated with the development of communications equipment technology, and by the mid 1990s the cluster began to achieve a critical mass that propelled it toward becoming a world-leading networking telecommunications center.

High Levels of R&D. A key component to continued research and innovation is the amount of investment poured into R&D efforts. Data from 1991 through 1999 shows that RTP has consistently received more than six to seven times the national average of federal expenditures for university R&D.

Skilled Workforce. Graduates from local colleges and universities have provided the region with a steady supply of specially trained scientists and engineers, and this large labor pool helped attract firms to the RTP. A 1998 survey conducted by Michael Porter and his colleagues on their "Clusters of Innovative Study" in the Research Triangle found that the region produced approximately 1 percent of the total U.S. advanced and bachelor's degree holders in the hard sciences and engineering fields. During that same year, the Research Triangle had 0.91 percent of the nation's scientists, engineers, and related technicians, and it had 0.53 percent of the nation's upper-level scientists and engineers.

Outstanding Marketing. In the early 1980s, the region possessed a strong infrastructure asset (the 6,900 acre Research Triangle Park) and three outstanding universities, but remained relatively undiscovered and was not yet on the top of most technology companies' short list of locations. In their market research, RTP managers discovered that most companies and site location firms paid a great deal of attention to the lists of "best locations to do business" that were beginning to become popular in site-location publications (e.g. *Area Development* and *Places Rated Almanac* and general business media (e.g., *Fortune* and *Money*). Their research also revealed that nearly all the rating systems focused only on metropolitan areas with populations exceeding 1million.

At the time, the individual populations of Raleigh, Durham, and Chapel Hill all fell below the 1 million threshold. As a result, Research Triangle did not get included on most of the metropolitan region ranking lists. In response, RTP managers contacted all of the major publications and made their case that Research Triangle business region was actually composed of the populations of Raleigh, Durham, and Chapel Hill, which together exceeded 1 million. Most of the publications agreed with this approach, and the following year (1982) Research Triangle was ranked among the top places to do business in the United States. *Fortune* rated Research Triangle as the top place to do business in 1982. Following this marketing coup, RTP and the surrounding region began to get flooded with calls from new companies considering the area as a site for new business.

Catalytic Government Activities

Government activities have had a tremendous influence on the Research Triangle. The efforts of local and state institutions brought information technology and bioscience research and training facilities to the area. Coupled with the state and federal government-funded R&D programs, these actions have been, and continue to be, critical to the Research Triangle's success.

The range of incentives and services provided primarily by the state government includes the following:

Tax Incentives (North Carolina William S. Lee Quality Jobs and Expansion Act)

- Corporate income tax reduction
- Investment tax credit
- Job creation tax credit
- Worker training tax credit
- Research and development tax credit
- Business property tax credit

Site Selection Services

- Employee relocation assistance
- Community orientation briefing and tour
- Assistance with visitation itineraries
- Liaison with service providers
- Liaison with public officials
- Available site and building inventory
- Statistics and research information

Financing

- Industrial revenue bonds (for manufacturing only)
- Small Business Administration loans
- Community development bock grants (low/moderate-income employment opportunities required)
- Rural economic and community development
- Venture capital funds
- State technology-based equity funds
- Manufacturer's incentive tax formula

Infrastructure Programs

- Utility extensions
- Raleigh-Durham International Airport
- Moor County Commercial Airport
- Industrial access roads

Employee Screening, Placement, and Training

- Free customized pre-employment job training through area community colleges
- Screening and placement services through Employment Security Commission's Job Service
- On-the-job training/youth summer project

Higher Education-Based Support Programs

- MCNC, North Carolina's microelectronics, computing, and networking center
- Industrial Extension Service
- Kenan Institute of Private Enterprises
- Small Business and Technology Development Center

Other Key Players and Initiatives

Research Triangle Foundation of North Carolina (RTF). RTF a nonprofit foundation that operates and governs the Research Triangle Park, has been extremely successful in steering the RTP's growth. RTF was instrumental in attracting prominent R&D entities to the Park. For example, the early attraction of IBM did a great deal to increase the visibility of RTP.

RTF planners also aggressively promoted the RTP's image. They consciously decided to sacrifice the total amount of usable building space to create a high-quality environment for workers. This low-density approach was made possible by the state's inexpensive land costs. In addition, development standards were strictly enforced, with an architectural review board working closely with tenants and developers. The relationship was ideal in that it (1) led to creating a working environment that serves firms and employees in the park well, (2) provided a positive setting for marketing to new tenants, and (3) generated an attractive image in the media that translated into "free" promotion.

Research Triangle Institute (RTI). One of the key "relationship-builders" in RTP has been RTI. Founded in 1958, RTI was RTP's first tenant. RTI serves as a focal point for attracting other world-class research institutions to the area. RTI is a nonprofit research institute that operates separately from its three "parent" universities, but maintains close working ties at many levels with those universities. The roles and relationships that yielded success in Research Triangle offer important guidance to those seeking to emulate the formula. Initially, it was the three major universities that crafted the vision and strategy for Research Triangle. They established the Research Triangle Foundation and obtained support from government business. They also created Research Triangle Institute. The capabilities of researchers and scientists of RTI have acted as a magnet for attracting high-tech companies to the park. RTI provided a valuable contribution in helping create a critical mass of R&D activity that made RTP attractive to private-sector companies.

Council for Entrepreneurial Development (CED). The CED was founded in 1984 as an outgrowth of collaboration between the three area universities and the Raleigh, Durham, and Chapel Hill chambers of commerce. Its mission was to stimulate the creation and growth of high-impact companies in the greater Research Triangle area. CED achieves its mission by providing programs and services in four major areas: education, capital formation, mentoring, and communications. Through these efforts, CED provides entrepreneurs with the knowledge and skills that ensure their success while raising awareness of the contribution that entrepreneurial companies make to the region's communities and economy.

A private, nonprofit organization supported by membership dues, program revenues, and contributions, CED is governed by an executive committee and an operating board of directors with input from a larger board of advisors. With more than 5,000 active members representing 1,300 companies, CED is the largest entrepreneurial support organization in the United States. CED provides an interactive forum for entrepreneurs, investors, service professionals, academicians, researchers, and public policy makers who combine their energies to create an environment in which entrepreneurship can flourish. CED helps entrepreneurs in a wide range of industries and at all stages of development—from high-tech-product-based organizations to professional service firms, from one-person start-ups to 1,000-person businesses.

The success and effectiveness of CED's approach to fostering a productive environment for emerging-growth companies has led North Carolina to consider franchising this approach across the entire state.

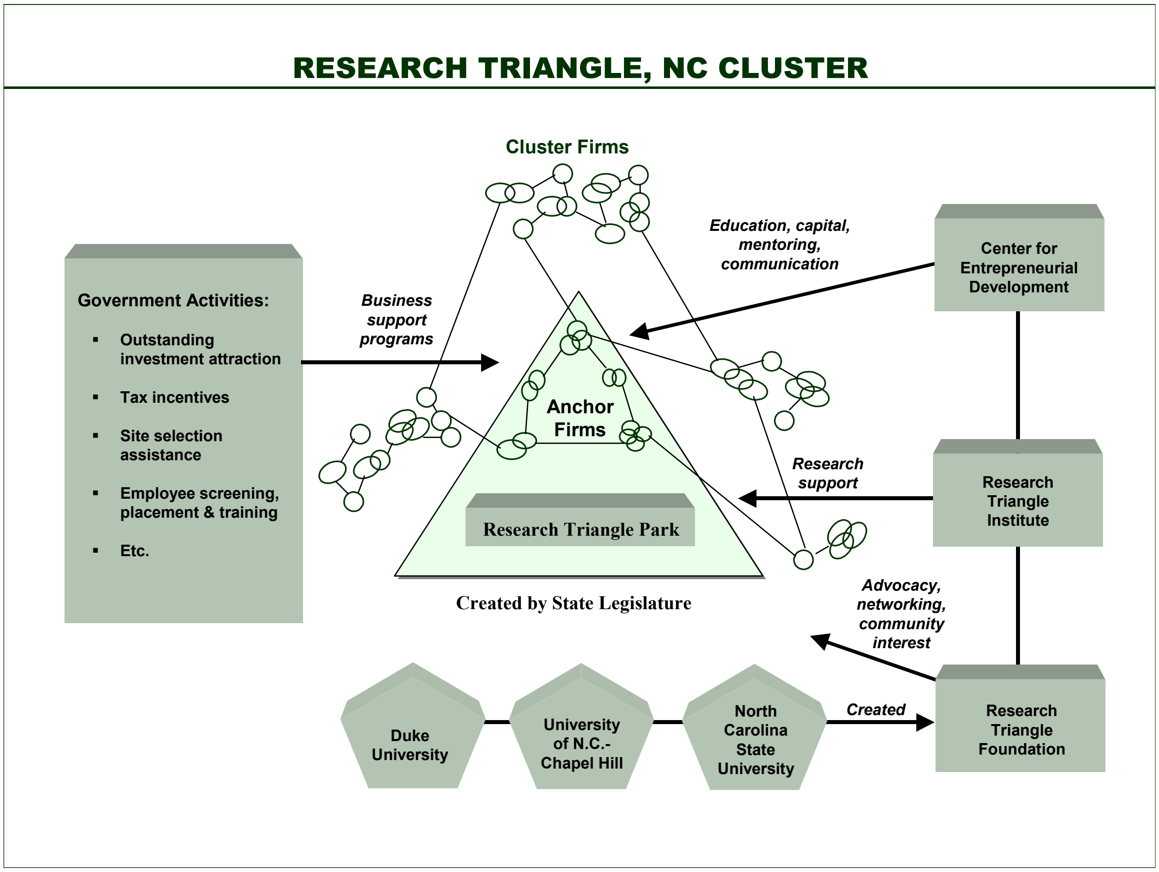
Insights and Lessons Learned

The emergence of Research Triangle as an IT cluster was based on strategic decisions, investments, and marketing efforts that occurred from the late 1950s through the early 1980s. The IT industry's presence is a direct consequence of building a research park, closely linked with the research capabilities of the three regional universities.

- Established by the state legislature to attract high-value economic growth to North Carolina, RTP was built in 1959 around the three universities located in Raleigh, Durham, and Chapel Hill. The initiative has been extremely successful, and today, over 50,000 people work at 136 research and development, office, and high-tech manufacturing facilities in the RTP. Setting up a quasi-independent, private, nonprofit foundation proved a critical step in running RTP.
- Locating RTI as the park's first tenet was a key factor. RTI provided new companies with a very good pool of scientists and engineers to conduct contract research and serve as its focal point.
- RTP was very resourceful in its marketing campaign in the early 1980s, and found a way to "get on the map" with site location firms and companies looking for a high-technology business park location.
- The attraction of well-known technology companies such as IBM and Cisco Systems anchored the park.
- The region is home to a highly-educated talent pool. A close linkage with the research universities has been a major asset in attracting, retaining, and growing knowledge industry firms.
- Research Triangle houses various other internationally competitive clusters that have strong synergies with IT, including biopharmaceuticals, clinical research, and venture capital.

Figure 5.4 depicts this cluster.

Figure 5.4



A number of insights can be drawn from Research Triangle's experience.

Build the research infrastructure to attract knowledge companies. The key turning points in RT's development were (1) the construction of Research Triangle Park, (2) obtaining cooperation of the three regional universities, and (3) marketing of the region as a major metropolitan area.

Use well-known technology companies as anchor firms. Marketing personnel at RTP utilized prominent companies such as such as IBM and Cisco Systems as anchor firms.

Nurture firms with entrepreneurial assistance. The Council for Entrepreneurial Development's mission is to stimulate the creation and growth of high-impact companies in the greater Research Triangle area. CED addresses this mission by providing programs and services in four major areas: education, capital formation, mentoring, and communications. Through these efforts, CED furnishes entrepreneurs with the knowledge and skills that ensure their success.

Phoenix

Cluster Scope and Development Path

The High-technology Industry Cluster in greater Phoenix has been the driving force behind the region's dramatic economic growth. The High-technology Industry Cluster resulted from direct intervention by various public and private organizations that directed a course of economic action in response to Arizona's real estate collapse in 1988.

The cooperative efforts between the Arizona Department of Commerce, Arizona Economic Council, greater Phoenix Economic Council, and Greater Tucson Economic Council led to a blueprint to diversify Arizona's faltering economy. The blueprint, Arizona Strategic Plan for Economic Development (ASPED), was completed in 1990[19] and paved the way for adopting a cluster-based strategy aimed at attracting and sustaining Arizona's industries. In 1992, the plan was renamed the Governor's Strategic Partnership for Economic Development (GSPED).

A cornerstone of the recent economic development experience in Arizona has been the highly successful cluster development program. The cluster programs have utilized public-private partnerships to implement action plans in industry clusters. The industry cluster groups in the GSPED include:

- High-technology
- Bioindustry
- Environmental Technology
- Food Fiber and Natural Products
- Minerals and Mining
- Optics; Plastics and Advanced Composite Materials
- Senior Industries Development
- Software
- Tourism
- Transportation and Distribution

High-technology activities occupy an important niche in greater Phoenix, which serves as a hub for producing semiconductors for the aerospace companies and chip manufacturers. The Arizona Department of Commerce has established an Office of High-technology, whose mission is to help existing high-technology companies expand and to work with the National Marketing Division to continue to attract more of these companies to the area. The emergence of the high-technology cluster has been a driving force behind the dramatic economic growth that greater Phoenix has experienced over the last 10 years. High-technology now has the highest annual economic impact of any industry in the state, and accounts for 56 percent of all manufacturing jobs statewide. High-tech industries generate nearly $33 billion a year in economic activity, including $14 billion in direct activity. In 1997, the American Electronics Association ranked Arizona third in

[19] Consultants from SRI International helped develop the plan.

the nation in semiconductor manufacturing jobs and 18th for the overall number of high-tech jobs.

Arizona's high-technology cluster is divided into two subgroups: aerospace and electronics. The specialized aerospace component includes research and development, products and systems for commercial aeronautics, space and military markets, and materials and components suppliers. Specific industries in the aerospace cluster are:

- Aircraft
- Aircraft engines and parts
- Aircraft equipment
- Guided missiles and space vehicles
- Space propulsion units and parts
- Space vehicle equipment
- Search and navigation equipment
- Aerospace castings
- Aerospace investment castings
- Arming and fusing devices for missiles
- Defense communication and detection systems.

The cluster also encompasses firms that maintain and rehabilitate the nation's commercial aircraft fleet. These activities are anchored by firms such as Honeywell, Boeing, and Allied Signal.

Aerospace Firms in Phoenix

- Honeywell
- Boeing
- Allied Signal
- Raytheon
- Pimalco
- Orbital Sciences Corporation
- IMC Magnetics
- Talley Defense Systems
- Universal Propulsion
- Simula, Inc.

The other component is electronics, which generates products and systems for computer industries, semiconductors, electronic equipment, telecommunications, and related professional services. Examples of industries in this cluster include:

- Computers
- Computer storage devices
- Computer peripheral equipment
- Electron tubes
- Printed circuit boards

- Semiconductors
- Electronic components
- Telecommunications equipment
- Data processing services
- Computer maintenance and repair services.

The following are examples of large electronics firms with operations in greater Phoenix:

Electronics Firms in Phoenix
• Motorola
• Intel
• Microchip Technology
• Continental Circuits
• AG Communications Systems
• Sumitomo Sitix Corp
• Medtronic Micro-Rel
• ADFlex Solutions
• Litton Electo Optical Systems
• Avnet

Market Magnets and Critical Assets

Since the mid-1970s, greater Phoenix has been a prime example of the process of regional restructuring in America. Continuous improvements of urban renewal and expansion have led greater Phoenix to become a dynamic and growing region. It is now known for its favorable business climate, strong educational system, advanced fiber optics communication networks, and excellent transportation system. The city's proximity to urban centers in California and Texas, as well as fast growing markets in Mexico and Latin America, are important factors for economic development. Greater Phoenix's strong magnets have lured many high-tech companies. These magnets are described below.

Core Companies. Greater Phoenix has amassed a large number of high-technology companies, including a few giants that have established major subsidiaries in the region.

Another large segment of the cluster is data services and information processing. Greater Phoenix has built upon this relatively lower-value segment of the industry with higher-value cluster segments such as telecommunications equipment, electronics, and software development. Overall, the metro area is home to over 25 Fortune 500 companies in the IT sector.

Motorola, Inc.

Motorola was founded in 1928 by Paul V. Galvin as the Galvin Manufacturing Corporation in Chicago, Illinois. In 1947, the company formally changed its name to Motorola, Inc. Around the same time, the company pursued government work and opened a research laboratory in Phoenix to explore solid-state technologies. By 1959, Motorola had become the leader in military, space, and commercial communications as well as consumer electronics. In 1964, Motorola was Arizona's biggest private employer, with a workforce of 8,400 people. Today, Motorola is the region's largest high-tech employer, employing over 20,000 people and specializing in wireless infrastructure systems and high-performance memory technologies.

Honeywell Aerospace Solutions

Founded in 1888, Honeywell has become the leading global provider of integrated avionics, engines, systems, and service solutions for aircraft manufacturers, airlines, business, and general aviation, military and airport operations. Its corporate headquarters is in Morristown, New Jersey, but has business units throughout the continental United States. Its aerospace business unit has a strong presence in Arizona.

Honeywell is Arizona's largest non-governmental employer, with more than 15,000 workers who produce jet engines, avionics, and navigational systems in Phoenix, Tempe, and Tucson. Honeywell's Aerospace Solutions Division is a $10.5 billion company and is currently headquartered in Phoenix. Honeywell Aerospace is the region's major aerospace employer, employing over 7,500 workers.

Educational Institutions. Greater Phoenix is home to a variety of higher educational institutions that produce a steady flow of new workers and provide opportunities for continuing education and customized training. The region is nationally recognized for its higher educational institutions and research centers. Greater Phoenix has 47 colleges and universities with 30 satellite campuses. These include one research institution, six baccalaureate institutions, 11 community colleges, nine business institutions, eight medical institutions, six technology institutions, four vocational institutions, and two art colleges.

Arizona State University (ASU). Arizona State University is the nation's third largest public research university, with more than 50,000 students at its three anchor campuses and numerous extended campus locations. The ASU College of Engineering and Applied Sciences includes Chemical, Biomedical, and Materials Engineering; Mechanical and Aerospace Engineering; and Computer Science and Engineering departments. In addition to the specialized degree programs, ASU also has several research institutions, including the Telecommunications Research Center, the Center for Solid State Electronics

Research, the Materials Research and Science and Engineering Center, and the System Science and Engineering Research Center.

Table 5.5. Selected Core IT Companies in Phoenix

Industry Segment	Company
Computer Hardware	Pitney Bowes Apple Computer Gateway Intel
Software	Neoplanet JDA Software Group Gateway Data Services National Computer Systems Computer Place, Inc. Cycare Business Group Cadence Design Systems
Telecommunications	Qwest Communications AT&T Wireless Verizon Wireless WorldCom Cox Communications Motorola
Data Services and Information Processing	American Express Bank of America Chase BankCard Services Discover Card State Farm Insurance Electronic Data Systems Unisys Computer Sciences

Maricopa Community Colleges. Greater Phoenix provides community college education through the Maricopa Community College District (MCCD). MCCD is the second largest community college system in the nation, serving more than 102,000 full-and part-time students at 10 colleges throughout the metropolitan area during 1999.

The MCCD has been instrumental in providing vocational training to thousands of employees in the greater Phoenix area. MCCD has received national honors for its innovative workforce development programs. Successful programs include the Motorola University Partnership at the Mesa Community College in which the collaboration of Motorola and the community college provides a unique curriculum, faculty internships, and school-to-work programs specifically tailored to the semiconductor industry.

Another key industry program is the Semiconductor Industry Education Partnership (SIEP). The program was created in response to the high demand for advanced technicians for the fast-growing semiconductor industry in greater Phoenix. Through joint collaboration with corporate partners, the program has helped to increase the pipeline of students in the semiconductor technical programs.

DeVry Institute of Technology. DeVry is one of the many private colleges and universities located throughout greater Phoenix. Some sample courses provided by DeVry include electronics technology, computer information systems, and telecommunications management.

Labor Force. The region has seen a major increase in population during the last 15 years. This tremendous growth in population has provided a good supply of labor for new and existing employers, particularly for various high-tech-related firms in the area. A large supply of trained, reliable workers is an important advantage. Arizona historically has been among the top states in the nation in employment growth, with most of that growth occurring in greater Phoenix.

Catalytic Government Activities

State and local governments have played pivotal roles in implementing policies and programs aimed at economic development. The region's real estate collapse set the stage for public/private cooperation. A major public and private partnership was forged to evaluate the state of Arizona's economy in 1988. The efforts of the Arizona Department of Commerce, Arizona Economic Council, greater Phoenix Economic Council, and Greater Tucson Economic Council resulted in a blueprint for economic growth driven by a cluster-based strategy known as the Arizona Strategic Economic Development (ASPED).

Upon completion of the ASPED process in 1992, with assistance from SRI International, the plan was implemented by former Governor Fife Symington. The program was renamed the Governor's Strategic Partnership for Economic Development (GSPED).

GSPED. The basis of GSPED is a cluster-based economic development strategy, which involves targeted marketing to attract and sustain industries that create quality, high-paying jobs and benefit the entire economy. Arizona is nationally recognized as a pioneer in cluster-based economic development. In a recently published book – *Building Economic Communities: How Civic Entrepreneurs Are Transforming America* – authors Doug Henton, John Melville, and Kim Walesh cite Arizona as exemplary of cluster development.

GSPED is administered by the Arizona Department of Commerce on behalf of the public/private partnership representing each of the clusters, which includes high-technology. GSPED continues to be a powerful and successful roadmap guiding Arizona's economic growth.

Government and public-sector forces are changing dramatically. While the state government helps guide Arizona's economic policies, the trend of taking responsibility for a healthy economy has shifted from the federal government to local regions. This is particularly true in the case of greater Phoenix where the local government tries to outperform its neighboring regions in attracting high-technology companies.

Several tax incentives have been put into place for businesses locating in the area. For example:

Accelerated Depreciation. In addition to the exemption, the state has created an aggressive accelerated depreciation schedule covering a four-year period in which the rates are 35 percent, 51 percent, 67 percent, and 87 percent for years 1 through 4, respectively.

Increased Research Activities. Corporations may claim a credit for qualified expenses associated with research conducted in Arizona, including research undertaken at a state university and funded by the company. For tax years beginning in 2002, the tax credit cap is $2.5 million. If the allowable expenses under the federal regular credit computation method do not exceed that figure, the allowable credit is 20 percent of this amount. If the allowable expenses under the federal regular credit computation method do exceed $2.5 million, the allowable credit amount is $500,000 plus 11 percent of the amount of expenses over $2.5 million, subject to certain limitations. The taxpayer may carry forward any unused credit over the next 15 consecutive taxable years.

Foreign Trade Zones. Foreign trade zones provide economic incentives to companies doing business in international markets. This type of zone allows businesses to store, repackage, display, and assemble goods duty-free and without any customs formalities. In addition, Arizona is the only state that provides an 80 percent reduction in real and personal property taxes for companies that qualify for foreign trade zone designation. There are currently five foreign trade sub-zones in greater Phoenix, although an unlimited number of sub-zones can be established. The existing zones are in Phoenix, Glendale, Chandler, Mesa, and Buckeye.

Sales Tax Incentives and Exemptions. The following sales tax incentives are offered to IT-related companies:

- **Clean rooms.** Clean room installation expenditures and related machinery and equipment purchases are exempt from sales and use taxes.

- **Aircraft, Related Instruments, and Modification Equipment.** Those exempt from sales tax on their purchases of aircraft, instruments, and modification equipment include the holders of a federal certificate of public convenience and necessity, a supplemental air carrier certificate under federal aviation regulations, or a foreign air carrier permit for air transportation. Also included are foreign governments and non-Arizona residents whose use of this purchased equipment will occur outside Arizona.

Other Key Players and Initiatives

The greater Phoenix Economic Council (GPEC) has been an instrumental in much of the region's economic growth. Since its inception in 1989, GPEC has helped more than 260 companies expand or relocate here, creating more than 45,000 jobs.

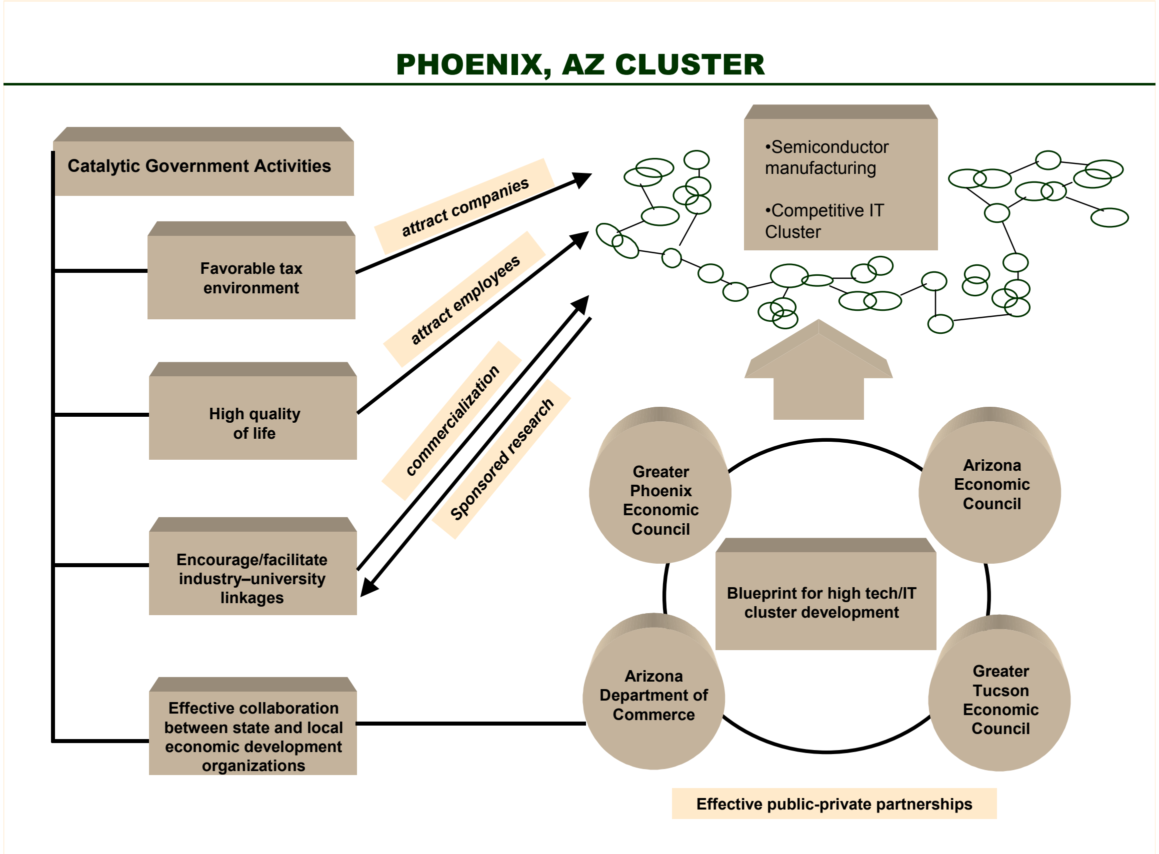
GPEC works to ensure the economic vitality of greater Phoenix. Its economic development strategic plans are have been sharply focused on technology-based industries. Specific initiatives have included public/private partnerships within each cluster working group, encouraging university research with an economic development impact, developing a statewide university-industry technology transfer strategy, and attracting a larger base of growing technology-based companies.

Insights and Lessons Learned

Greater Phoenix has emerged as a competitive IT cluster over the past 10 to 12 years. The IT industry has built upon the lower-value-added information processing segment of the industry and has supplemented it with higher-value segments such as software development, telecommunications equipment and services, and electronic manufacturing. State government and the greater Phoenix Economic Council have created some of the most effective cluster-based public/private partnerships and university-industry partnerships in the country. A technician-level workforce development initiative was important to the retention of the cluster.

Figure 5.5 portrays the Phoenix cluster.

Figure 5.5



A number of lessons can be drawn from greater Phoenix's experience.

Work collaboratively at the state and regional levels. Greater Phoenix benefited from a close working relationships between state and regional economic development professionals. The state Department of Commerce and the greater Phoenix Economic Council worked with the same set of target industries for attraction, growth, and start-up, and they worked to improve the regulatory tax environment for these industries.

Foster public/private partnerships and university-industry partnerships. The cluster development programs in greater Phoenix have been very successful, particularly because of the public/private partnerships and university-industry partnerships forged within the target clusters. Arizona State University and the regional community colleges have custom-designed courses to meet the specific need of local cluster companies.

Build upon existing cluster strengths and expand into related segments. Phoenix's IT industry cluster has evolved substantially over the past 10 years. Initially, the cluster was dominated by the information-processing segment of the industry. Over time, other higher-value segments such as software development, telecommunications equipment and services, and electronic manufacturing developed, partly as a result of their symbiotic relationship with the local information-processing segment. In addition, greater Phoenix also was able to build upon the existing infrastructure and skill sets within the information-processing/call-center segment to attract high-end customer support centers paying attractive wages. One example of this is a Microsoft technical support center located in Phoenix.

Summary

Research activities resided at the center of all five of these U.S. case studies. Silicon Valley in particular demonstrates the value of multiple research nodes—world-class universities, federal laboratories, and corporate research units—to high-technology cluster development. Austin illustrates a mix of development approaches, including large anchor firms and the development of research intermediaries—MCC and Sematech—in a collaborative economic development environment. San Diego and Phoenix used an approach involving thoughtful assessment of assets and implementation of R&D programs to enhance these assets, all wrapped around a technology development plan. Research Triangle also represents a comprehensively planned approach centered on the recruitment of large anchor tenants. While Research Triangle did recruit some large anchor tenants, policymakers have become concerned about weaknesses in the entrepreneurial side of the original strategy.

These case studies refer to many specific R&D programs. While Georgia has implemented versions of many of them, it still may be worthwhile to compare them against the broad portfolio of Georgia programs to determine gaps and identify opportunities for new initiatives.

Also these cases hold much information about incentives that relate to R&D firms. Notwithstanding that research remains at the core of such clusters, to the extent that incentives such as R&D tax credits and accelerated depreciation of research equipment affect company location decisions at the margins, a review of Georgia's incentives relative to those presented in the cases could be useful.

Section 6. Analyzing Research Clusters: An International Perspective

We have seen that research matters in high-technology cluster development generally and Yamacraw-related industries in particular. Because of the critical role that research plays, the project team employed Technology Opportunities Analysis (TOA) to identify research-based clustering. TOA is a method of profiling scientific and technical research to understand research and development patterns. Developed at Georgia Tech, TOA combines bibliometrics with text mining. TOA uses search strategies to identify abstracted records from large electronic databases, and term occurrence patterns to analyze the results. TOA can be used to make comparisons of publication, project, citation, patent, business, and popular press activity on a topic of interest. In addition, analyses can be conducted of research activities and outputs, technological foci, collaboration linkages, and indicators of innovation and commercialization.[20]

Why are research publications worth examining? A body of research finds relationships between publications, patents, and employment (Acs, RitzRoy, and Smith 1995, Zucker and Darby 1995). While such a relationship in the Yamacraw area cannot be completely confirmed because of the time lag in published employment data, past studies predict that there is value in examining publication citations as a determinant of cluster development.

TOA analysis was used to assess the Yamacraw research domain. The analysis searched and retrieved relevant research publication abstracts from EI Compendex (ENGI), a database that covers the research domains of interest. The database contains a good portion of the world's open R&D literature on engineering, electrical engineering, computing, and information science. ENGI is skewed toward English language publication, but abstracts other sources as well. ENGI is very timely in abstracting publications. The database we used was generally up-to-date, although the databases had not fully indexed research articles published in the last three months of 2001.

Global Research Production—Analysis of Publications

Defining the Yamacraw Research Domain

To define the Yamacraw research domain, researchers searched abstracts in the ENGI database of research published between 1986 and 2001. Researchers formed keyword search strings that drew on the technical emphases of Yamacraw's senior researchers. Various groupings of keywords were tried in database searches conducted during November and December 2001.

The resulting TOA was based on the following search term:

((MESFET Devices) OR (Multichip Modules) OR (Flip Chip Devices) OR (Microwave Amplifiers) OR (Single Level Integrated Module)) OR ((Embedded near1 (System OR

[20] For more information on TOA, see http://tpac.gatech.edu. This web site contains further description of TOA, sample analyses, and key papers.

Systems)) OR (System near3 Chip) OR (System near3 Package) OR (Virtual near1 Prototyping)).[21]

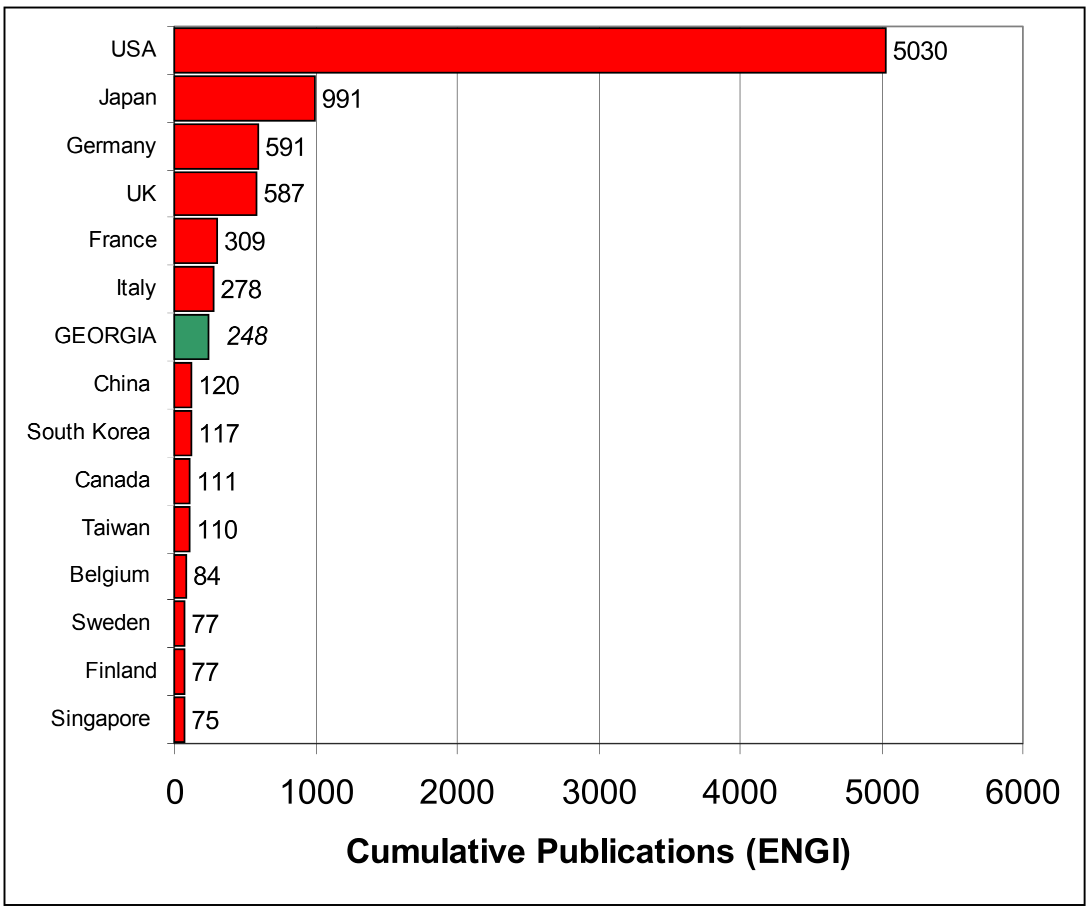
This term yielded 10,337 non-duplicate publications from a database of 14,272 records. The term captured about 75 percent of research publications listed for Yamacraw key faculty (Professors Joy Laskar and Vijay Madisetti).

The same term was used to analyze U.S. patents. The term resulted in 720 non-duplicate patents from a total of 2,498 patent records analyzed.

Yamacraw Domain Research by Country

Figure 6.1 shows the top 15 countries with 75 or more publications in the Yamacraw research domain. The United States is a clear leader, with five times the number of publications as the next closest country, Japan. Germany and the United Kingdom followed with nearly 600 publications each.

Figure 6.1. Yamacraw Research Domain – Total Number of Publications by Country



Source: TOA Analysis of Yamacraw Research Domain (ENGI), 1986-2001.

[21]Metal-Semiconductor Field Effect Transistor (MESFET)

Table 6.1 creates a high-level publishing profile of the top four producing countries. Controlling for size of population, the United States still produces roughly twice the number per thousand population than each of the other three countries.

The TOA analysis also compares research publication outputs by the lead author's type of home institution—academic, corporate, or government research laboratory. Each country has a distinct institutional profile. Yamacraw-related research in the United Kingdom comes mostly out of universities. Germany, to a lesser extent, relies on universities for research in the Yamacraw domain, but corporate and government laboratories are also important. In terms of share of output, Germany has the largest presence of government laboratories of the four leading countries. In the United States, corporate and university publications are equally prominent, with corporate publications being slightly more important. Japanese publications are dominated by corporate research. There are more than three corporate publications in Japan for every university- or government-authored publication. In interpreting these findings, we recognize that corporate R&D is less likely to result in publication than either academic or governmental R&D. Some companies have policies discouraging publication. Incentives for scientists and engineers to publish are less pronounced in industry than in academia. Therefore, these publication output figures probably understate corporate research activity.

Table 6.1. Output and Institutional Research Profile of Four Leading Yamacraw-Research-Producing Countries

Elements of Publication Production	**United Kingdom**	**Germany**	**United States**	**Japan**
Total publications	587	591	5,031	991
Publications per 1,000 population	0.010	0.007	0.018	0.008
Share of publications				
- Universities	**70.0%**	**46.4%**	42.4%	15.9%
- Government labs, research societies	5.1%	27.4%	5.9%	6.2%
- Corporations	24.9%	26.2%	**51.8%**	**77.9%**
Corporate to UGR publication ratio	0.3	0.4	1.07	3.5

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Analysis of Elements and Policies in Benchmark Clusters

This analysis takes a closer look at the three largest countries outside the United States in the Yamacraw research domain: Japan, Germany, and the United Kingdom. Each profile gives an overview of the research clusters throughout these countries. It then focuses on one of these clusters—Kanagawa, Japan; Bavaria, Germany; and Alba, Scotland—identifying corporate, research, and other organizational elements. Kanagawa and Bavaria have a notable number of publications, while Alba was selected because its origins are similar to those of Yamacraw. While not all of these case studies have been proven successful, they illustrate strategic approaches that could offer insights into the development of Yamacraw-like clusters across the globe.

Research Clusters in Japan: Focus on Kanagawa

Eight regions of Japan do sizable research in the Yamacraw domain. Kanagawa is the standout in publication production, accounting for more than 40 percent of Japan's total publishing output in the Yamacraw research domain. Tokyo ranks second, with less than half of the publication volumes of Kanagawa authors. (See Table 6.2.)

Despite the fact that Japan as a whole is dominated by corporate research, there is wide variability among the prefectures. Some prefectures—Kanagawa, Hyogo, and Shiga—have very high corporate-to-university/government-publication ratios. Tokyo and Osaka, on the other hand, tend to be dominated more by university/government laboratory research.

Table 6.2. Publication Output by Regional Cluster in Japan Shows That Kanagawa Is the Leading Region

Regional Cluster (Prefecture)	Publication Output	Corporate to University/ Government publication ratio
Kanagawa	417	19.9
Tokyo	181	2.3
Osaka	81	2.5
Ibaraki	59	1.6
Hyogo	49	23.5
Saitama	32	0.9
Shiga	31	14.5
Fukuoka	20	0.1

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

This profile focuses on Kanagawa and what makes it one of the leading industrial research producers in the Yamacraw domain. Kanagawa prefecture lies about 30 to 45 minutes from Tokyo, and many of its residents work and socialize there. The largest cities in the region are Yokohama and Kawasaki. Kanagawa has traditionally been viewed as an industrial machinery hub, with manufacturing employment running at about 760,000 workers. Ninety-eight percent of the manufacturers in Kanagawa are small and medium-sized enterprises. The prefecture is home to 17 research institutes, and nearly 1,000 people are engaged in R&D at these institutes as well as private company research labs, research centers, and university facilities.

Kanagawa owes much of its research strength to the region's critical mass of large corporate research institutes, as is reflected in the publication output in Table 6.3. The region's post-World War II economy developed around large Tokyo-headquartered factories that located their production facilities in the more populous coastal cities. Eventually, these firms decentralized their manufacturing functions to inland cities in the Kanagawa region. As road and communications networks improved, low-weight products did not need a coastal location. Also, automation of formerly high-labor-intensive functions reduced the need for an urban labor pool, land prices rose, and new construction of labor factories was prohibited in Yokohama and Kawasaki. The Yokohama-Kawasaki area declined as a result of this industrial restructuring. (Castells and Hall 1994)

Table 6.3 Large Corporations Are the Leading Producers of Yamacraw-related Research in Kanagawa

Organization	Research Output
NTT	136
Toshiba Corp.	81
NEC	71
Fujitsu	41
Mitsubishi Electric Corp.	31

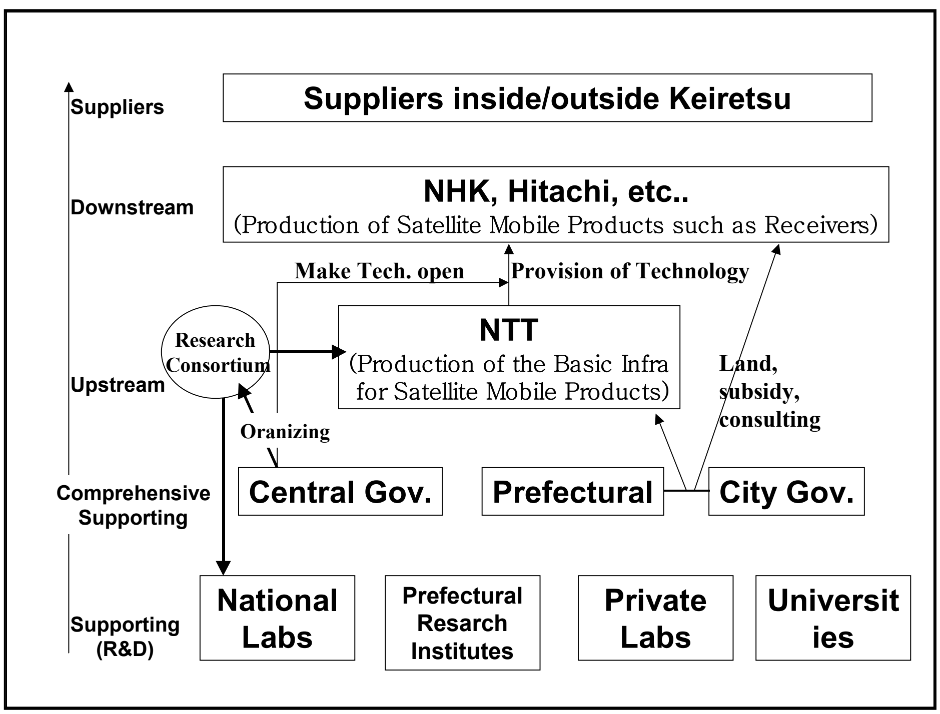
Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

In 1986, the region was approved for a research core project known as the Kanagawa Science Park (KSP). The concept, developed by the Ministry of Economy, Trade and Industry (METI, formerly MITI), involved building a cluster of four facilities: an open R&D facility, an education/training facility, a technological information exchange facility, and an incubator. The objective of the core project concept was to promote regional technology development.

KSP opened in 1989 under the management of a semi-public corporation, KSP, Inc. Initial capitalization of KSP, Inc. was $45 million, one-third of which came from the government and two-thirds from private-sector insurance company investment. The construction of the park cost $650 million. KSP has three main facilities. Innovation Center A is designed for start-ups, which pay below market rates, with the remainder of the building leased to public institutions, foundations, and prototype design and testing laboratories. Innovation Center B is a 10-story building for conventions, meetings, and training. The R&D Business Park Building is a multi-tenant facility for private research units. More than 30 large research companies rent space in KSP. Many are big corporations (e.g., Fujitsu, NEC, Mitsubishi), some are joint ventures (e.g., Fuji Xerox, Nippon Otis), and others are foreign companies (e.g., Johnson Plymer, Xanagen). Start-up firms account for nearly 40 tenants of KSP. These figures are down from KSP's peak occupancy during Japan's bubble economy (1986-1991), and vacant research space exists. (Shapira 1995)

Following the KSP model, the Yokosuka Research Park (YRP) opened in 1997, as part of the Telecom Research Park Plan of the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT). The park is targeted to mobile communications (next-generation cellular phone, stratosphere wireless relay system, joint development of mobile multimedia applications, high-level highway traffic system) technologies. There are more than 40 tenants, including large corporations (e.g., NTT Software, Oki Electric Industry, Hitachi Cable/Metals/Chemical, NTT DoCoMo R&D Center, YRP Laboratory of Matsushita Communication Industrial Company), public research laboratories (e.g., the MPHPT's Communications Research Laboratory), foreign companies and joint ventures (e.g., Nippon Ericsson, Nippon Motorola, NOKIA, Philips Japan), and start-ups. Figure 6.2 illustrates how the YRP cluster works: (1) MPHPT provides funding, along with local subsidies, for a research park and consortium; (2) NTT engages in basic infrastructure experiments for mobile communications; (3) large corporate R&D units use the infrastructure to test applications (e.g., NHK's 2 GHz direct broadcast satellite (DBS) receivers for public transportation and personal automobiles; Hitachi's high-speed optical receivers); and (4) the *keiretsu*'s tight supplier and customer relationships diffuses technologies into the Kanagawa region.

Figure 6.2 Large Corporate IT Cluster



Research publications and direct observation indicate that Kanagawa is a leading center for Yamacraw-related research in Japan. Although the government and private sector made huge investments in research parks and some of the corporate tenants have not done well lately, on the whole Kanagawa has built up a critical mass of corporate research.

The KSP model differs from Yamacraw in a couple of ways. First, universities are not attached to KSP. Japanese universities typically do not play a strong role in technology transfer, although KSP has a few prefectural foundations with research facilities in the park that provide space for professors to do applied work. Second, the parks reflect a large corporate model, despite the presence of start-up firms at KSP and YRP (many of which are joint ventures of large corporations). The prefectural and city governments have been trying to develop a small-firm superstructure around KSP. For example, the Yokohama Venture Manager Program dispatches managers from large corporations to act as mentors to start-up firms. However, venture development is difficult in Japan because of the country's risk-adverse business climate.

Research Clusters Germany: Focus on Bavaria

Unlike Japan, Germany is not led by one high-producing region. Roughly 100 articles on Yamacraw-related research topics have come out of four *länders*—Bavaria, Baden-Württemberg, North Rhine Westfalia, and Berlin. Additional centers of research are Niedersachsen, Hessen, and Sachsen. With the exception of Baravia and Baden-Würtemberg, these clusters tend to be dominated by university research. (See Table 6.4.)

Table 6.4. Four Regions in Germany Produced More Than 100 Publications in the Yamacraw Research Domain

Regional cluster (Länder)	Publication output	Corporate-to-university-output ratio	Main cities in Region
Bavaria	123	1.5	Munich
Baden-Württemberg	103	0.9	Stuttgart, Ulm, Karlsruhe
North Rhine Westfalia	103	0.2	Aachen, Düsseldorf and Köln
Berlin	102	0.1	
Niedersachsen	45	0.1	Hannover, Braunschweig
Hessen	42	0.1	Darmstadt
Sachsen	22	0.2	Dresden

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Innovative corporations, strong engineering and science universities, good educational systems for semi-skilled workers, and extensive use of modern manufacturing processes characterize Germany's R&D strengths. There are 335 public universities, including 222 technical colleges. Germany also has several well-known applied research institutes. The Max Planck Society and institutes support interdisciplinary studies in chemistry, biotechnology, pharmacology, medical technology, solid-state physics, and the manufacture of new materials as well as humanities and social sciences. The Fraunhofer Society has 56 institutes with 11,000 scientists and engineers and other employees who conduct applied technical research. The Helmholtz Association has 16 large institutes that conduct basic research and commercialization in key technology areas. There are also 82 Blue List institutes. These four applied research institutes are largely federally funded, with some moneys coming from state government, member donations (in the case of the Max Planck institutes), and contract research (the main source of funds for the Fraunhofer institutes).

This profile focuses on Bavaria, which is the leading producer of Yamacraw-related publications. Located in southeastern Germany, Bavaria has a total population of more than 12 million. Munich is the capital of the region and the largest city. Bavaria's per capita income is the highest of any of the *länders*, deutch mark (DM) 53,000 ($28,191) in 1998. In 2000, 25 percent of all patent applications were filed in Bavaria, which is two times more than other areas on a per capita basis. One reason for Bavaria's position in R&D is the considerable investment made in the region by federal and state governments. The German federal government made a concerted effort to invest in R&D in the southern part of the country, funneling DM 3.1 billion into the region in 1993, and 5.3 billion in 1996. The state government provided a DM 1.88 billion match in 1993 and today spends nearly 15 percent on R&D. There are 11 universities and 15 technical colleges in Bavaria as well as two public research laboratories.

Table 6.5 indicates that Siemens and the Technical University of Munich (TUM) are the leading sources of research publications in the Yamacraw domain. TUM was one of the first higher educational institutions to combine all engineering disciplines independently of the standard university curriculum. TUM offers such natural science and engineering specialties as vehicle industry, telecommunications, neutron research, food technology, and software engineering. TUM has 440 professors and 20,000 students, most of whom come from Germany. Many TUM students work on industry-supported projects as diploma and doctoral candidates.

Table 6.5. Siemens and the Technology University of Munich Are the Leading Producers of Yamacraw-related Research Publications

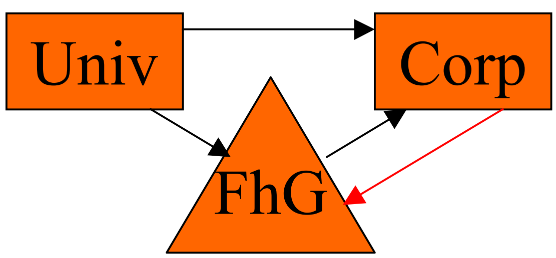
Organization	Publication Output
Siemens AG, Muenchen, Ger	43
Technische Universitaet Muenchen, Muenchen, Ger	28
Infineon Technologies AG, Munich, Ger	6
Univ of Erlangen-Nuremberg, Erlangen, Ger	5
DELO Industrieklebstoffe GmbH & Co KG, Landsberg am Lech, Ger	4
Siemens AG, Erlangen, Ger	4
Deutsches Zentrum fuer Luft- und Raumfahrt, Wessling, Ger	3
Motorola GmbH, Munich, Ger	3
Fraunhofer Inst for Integrated Circuits, Erlangen, Ger	2
MBB Space Communications and Propulsion Systems Div, Ger	2
Technische Universitaet Muenchen, Garching, Ger	2

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Automotive firms traditionally dominated Bavaria's industrial base. BMW and Audi are headquartered in Bavaria, and more than 13 percent of Bavaria's employees work directly in the automotive sector. This base of automobile-related technology helped Bavaria leverage its advanced manufacturing capabilities to develop its information technology sector. The move of Siemens to Bavaria is an example. Following the post-World War II collapse of Berlin's electrotechnical industry, Siemens moved its headquarters to Munich to take advantage of the area's tradition of crafts-based precision engineering and university system (among other factors). Siemens currently leads Germany and Europe in number of patent applications (7,500 reported in 1999). It also has invested heavily and increasingly in R&D and new production processes in its Bavarian locations, including a research center in München-Perlach, a new plant for the Medical Engineering Group in Erlangen, as well as facilities in Regensburg in chip production and automotive products. Suppliers and partners have located facilities in Bavaria to be near Siemens. The information technology and knowledge infrastructure that supports Siemens also attracted many German Internet companies. Bavaria now accounts for half of all German information technology sales, according to the Bavaria state government, and is known as the Bavarian Silicon Valley (Steinberg 2000, Wired 2000).

The most distinctive feature of the Bavarian information technology cluster is the role of intermediary institutions. Siemens and TUM and other research universities do have some direct relationships through internships, lecturing, and some research activities. However, German corporations and universities often use public research institutes as intermediaries, as reflected in Figure 6.3. These intermediaries allow professors and students to work away from the university on more applied problems.

Figure 6.3 The Bavarian Technology Cluster



There are 11 Max Planck institutes and eight Fraunhofer centers in Bavaria. Table 6.6 lists those that do applied research in the Yamacraw domain. In addition to the research centers, the Fraunhofer Patent Center for German Research (PST) in Munich promotes, captures, and markets intellectual property. ·One of PST's projects, the Bayern Patent, is design to offer licensing services, including contacting and advising the universities, technological assessment and evaluation, marketing licenses, and drafting agreements with industrial companies. Current and planned investment of DM 7 million from the state government during 2000-2003 supports this project.

Another intermediary organization is the Association of Bavarian Research Cooperations. Established in 1993 in Munich, the association is designed to promote the concept of scientific research in the community, facilitate inter-university research activities, provide a platform for discussion of common interests, and improve information exchange. Association activities include collaborative industry-university research, a database catalog of research projects, and promotion of targeted work in high-performance computing, software engineering, biomaterials, and medical fields. More than 100 large corporations and small and medium-sized enterprises are members of the association. Funds from state government, federal government (ministry of education, science, research and technology), private organizations, and European Union (EU) support the association.

Table 6.6 Fraunhofer Regional Centers in Bavaria

Name (Location)		Research Field	Website
Integrated circuits and device technology development (Erlangen; Nurnberg)		Telecommunications, electronic quality-assurance systems, X-ray technology, ASICs, image sensor systems, transport logistics, video and audio encoding, circuit and system design	www.iis.fhg.de
Silicate Research (Freising)		Development of non-metallic inorganic materials, organic/inorganic hybrid polymers, coating and laminating technology, composites, analysis.	www.isc.fhg.de
Process Engineering and Packaging (Freising)		Development, optimization, and quality assurance for packaging and sensitive packaged goods, disposal, recycling, process and product optimization, processing machinery and engineering.	www.ivv.fhg.de
Mu-nich	Communication Systems	Transmission systems for modern broadband network structures in the local access area and in-house networks, communications protocols, system components and terminals, system and service integration in voice and data communication, development of demonstration systems and prototypes, demonstration of results in the context of demonstration centers and pilot projects, services related to communications and information technology	www.esk.fraunhofer.de
	Microelectronic Circuits and Systems	Planning, design, prototype production, and testing of micro-electronic circuits and systems. Multistandard and multimedia capable transceiver ICs; wireless Internet; single-chip modems for Bluetooth; Hiperlan/2 and Firewire on air; GSM/UMTS solutions; mobile communication of the future "beyond 3G".	www.esk.fraunhofer.de
	Patent Center for German Research	-60 staffs (2002) -Mission 1) Registration and Protection of intellectual property rights resulting from Fraunhofer R&D projects 2) Acquisition and Evaluation of inventions from other institutions. Help to convert their inventions into patent and license through technical consulting and strategic planning. 3) License agreement with companies in order to fully exploit the outcome.	

Despite the many intermediaries for transferring innovations into existing businesses, Germany traditionally has been weaker than the United States in transferring technological innovations to higher-risk startup firms. There is currently more of a movement toward entrepreneurship, however. For example, the Bavarian state government created a DM 15 million seed fund in May 2001 for early-stage ventures. Sixty percent of the fund is targeted to technology ventures such as software, medical technologies, and IT technologies.

Key factors in Bavaria's development include: (1) a tradition of high-tech automobile manufacturing capabilities, (2) extensive R&D investment from federal and state governments, (3) network of universities and technical schools, (4) the location of a large research-intensive corporation (Siemens), and (5) the extensive use of research intermediaries to transfer scientific know-how that often stays inside the university to large and small corporations. At the same time, Bavaria still has not reached the level of U.S. technology venture risk-taking.

Research Clusters in United Kingdom: Central Scotland and Alba

Much of the United Kingdom's research output in Yamacraw fields is being done in London. The United Kingdom's research tends to be university-led. (See Table 6.7.)

Table 6.7. Publication Output by Regional Cluster in the United Kingdom Shows That London Is the Leading Region

Regional cluster	Publication output	Corporate to University/ Government output ratio
London	118	0.2
Yorkshire and Humber	63	0.1
East Midlands	59	0.7
Cambridge/M11 corridor	56	1.3
Southeast England	54	0.7
Northwest England	47	0.1
West Midlands	46	0.7
Central Scotland	37	0.1
Oxford/M4 Corridor	29	0.6
Northern Ireland	22	0.0

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Central Scotland and the Alba Centre

While Central Scotland is not the leading provider of research in the United Kingdom, it is the focus of this profile because its inception resembled that of Yamacraw. Both programs employed electronic design technology firm Cadence to assist in designing their strategies. The Alba Centre is similar to Yamacraw in that it puts universities in a prominent role, even if the Alba model does not have a prominent research institution in the same way that Yamacraw does. Table 6.8 indicates that a small number of publications comes out of Central Scotland's four major research universities.

Table 6.8 Major Universities Are the Leading Producers of Yamacraw-related Research in Central Scotland

Regional cluster	Publication output
Univ of Glasgow, Glasgow, Scotl	10
Heriot-Watt Univ, Edinburgh, Scotl	9
University of Strathclyde, Glasgow	7
University of Edinburgh	5
Motorola, Glasgow, Scotl	1
Napier Univ, Edinburgh, UK	1
Natl Engineering Lab, Glasgow, Scotl	1
Natl Semiconductor (U.K.) Ltd, Greenock, UK	1
Sir William Halcrow & Partners, Scotland Ltd, Scotl	1
Univ of Stirling, Stirling, Engl	1

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

The Alba Centre is an initiative to develop and promote the electronic design industry, with a focus on system level integration (SLI) and system on chip (SOC) technology. The Alba Centre was launched in 1997 by Scottish Enterprise, Scotland's lead economic development agency, in partnership with academia and industry.

The Alba Centre has five main components:

1. Institute for System Level Integration. The Institute for System Level Integration (ISLI) is a private company that manages shared educational resources of four major Scottish universities—Edinburgh, Glasgow, Heriot-Watt, and Strathclyde. ISLI offers an engineering doctorate and master's degrees (in class and via the Internet), and certificates in system-level integration and a professional develop program in test engineering. By ISLI's second year (2001), a total of 14 doctoral students, 24 full-time master's students, and 47 part-time masters students had been or were being educated under ISLI. Each doctoral student conducts industrially sponsored research. Sponsors such as Cadence and Motorola provide tools, methodologies, and designs.
2. Virtual Component Exchange. The Virtual Component Exchange (VCX) was created to target the market for third-party semiconductor intellectual property (SIP). VCX offers a protected Web-based trading floor for buyers and sellers of SIP and virtual components. VCX enables companies to search for a venture capital firm, evaluate confidential data, and negotiate a license agreement as well as standard term sheets and license agreements for deal negotiations. By March 2001, 50 members joined the VCX.
3. The Alba Campus. The Alba Campus is a 96-acre technology complex located in Livingston, between Edinburgh and Glascow. The park aims to create a nucleus of electronic design industries—design services, intellectual property (IP) providers, systems houses, electronics design automation (EDA) companies, vertically integrated firms, fabless design firms, foundries, and embedded software companies. It is operated by a public-private partnership. Current and planned investment in the

park is around £40 million. The park will offer flexible incubator space for fast start-up ventures, multi-tenant luxury office buildings, and single-occupant facilities. Tenants include Epson, Sagantech, Simutech, Test Advantage, Virtio, and Verilab.

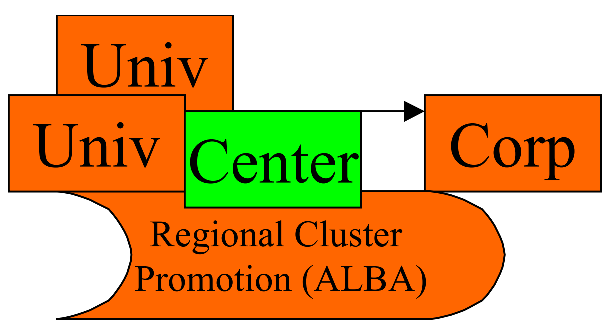
4. Centres of Excellence. A concentrated research capability in test engineering and prototype characterization has been established at the Microelectronics Test Centre. The Centre entered into a partnership with Test Advantage, and offers an educational component through ISLI.

The Alba Centre also offers corporate memberships through the Alba Associates Programme and is planning to set up a consultancy service to assist embedded software companies. Parallel to Alba, there is a nationwide Department of Trade and Industry (DTI) initiative to assist electronics design companies (e.g., on issues such as time-to-market, cost reduction). The initiative follows an extension model, employing eight support centers staffed with experienced electrical engineers and equipped with design tools.

Alba is still in its early stages, so its success is difficult to evaluate. At its peak, the semiconductor and electronics sectors in central Scotland area employed more than 40,000, with another 30,000 in ancillary industries. The economic downturn in 2001 negatively impacted the area. More than 10,000 semiconductor- and electronics-related jobs were lost from layoffs and from closures of an NEC silicon chip factory, a Motorola mobile phone assembly plant, and a Texas Instrument design center. A Hyundai chip assembly plant, which was to be the largest single foreign direct investment project in history, never opened.

As Figure 6.4 indicates, the Alba cluster leverages universities to promote an electronics design cluster by attracting large corporations. Alba is similar to Yamacraw in that universities are the focal point of the initiative. However, Alba offers more services targeted to existing electronics design firms, with the VXC being one example. And although Alba has a venture component, it does not offer the degree of support that Yamacraw does for entrepreneurial activities.

Figure 6.4. The Alba Regional Cluster Model



Profile of the U.S. Yamacraw Domain

TOA can also be used to assess research activity in the United States. This section examines research activity by institution. It then groups institutions into metropolitan areas and examines their composition of university, corporate, and government research. Georgia/Atlanta is compared with other Yamacraw domain centers, and implications for filling in the Yamacraw cluster are drawn.

Table 6.9 shows that the top publishing organizations ranked in descending order by number of publications. Because there is a break between the 19 most prolific institutions and the next group, and to avoid getting into the lower publication ranges that may be affected by random misspellings or undetected geographic name changes, this table stops at the top 19.

Universities account for 13 of the top 19 publishing institutions. Five are corporations and one is a government laboratory. Across all types of institutions, Georgia Tech is the leading producer of publications in the Yamacraw research domain. Georgia Tech produces more than twice the number of publications of the next highest ranking research university—the University of Maryland.

Table 6.9. Georgia Tech Leads All U.S. Institutions in Number of Publications in the Yamacraw Research Domain

Rank	Publications	Affiliation	Type*
1	227	Georgia Inst of Technology, Atlanta, GA	U
2	90	Univ of Maryland, College Park, MD	U
3	72	Univ of California, Los Angeles, CA	U
4	64	TRW, Electronics, Redondo Beach, CA	C
5	63	Univ of Colorado, Boulder, CO	U
5	63	Texas Instruments Inc, Dallas, TX	C
7	56	Motorola Inc, Tempe, AZ	C
8	53	Univ of Illinois at Urbana-Champaign, Urbana, IL	U
9	50	Univ of California, Santa Barbara, CA	U
10	49	IBM Research, Yorktown Heights, NY	C
11	47	Naval Research Lab, Washington, DC	G
12	46	Univ of Texas at Austin, Austin, TX	U
13	45	Univ of California, Berkeley, CA	U
14	44	Cornell Univ, Ithaca, NY	U
15	43	AT&T Bell Lab, Murray Hill, NJ	C
16	42	Univ of Michigan, Ann Arbor, MI	U
17	41	Massachusetts Inst of Technology, Cambridge, MA	U
17	41	Stanford Univ, Stanford, CA	U
19	40	Princeton Univ, Princeton, NJ	U

*u=university, c=corporation

Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Table 6.10 shows the 10 leading states in publication output. More than seven of every 10 publications in the Yamacraw research domain come from organizations in these states.

California is the leading state with 1,268 publications, or more than three times the output of the next closest state. Among the top five states, corporations are responsible for the great majority of Yamacraw research publications. In contrast, Georgia is significantly low in publication generated by corporations, with more than 90 percent of its publications coming from Georgia Tech.

Table 6.10. California Leads All States in Yamacraw Research Publications, With Georgia Ranking Sixth.

State	Corp	Gov	Univ	Total	% Corp	% of US	Cumulative
California	822	25	421	**1268**	65%	25%	25%
New York	237	6	137	**380**	62%	8%	33%
Texas	255	4	91	**350**	73%	7%	40%
Massachusetts	224	1	107	**332**	67%	7%	46%
New Jersey	236	11	50	**297**	79%	6%	52%
Georgia	18	1	229	**248**	7%	5%	57%
Maryland	55	34	122	**211**	26%	4%	61%
Arizona	128	1	53	**182**	70%	4%	65%
Illinois	59	11	79	**149**	40%	3%	68%
Pennsylvania	40	0	107	**147**	27%	3%	71%

Note: Top 10 states - accounting for 71% of all U.S. research production in Yamacraw Research Domain.
Source: TOA Analysis of Yamacraw Research Domain, 1986-2001.

Traditionally, one benefit of corporate research is that it is more apt to impact the economy than is research by universities or government laboratories. We examine this notion in Table 6.12 by comparing the number of jobs created in the 1992-1997 time frame in the industries we determined in Section 4 to be Yamacraw-related industries.[22] to the numbers of publications by metropolitan area. We found general support for this notion. With the exception of the Washington D.C. area, cities with high percentages of corporate publications ranked higher in jobs created in Yamacraw –related industries. Atlanta ranks fourth in number of Yamacraw-related publications and ninth in employment in Yamacraw-related industries. Simple bivariate correlations of the number of employees in Yamacraw-related industries in the 1992-1997 time period, and the number of corporate and university publications, indicate that corporate publications are more highly correlated with employment than are university publications. (r=.6) for corporate publications versus r=.4 for university publications.) Regression analysis suggests that for every corporate publication, there were 53 Yamacraw-related jobs in the 1992-1997 timeframe as opposed to less than half that number of jobs for every university publication.

[22]These industries were:
3661 Telephone and Telegraph Apparatus
3663 Radio and Television Broadcasting and Communications Equipment
3674 Semiconductors and Related Devices
3812 Search, Detection, Navigation, Guidance, Aeronautical, and Nautical Systems and Instruments
3825 Instruments for Measuring and Testing of Electricity and Electrical Signals
7371 Computer Programming Services
7373 Computer Integrated Systems Design

Table 6.11. Atlanta Has the Fourth Highest Number of Publications in the Yamacraw Research Domain, Ahead of Boston and Behind San Francisco, Los Angeles, and New York.

Metropolitan Area	Pubs	Pubs/million	% Corp
San Francisco-Oakland-San Jose, CA (CMSA)	579	84.2	80%
Los Angeles-Riverside-Orange County, CA (CMSA)	373	23.3	53%
New York-No. New Jersey-Long Island, NY-NJ-CT-PA (CMSA)	306	15.2	84%
Atlanta, GA (MSA)	242	62.7	6%
Boston-Worcester-Lawrence-Lowell-Brocktn, MA-NH (NECMA)	234	39.7	67%
Washington-Baltimore, DC-MD-VA-WV (CMSA)	222	30.2	14%
Austin-San Marcos, TX (MSA)	172	150.1	73%
Phoenix-Mesa, AZ (MSA)	149	49.4	80%
San Diego, CA (MSA)	93	33.0	51%
Detroit-Ann Arbor-Flint, MI (CMSA)	89	16.3	8%

Source: TOA Analysis of Yamacraw Research Domain (ENGI), 1986-2001.

Table 6.12. Atlanta Ranks Ninth in Number of Yamacraw-related Jobs in the 1992-1997 Time Frame

MSA or CMSA	Yamacraw-related Jobs 1992-97	Jobs Rank	Yamacraw-related Publications	Publications Rank
San Francisco-Oakland-San Jose, CA (CMSA)	30010	1	579	1
Chicago-Gary-Kenosha, IL-IN-WI (CMSA)	25679	2	40	19
Boston-Worcester-Lawrence-Lowell-Brocktn, MA-NH (NECMA)	20772	3	234	5
Washington-Baltimore, DC-MD-VA-WV (CMSA)	20478	4	222	6
Dallas-Fort Worth, TX (CMSA)	17641	5	84	12
Los Angeles-Riverside-Orange County, CA (CMSA)	13670	6	373	2
New York-No. New Jersey-Long Island, NY-NJ-CT-PA (CMSA)	9943	7	306	3
Austin-San Marcos, TX (MSA)	8985	8	172	7
Atlanta, GA (MSA)	7124	9	242	4
Phoenix-Mesa, AZ (MSA)	6377	10	149	8
Seattle-Tacoma-Bremerton, WA (CMSA)	5981	11	35	22
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD (CMSA)	5494	12	21	30
Minneapolis-St. Paul, MN-WI (MSA)	5462	13	49	18
Raleigh-Durham-Chapel Hill, NC (MSA)	5277	14	76	13
Pittsburgh, PA (MSA)	3732	15	40	19
Cleveland-Akron, OH (CMSA)	2267	16	36	21
Houston-Galveston-Brazoria, TX (CMSA)	2210	17	16	34
Syracuse, NY (MSA)	2191	18	17	33
Indianapolis, IN (MSA)	2003	19	6	39
Milwaukee-Racine, WI (CMSA)	1876	20	25	27
Detroit-Ann Arbor-Flint, MI (CMSA)	1723	21	89	10
San Diego, CA (MSA)	-2,011	42	93	9

Source: TOA Analysis of Yamacraw Research Domain (ENGI), 1986-2001.

Summary

This section utilized the TOA text mining technique to examine research clusters in the Yamacraw domain. The analysis showed that the United States is the leading producer of Yamacraw-related output, followed by Japan, Germany, and the United Kingdom. Within the United States, Silicon Valley accounted for 25 percent of research output, which corresponded to a substantial amount of job creation. Atlanta ranked fourth in publication output, but fell to seventh in new job creation.

Three main cluster development approaches were identified from the data: (1) the large corporate research unit model, as illustrated by Kanagawa; (2) the intermediary applied research organization model, as represented by Bavaria (and even more so by Baden-Württemberg); and (3) the university-centered model, that Atlanta and Alba reflect.

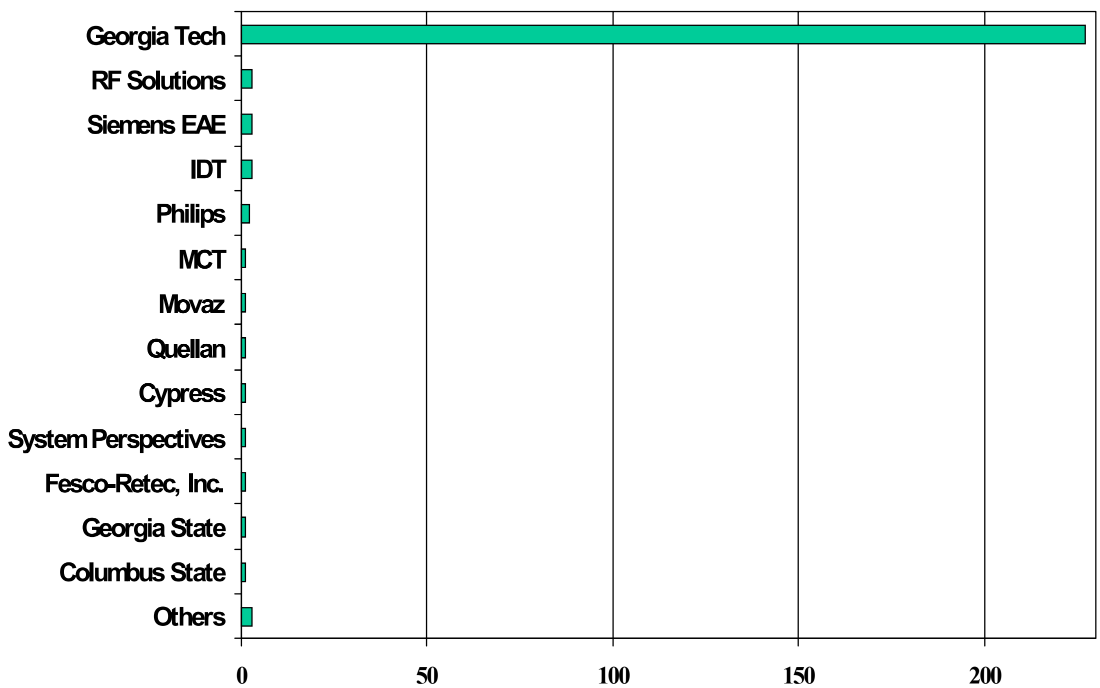
Table 6.13. Typology of Yamacraw Cluster Growth

University Centered	Applied Research	Corporate Cluster
Atlanta		San Francisco-Oakland-San Jose
Detroit		New York-New Jersey
Washington-Baltimore		Los Angeles-Riverside
		Boston-Worcester
		Austin-St. Marcos
		Phoenix-Mesa
		San Diego
Central Scotland (UK)	Baden-Württemberg (DE)	Kanagawa (Japan)
	Bavaria (DE)	

Section 7. Recommendations

Georgia's investments have created a distinctive research presence in the broadband device and embedded systems fields. Table 7.1 shows that Georgia Tech is the focal point of this research cluster, accounting for more than 90 percent of publications in the state. The prevalence of Georgia Tech research should be put into context—the research domain was defined according to senior Georgia Tech researchers' publications. Further, while Georgia Tech produces most of the research in the Yamacraw domain, some corporate research is done in Georgia, much of it by Yamacraw members. There also is the potential for research nodes at other universities, as the TOA found a publication from Georgia State and one from Columbus State. Nevertheless, the Yamacraw cluster in Georgia is essentially oriented around a single university.

Figure 7.1 Georgia Tech Turns Out Most of the Yamacraw Domain Research, with Yamacraw Member Firms Producing Some Research Output.



Yamacraw members include RF Solutions, IDT, MCT, Movaz, Company F, and Cypress.
Source: TOA Analysis of Yamacraw Research Domain (ENGI), 1986-2001.

Now that Georgia has the foundations of a cluster, what should the next steps be fore extending it? Interviews with Yamacraw Design Center members, as well as the GIS analysis, suggested that while there are geographic concentrations of firms in the industry, geographic proximity for suppliers and customers was not a requirement. Therefore, traditional vertical supplier-customer strategies are less likely to build out the Yamacraw cluster.

The recommendations in the section instead will focus on creating a dense, knowledge-based cluster through encouraging corporate and other forms of R&D in Georgia. This section includes recommendations for short- and long-term activities. Short-term strategies involve GDITT using R&D output to identify prospective firms for recruitment. Long-term strategies are explored in four scenarios for further cluster development, with a particular focus on scenarios with heavy corporate R&D and multiple nodes of R&D from federally and industry-funded research institutes. It should be noted that the recommendations here do not constitute an assessment of the current Yamacraw approach. Rather, they are intended to provide possible next steps for the Yamacraw cluster.

Targeting Prospective Companies Doing Corporate Research

Short-term recommendations call for the state to explicitly incorporate a corporate research element into its criteria for targeting prospective Yamacraw members and other inward investment opportunities. There are challenging in identifying corporate research leaders, however. For example, firms may have done research in the Yamacraw domain in the past, but that does not guarantee that they are currently conducting research.

TOA identified firms with R&D activity (that is, research publications and patents) in the Yamacraw domain. (See Tables 7.1 and 7.2.) Three time periods were selected for comparison and analysis: pre-1990, 1990-1996, and 1997-2001. The number of patents and publications in the tables is not just for the company's headquarters location, but for all company locations. One further issue relates to using patents as an indicator of R&D activity. Patents are a somewhat controversial measure of R&D activity. Some technologies hinge on patenting while others do not. Also, the U.S. patent database is slanted toward American companies, although research has shown that foreign companies are active in submitting U.S. patents (Pavitt 1988). Patenting can be an important indicator of a company's having intellectual property worth protecting in the United States.

Several insights can be gleaned by examining changes in corporate R&D activity over time. First, research and patenting activity levels have increased in recent years. This increase suggests that the Yamacraw domain is still in a growth cycle.

Second, we found remarkable consistency among some of the most active corporate research organizations. IBM ranked in the top three publishing corporations and ranked first in number of patents. Motorola likewise ranked among the top five corporations both in patents and publications over the three time periods. Also appearing with some consistency were Texas Instruments and Hewlett-Packard.

A few new companies appeared in the recent time period. Micron, AMD, and LSI rose to be among the top five firms in patenting activity in the 1997-2001 time period. Some smaller companies also had more R&D activity since 1997—Xilinix, Wavetek, and (in the patenting list), Caliper. At the same time, AT&T Bell Labs dropped off patenting and publishing lists in the 1997-2001-time period.

Table 7.1 Top 20 Companies in Number of Publications in the Yamacraw Research Domain

Publishing Organization	-1989	Publishing Organization	1990-1996	Publishing Organization	1997-2001
IBM Corp	28	AT&T Bell Labs	67	NTT	98
AT&T Bell Lab	20	IBM Corp.	65	Motorola, Inc. USA	91
NTT	15	Motorola, Inc.	56	IBM Corp.	80
NEC	15	NTT	53	Lucent Technologies/AT&T Bell Labs	50
Raytheon Microelectronics	14	Texas Instruments	38	NEC	42
GE Electronics Lab	13	GE Electronics Lab	29	Mitsubishi Electric Corp.	33
Texas Instruments	11	TRW, Inc.	27	Toshiba Corp.	32
Motorola Inc, USA	10	Raytheon Microelectronics	26	Texas Instruments	31
Hewlett-Packard Co.	10	Toshiba Corp.	23	Hewlett-Packard Co.	28
Rockwell International	10	Hewlett-Packard Co.	21	Hughes	26
TRW, Inc.	9	Matsushita Electr. Ind. Co., Ltd.	20	Matsushita Electr. Ind. Co., Ltd.	23
Intel Corp.	9	NEC	18	TRW, Inc.	22
Mitsubishi Electric Corp.	8	Hughes	18	Wavetek	16
Toshiba Corp.	7	Intel Corp.	16	Philips Research	16
Hughes	7	Rockwell International	15	Raytheon Microelectronics	15
Fujitsu Lab. Ltd.	6	Mitsubishi Electric Corp.	10	Siemens AG	15
Siemens AG	5	Honeywell, Ltd.	10	Honeywell, Ltd	15
Honeywell, Ltd.	5	Siemens AG	9	Rockwell International	14
Philips Research	4	Xilinx, Inc.	8	Xilinx, Inc	14
		Wavetek	8	Fujitsu Lab Ltd	11
		Fujitsu Lab Ltd.	6	Intel Corporation	10

Source: TOA Analysis of Yamacraw Research Domain (ENGI), 1986-2001.

Table 7.2 Top 20 Companies in Number of Patents in the Yamacraw Research Domain

Patenting Organization	-1989	Patenting Organization	1990-1996	Patenting Organization	1997-2001
IBM, Corp.	27	IBM, Corp.	48	IBM, Corp.	99
Texas Instruments	24	Motorola, Inc.	23	Micron Technology, Inc.	47
Motorola, Inc.	8	NEC	21	Advanced Micro Devices	45
Raytheon Microelectronics	7	Hewlett-Packard Co.	19	LSI Logic Corp.	44
Thomson-CSF Puteaux	5	Hughes	14	Motorola, Inc.	36
AMP, Inc.	4	National Aeronautics & Space Admin.	13	Xilinx, Inc.	34
AT&T Corp.	4	AT&T Corp. /AT&T Bell Labs.	12	NEC	33
General Electric Co.	4	Texas Instruments	11	Xerox Corp.	31
Hewlett-Packard Co.	4	Murata Manufacturing Co., Ltd.	10	Texas Instruments, Inc.	30
Hobart Corp.	4	Sumitomo Electric Industries, Ltd.	10	Lucent Technologies/AT&T Bell Labs	29
NEC	4	Xilinx, Inc.	10	Caliper Technologies Corp.	36
Rockwell International	4	Hitachi, Ltd.	9	Sun Microsystems, Inc.	22
The Coca-Cola Company	4	Microelectronics & Computer Tech. Corp.	9	VLSI Technology, Inc.	21
Trilogy Computer Dev. Ptnrs.	4	Siemens AG	9	Hewlett-Packard, Co.	17
Westinghouse Electric Corp.	4	VLSI Technology, Inc.	9	Hitachi, Ltd.	15
Bell Telephone Labs.	3	Staktek Group L.P.	8	Siemens AG	13
Cornell Research Foundation	3	Dynetics Enineering Corp.	6	U.S. Philips Corp.	12
Harris Corporation	3	Boeing	6	Andritz-Ahlstrom Inc.	11
Honeywell, Ltd.	3	Dallas Semiconductor Corporation	5	Lockheed Martin Energy Sys.	11
Hughes	3	Digital Equipment Corp.	5	Sarnoff Corp.	11

Source: TOA Analysis of Yamacraw Research Domain (U.S. Patents database), 1986-2001.

Although they do not appear in U.S. patenting databases, several international firms have significant strength in the Yamacraw domain. NTT was the leading publishing corporation in the 1997-2001 time period and was consistently among the top five firms in publishing output across all three time periods. Also present among the leading research corporations were NEC, Mitsubishi Electric, Matsushita Electric, Philips, and Siemens.

It is interesting that public organizations do not patent at the rate that private companies do. The highest number of patents from any public organization is 12 patents from NASA in the 1997-2001 time frame. Georgia Tech has only one patent in the Yamacraw domain during this time period. Other public institutions patenting in this domain include Microelectronics Center of North Carolina with five, North Carolina State University with three, and Case Western Reserve with three.

Even though IBM is the leading patenting company in the Yamacraw domain, how important are Yamacraw-related patents to IBM? The firm has the most technology patents of any U.S. company. But is may be easiest to focus on companies for which Yamacraw research is more central to their strategy. One way to examine the importance of Yamacraw patents to a company is to compare them to all of the company's technology patents. Table 7.3 provides this information. For IBM, Yamacraw-related patents compose less than 1 percent of all its technology patents. On the other hand, five companies—Caliper, Rambus, Xilinx, LSI Logic, and Sumitomo Electric—have more than 2 percent of their technology patents in the Yamacraw domain.

Table 7.3. Importance of Yamacraw Domain to All Technology Patents Among the Top 150 U.S. Technology Patenting Companies

Affiliation	Yamacraw Total 1997-2001	Yamacraw Annualized 1997-2001	All Patents Annualized 1996-2000	Yamacraw % All Patents Annual Average
Caliper Technologies Corp	36	7.2	10	72.00%
Rambus	10	2.0	17	11.76%
Xilinx, Inc.	34	6.8	80	8.50%
LSI Logic Corporation	44	8.8	275	3.20%
Sumitomo Electric Industries, Ltd.	10	2.0	72	2.78%
Advanced Micro Devics, Inc.	45	9.0	579	1.55%
Sun Microsystems, Inc.	22	4.4	347	1.27%
Micron Technology, Inc.	47	9.4	766	1.23%
Xerox Corporation	31	6.2	665	0.93%
Texas Instruments	30	6.0	663	0.90%
IBM Corporation	99	19.8	2408	0.82%
Raytheon Company	10	2.0	257	0.78%
Lockheed Martin Energy Systems, Inc.	11	2.2	317	0.69%
Motorola, Inc	36	7.2	1232	0.58%
Lucent Technologies, Inc.	29	5.8	1046	0.55%
Hewlett-Packard Company	17	3.4	729	0.47%
NEC Corporation	33	6.6	1603	0.41%
U.S. Philips Corporation	12	2.4	893	0.27%
Hitachi, Ltd.	15	3.0	1209	0.25%
Siemens Aktiengesesllschaft	13	2.6	1170	0.22%
Andritz-Ahlstrom Inc.	11	2.2	n/a	n/a
Sarnoff Corporation	11	2.2	**	**
VLSI Technology, Inc.	21	4.2	*	*

*Acquired by Philips. ** Acquired by SRI
Source: TOA Analysis of Yamacraw Research Domain (U.S. Patents database), 1997-2001 and Jonietz (2002).

Four Scenarios for Yamacraw Cluster Development

Yamacraw has created the foundations of a distinctive cluster. The next phase of cluster development could see the cluster become denser. Dense research clusters have more nodes of research from various sources—other universities; corporate associations, consortia, and institutes; and federally funded research laboratories. They also have more businesses engaged in commercialization activities. There are four ways that the next phase might be conceptualized:

- Single university with spin-outs.[23] The university is the center of the cluster, responsible for most of the research output. Small firms spin-out from university research. Some small research divisions locate relatively near the university. This is essentially a continuation of the present Yamacraw approach.
- Multiple university and corporate research cluster. Two or more major universities and government laboratories spin out companies. This research cluster attracts large corporate research units, spin-offs from these corporate research units, and additional partners, competitors, customers, and suppliers.
- Large corporate research complex. Multiple large corporate R&D units locate in one or more research park, stimulated by government funding. Some small joint-venture start-ups are collocated.
- Corporate-university-intermediary complex. An intermediary organization attracts large corporations. Research is conducted at the intermediary organization, by university scientists, and by corporate researchers.

Each scenario has opportunities and challenges. Based on information gleaned from the case studies profiled in this report, the TOA, and the author's best judgment, opportunities and challenges associated with each scenario are summarized in Table 7.4.

The single-university with spin-outs scenario has strengths in attracting faculty and developing university research. It is also associated with entrepreneurial start-ups developing from university research. Some out-of-state companies will establish small divisions to observe and take part in the university research. While this scenario can spin-out and attract small facilities, the lack of a large corporate research anchor or mass of private-sector research limits its potential to develop a sizable corporate research base.

The multiple-university-and-government-research-institution approach attracts some large corporate research in addition to its diverse university and government base. Spin-offs from corporate headquarters and research units are prevalent in this scenario. The challenge of this model is to develop additional research organizations while concentrating enough resources to develop a critical mass of expertise in the field.

Large corporate research complexes have strengths in generating corporate R&D. A large corporate research unit can attract other research divisions to collocate facilities, and industrial research synergies can result in new products and corporate joint ventures. On the other hand, if a single large corporation overly dominates the complex, the development of the complex could rise and fall with the success of the company. Lack of involvement of university researchers also can be a problem for these complexes. In addition, some large corporate research complexes have had difficulties generating entrepreneurial activity, although spin-offs of corporate joint ventures have been evident.

[23] We use the Corporation for Enterprise Development's definition, which distinguishes spin-outs (typically coming from university research) from spin-offs (typically coming from corporate technologies). See Innovation Assets, 2001 Development Report Card for the States, Corporation for Enterprise Development, 2001. http://drc.cfed.org/?section=measures&page=innovation.

Table 7.4. Comparison of Cluster Models in the Yamacraw Domain

Cluster Model	Single university with spin-outs	Multiple university and corporate research cluster	Large corporate research complex	Corporate, university, intermediary complex
Cluster description	University is dominant research producer. Small firms spin-out from university research. Small design center divisions locate relatively near the university.	Two or more major universities, government laboratories spin-out companies and attract large corporate research units	Multiple large corporate R&D units locate in a research park. Some small joint venture startups are collocated.	Intermediary organizations encourage university research applied to corporate problems
Example	Georgia	Silicon Valley	Kanagawa	Bavaria, Austin
University research contribution	High	High	Low	Moderate
Private research contribution	Low	Medium to high	High	Medium to high
Spin-out potential	High	High	Low to moderate	Low to moderate
Spin-off potential	Low	High	Moderate	Moderate
Employment	Moderate	High	High	Moderate
Research Output	Publications – High Patents – Low	Publications – High Patents – High	Publications – Moderate Patents – High	Publications – Moderate Patents – High
Ability to attract university faculty	High	High	Low	Moderate to high
Ability to attract other firms	Moderate	High	High	Moderate
Issues for Georgia	Transitioning to corporate research cluster	Lack of multiple research institutions	Difficulty of attracting large corporate anchor in current economic climate	Difficulty of developing an intermediary

A final scenario is a complex anchored by intermediary organizations. These entities can range from industry associations to industry-funded research consortia to private research institutions. Intermediary organizations offer opportunities for academics to work on applied industry problems in an environment separate from their university setting. Corporations may locate research units near these intermediary organizations to facilitate interactions with the research institute. The challenge is to create an intermediary organization with sufficient core funding and stature in the industry to attract private-sector members' interest. Otherwise intermediary organizations risk emphasizing survival, which can hurt the organization's focus as it goes in any direction for which it can get funds.

The latter three scenarios have a common theme. All involve the establishment of an expanded corporate research presence as a recommended possible future step for enhancing the Yamacraw cluster. Implementation of any of these strategies would take time to reach fruition.

Summary of Findings and Recommendations

This report reviewed research studies suggesting that clusters can benefit technology firms by making them more competitive and enabling cost reductions, shared resources, and research interactions with geographically proximate firms. Some studies documented that certain industry clusters have been unable to weather economic downturns. However, it was found that cluster-based strategies with a critical mass of R&D infrastructure, interactions among university researchers and innovative firms, concentration of knowledge workers, and entrepreneurship can stimulate high-technology development.

The study also found that employment in Yamacraw-related industries exhibited spatial clustering around metropolitan areas. Clusters in Yamacraw-related industries did expand and contract depending on economic cycles. In addition, a number of metropolitan areas, including Atlanta, grew from being almost nonexistent in 1986 to a major national cluster by 1997.

Before starting the study, we hypothesized that the best way to develop the Yamacraw cluster would be to develop the vertical supplier-customer chain. However, we found that physical suppliers were not that important to the Yamacraw member companies we interviewed. Likewise, customer proximity was not necessary to all firms. Yamacraw members did say they valued being near other similar firms, research, and knowledge workers.

The importance of research in sustaining and enhancing successful technology clusters was clearly demonstrated in examining Yamacraw-related clusters across the nation and the globe. Georgia should focus on enhancing its highly successful academic research posture by attracting both commercial R&D units and federally funded research institutes. Scenarios for enhancing the state's research activity, which could be pursued individually or simultaneously on several different fronts, include: (1) developing multiple university, government, and corporate research institutes; (2) attracting a large anchor research corporation; and (3) creating or attracting an intermediary organization to link corporate and university researchers. It is recommended that development of additional research nodes be considered a major follow-on activity in the Yamacraw area.

The study also recommends that GDITT use R&D activity as a primary screening tool for attracting prospective companies (particularly their corporate R&D units) to Georgia. Based on a firm's research activity, the state can decide whether and how special research relationships can be developed. Table 7.5 lists firms having significant patenting and/or publication activity since 1995, which can be used as a starting point. This list should be considered preliminary, as it has not been screened for interest in or financial capability for expansion. There are two types of firms in the list:

- Relatively smaller niche firms—Caliper, Zilinx, and Rambus. These firms are compatible with Yamacraw's membership approach, although they may require some special research relationships. For example, Georgia Tech's biomedical engineering capability in combination with Yamacraw could be an interesting package for Caliper's lab-on-a-chip technology.
- The rest of the list consists of larger, more established companies such as Sumitomo and Sun. Research observatory space such as Georgia Tech's landing party service may prove attractive to these types of companies. Atlanta may also be a logical site for international firms considering a U.S. or East Cost research presence.

In addition to this list of research-intensive companies, Yamacraw members furnished names of firm with which they do business—either as partners, customers, or (in some cases) suppliers. (See the Appendix.) While this study did not generally find strong supplier-customer geographic linkages among firms in the Yamacraw sector, there still may be opportunities for attracting division of these firms to Georgia.

The U.S. case studies identified a variety of technology transfer and development programs. Case study cities such as San Diego and Phoenix took stock of their assets, developed a planned strategy, and instituted some long-term programs. While Georgia has implemented versions of many of these programs, it still may be worthwhile to compare them against the broad portfolio of Georgia programs to determine gaps and identify opportunities with regard to creating new initiatives or taking new approaches.

In addition, while research was at the center of the clusters examined in this study, the U.S. case studies contained a long list of economic development incentives that relate to R&D firms. To the extent that incentives such as R&D tax credits and accelerated depreciation of research equipment affect company location decisions at the margins, Georgia should review these incentives relative to what the state currently has available for technology companies.

Publication output is a significant metric to monitor. Georgia's publication output would predict a bright future, but lags in government employment reporting make it difficult to confirm this prediction. It would be useful to return in a few years and determine the extent to which the research output reported in this documents correlates with technology employment.

Table 7.5. List of Prospective Companies Based on Publication and Patent Output and Importance of Yamacraw Patents

Company	Yamacraw Research Score
IBM	100
Caliper	95
Motorola	73
Xilinx	68
Rambus	63
LSI Logic	55
NTT	49
Advanced Micro Devics	49
Texas Instruments	48
NEC	47
Lucent	45
Micron Technology	43
Sumitomo	36
Xerox	36
Sun Microsystems	33
Hewlett Packard Co	31
Raytheon Microelectronics	26
Philips	25
Siemens	23
Lockheed	20
Mitsubishi Electric	20
Toshiba	19
Hitachi	18
Hughes	16
Matsushita Electric	15
TRW	15
Wavetek	12
Honeywell	11
Rockwell	11

Appendix – Partners, Customers, or Suppliers of Yamacraw Member Firms Interviewed

Cisco
Lucent
Sycamore
Nokia
Alcatel
Broadcom
Cadence/Tality
Avant!
Mentor Graphics
Synopsys
Magma Design Automation
Sun
Shipley Electronics/Rohm and Haas Co.
Ballard Power Systems
Dow
Desire Micron
ADC
Peregrine Semiconductor
JDS Uniphase
Intel
Philips
Siemens, Siemens Medical Systems
Avionics
Honeywell
Thomson Detextis
Racal
Eurocopter
Boeing
Kelowna Flightcraft
Thomson-ATM, Alenia (Italy)
Indra (Spain)
Eurocontrol
Raytheon
Lockheed Martin
NavCanada
ITT Gilfillan
Lockheed Martin
Boeing
Northrup Gruman
GE Medical Systems
Toshiba Medical System
Philips Medical Systems
AGFA Medical Division
Acuson
A.L.I.
Kodak
Fuji
Konica
Hitachi Medical Systems
Data General
Fisher Imaging
Marconi
Richardson Electronics
Fujitsu
Swissray
IBM
Meta Solutions
RateIntegration
Output Technology Solutions
Compaq
Macromedia
Oracle
Tax Partners
CCH
Praeos
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Zortec
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