# Building from a Position of Strength: Arizona Advanced Communications and Information Technology Roadmap

March 2004

Prepared by
the Battelle Technology Partnership Practice
as part of the
**Arizona Statewide Economic Study**

ARIZONA DEPARTMENT OF COMMERCE
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March 2004


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This report was prepared for the Arizona Department of Commerce with funding from the Commerce and Economic Development Commission. It will be available on the Internet for an indefinite length of time at http://www.azcommerce.com/Economic/default.asp. Inquiries should be directed to the Office of Economic Information and Research, Arizona Department of Commerce, (602) 771-1100.

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To the Reader:

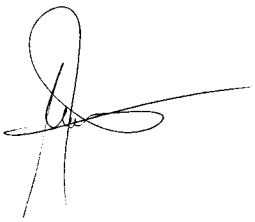
This Roadmap is part of a body of work known as the *Arizona Statewide Economic Study*, a decennial research project undertaken to provide the foundation for development of a 10-year economic strategy for Arizona. The *Arizona Statewide Economic Study* has been overseen by the Commerce and Economic Development Commission, the body responsible by state statute for developing the 10-year strategy.

Jointly commissioned by the Arizona Department of Commerce and the Arizona Board of Regents, the Advanced Communications and Information Technology (ACIT) Roadmap follows an earlier report, *Science and Technology Core Competencies Assessment*, which identified world-class research and development competence in Arizona's university system in the areas of biosciences, advanced communications and information technology, and a broad group of ecological sciences that provide the innovation platform for sustainable systems.

In addition to this Roadmap, companion technology plans resulting from the Core Competencies report include the *Sustainable Systems Prospectus*, another joint effort of the Commerce Department and the Arizona Board of Regents (available at http://www.azcommerce.com/Economic/default.asp); and the Biosciences Roadmap, spearheaded by the Flinn Foundation (www.flinn.org). Collectively, the ACIT and Bioscience roadmaps and Sustainable Systems Prospectus provide the focus and strategies needed to capitalize on Arizona's university R&D strengths in the creation of new products, new markets and high quality jobs.

Finally, we are most grateful to the members of the ACIT Steering Committee, a team of experts from Arizona's universities, the private sector and non-governmental organizations. Their input was instrumental in ensuring this Roadmap focuses on the primary, foundational issues critical to the success of all ACIT companies. Their service has been invaluable and on behalf of Governor Janet Napolitano and the Arizona Board of Regents, I thank and commend them for their dedication.

Sincerely,



Gilbert Jimenez
Director, Arizona Department of Commerce
and
Chairman, Commerce and Economic Development Commission

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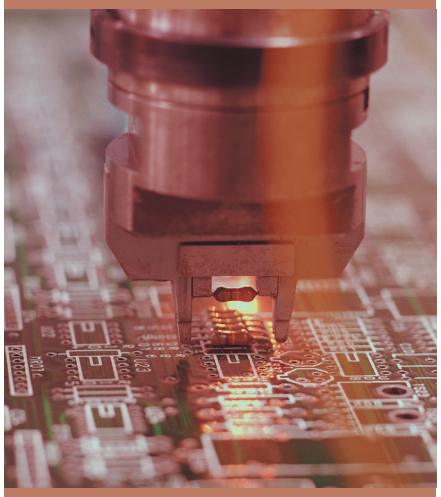
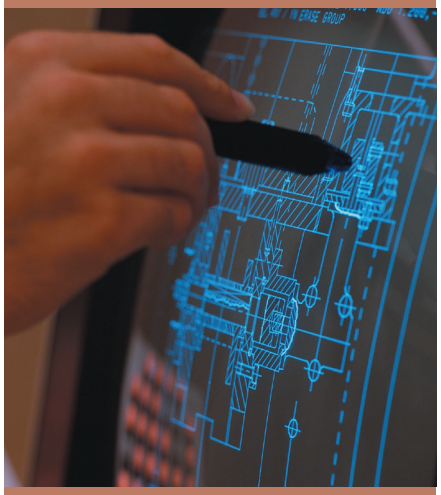
APPENDICES





BUILDING FROM A POSITION OF STRENGTH:

# ARIZONA ADVANCED COMMUNICATIONS AND INFORMATION TECHNOLOGY ROADMAP

PREPARED FOR:
Arizona Commerce and Economic Development Commission, Arizona Department of Commerce, and the Arizona Board of Regents

PREPARED BY:
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Cleveland, Ohio

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# Appendix A
# Data and Methodology

## Occupational Employment Statistics

The Occupational Employment Statistics (OES) program is a semi-annual mail survey conducted by the Bureau of Labor Statistics (BLS) to produce employment estimates for specific occupations across industry sectors and geographic regions. To reduce respondent burden, the collection is on a three-year survey cycle that ensures that establishments employing fewer than 250 workers are surveyed at most once every three years. Within this structure the OES program surveys approximately 200,000 establishments per semi-annual panel, taking three years to fully collect the required sample of 1.2 million establishments. The estimates for occupations in non-farm establishments are based on OES data collected for the reference months of October, November, or December. The OES survey is a federal-state cooperative program between the BLS and State Employment Security Agencies (SESAs). The BLS provides the procedures and technical support, draws the sample, and produces the survey materials, while the SESAs collect the data. SESAs from all 50 states, plus the District of Columbia, Puerto Rico, Guam, and the Virgin Islands, participate in the survey. Occupational employment and wage rate estimates at the national level are produced by BLS using data from the 50 states and the District of Columbia. Employers who respond to states' requests to participate in the OES survey make these estimates possible. Table A-1 details the four advanced communications and information technology (AC-IT) job functions and their related occupations used in this analysis.

**Table A-1: AC-IT Job Functions and Occupations**

| AC-IT Related Occupations | | |
|---|---|---|
| | **Standard Occupational Codes** | |
| **Computer and Information Systems Managers** | | |
| | 11-3021 | Computer and information systems managers |
| **Software and Systems Related Scientists, Engineers, Analysts, and Programmers** | | |
| | 15-1011 | Computer and information scientists, research |
| | 15-1021 | Computer programmers |
| | 15-1031 | Computer software engineers, applications |
| | 15-1032 | Computer software engineers, systems software |
| | 15-1041 | Computer support specialists |
| | 15-1051 | Computer systems analysts |
| | 15-1061 | Database administrators |
| | 15-1071 | Network and computer systems administrators |
| | 15-1081 | Network systems and data communications analysts |
| | 15-2011 | Actuaries |
| | 15-2021 | Mathematicians |
| | 15-2031 | Operations research analysts |
| | 15-2041 | Statisticians |
| | 15-2091 | Mathematical technicians |

**Table A-1: AC-IT Job Functions and Occupations (continued)**

| AC-IT Related Occupations | | |
|---|---|---|
| **Computer Hardware and Electronics Engineers and Technicians** | | |
| | 17-2061 | Computer hardware engineers |
| | 17-2071 | Electrical engineers |
| | 17-2072 | Electronics engineers, except computer |
| | 17-3023 | Electrical and electronic engineering technicians |
| | 17-3024 | Electromechanical technicians |
| **Electronic Equipment and Semiconductor Production Workers** | | |
| | 51-2022 | Electrical and electronic equipment assemblers |
| | 51-2023 | Electromechanical equipment assemblers |
| | 51-9141 | Semiconductor processors |

## County Business Patterns

The economic analysis primarily examines the economic changes that occurred in Arizona's AC-IT employment, establishments, and wages between 1998 and 2001.[20] The U.S. Census Bureau was the primary source for data used to analyze these changes. The Census Bureau collects employment,[21] establishment,[22] and payroll[23] data and distributes the information in the County Business Patterns (CBP) annual data series. However, the data typically has a 2-year time lag from collection to public dissemination. For the purpose of this economic study, CBP data were retrieved for the years of 1998 and 2001.

When analyzing economic activity at a sub-national level, the CBP data series presents several valuable advantages. The data are assembled from databases maintained by the Census Bureau and other federal government agencies. Data are extracted from the Business Register, the Annual Company Organization Survey, the Economic Census, the Annual Survey of Manufacturers, and Current Business Surveys, as well as from the administrative records of the Internal Revenue Service (IRS), the Social Security Administration (SSA), and the BLS. Relying on data collected by the government ensures a high degree of reliability and uniformity for comparison purposes.

CBP data are reported utilizing the North American Industry Classification System (NAICS). The new federally mandated classification system reflects recent changes in the economy. The new system was developed to better identify new and emerging industries. Industries that primarily create and disseminate a product subject to copyright, such as information technology, are now better identified under the new system. CBP is one of the first publicly available data sets to report economic information according to NAICS for multiple years. CBP makes it possible to use the most current and up-to-date industry classification system and also examine changes over time.

[20] Wages and all dollar amounts contained in this analysis are in nominal dollars.
[21] According to the U.S. Census Bureau, paid employment consists of full- and part-time employees, including salaried officers and executives of corporations, who are on the payroll in the pay period including March 12.
[22] According to the U.S. Census Bureau, an establishment is a single physical location at which business is conducted or services or industrial operations are performed. It is not necessarily identical with a company or enterprise, which may consist of one or more establishments.
[23] According to the U.S. Census Bureau, total payroll includes all forms of compensation, such as salaries, wages, reported tips, commissions, bonuses, vacation allowances, sick-leave pay, employment contributions to qualified pensions plans, and value of taxable fringe benefits.

Utilizing the CBP data series also enables the State of Arizona to build off of past state economic studies. In July of 2002, the Arizona Department of Commerce released Part I of the Statewide Economic Study. This study was primarily based on data obtained from the CBP data series. Maintaining consistency with previous studies makes it possible to leverage past analyses and examine subsequent progress.

Despite the fact that CBP is the best available data source to examine the Arizona AC-IT industry, like all data sources, it has limitations. By law, the Census Bureau is not permitted to publish any data that would disclose the operations of an individual employer. Therefore, data for industries with fewer than 100 employees are withheld to avoid this disclosure issue. However, this creates several gaps in the data series when attempting to examine a detailed industry within a certain geographic area.

To avoid the disclosure issue for the 2002 State Economic Study, the State of Arizona employed the services of Tom Rex, Research Manager at the Center for Business Research at Arizona State University. Mr. Rex developed a methodology whereby he is capable of providing employment estimates for Arizona industries where 2001 CBP data have been suppressed. Mr. Rex also provided this data to Battelle.

The time lag is another drawback of the CBP data series. The most recently available CBP issued in April 2003 reports data from captured in March 2001. Significant economic events affecting the AC-IT industry since early 2001 are unaccounted for in these most recent CBP data.

In cooperation with the Arizona Department of Economic Security, Battelle was able to obtain Current Employment and Wage (ES-202)[24] data for the AC-IT industry. Utilizing this information, Battelle was able to calculate a 2002 projection for the AC-IT industry and its associate nine subsectors.[25] The projections made it possible to estimate changes that had occurred in the AC-IT industry subsequent to the economic downturn that began in 2001.

Tables A-2 and A-3 detail the specific NAICS codes used to define the primary and embedded AC-IT sectors and subsectors.

[24] The Covered Employment and Wages (CEW) Program is a cooperative program involving the BLS of the U.S. Department of Labor and the SESAs. The CEW program produces a comprehensive tabulation of employment and wage information for workers covered by state unemployment insurance (UI) laws and federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program. Publicly available files include data on the number of establishments, monthly employment, and quarterly wages, by NAICS industry, by county, by ownership sector, for the entire United States. These data are aggregated to annual levels, to higher industry levels (NAICS industry groups, sectors, and supersectors), and to higher geographic levels (national, state, and metropolitan statistical area).

[25] The Arizona Department of Economic Security provided Battelle with employment, establishment, and annual wage information for the first, second, third, and fourth quarters of 2001 and 2002. Battelle analyzed the first quarter of 2001 and the fourth quarter of 2002. Based on the data for these time periods, a growth rate was calculated for each data category and then applied to the CBP data set. Understanding that the ES-202 data are from a different data set than the CBP data series, but faced with the need for timely and accurate data to analyze the AC-IT industry, Battelle was confident that, by applying growth, changes as opposed to raw absolute numbers, it could capture a rough estimate of industry activity over the past 2 years since 2001.

**Table A-2: Primary AC-IT NAICS Definition**

| NAICS Code Description | NAICS Code |
|---|---|
| **Computer and Peripheral Equipment** | |
| Electronic Computers | 334111 |
| Computer Storage Devices | 334112 |
| Computer Terminals | 334113 |
| Other Computer Peripheral Equipment | 334119 |
| Software Reproducing | 334611 |
| Prerecorded Compact Disc (except Software), Tape, & Record Reproducing | 334612 |
| Magnetic and Optical Recording Media | 334613 |
| **Communications and Media Equipment** | |
| Telephone Apparatus | 334210 |
| Radio and TV Broadcasting and Wireless Communications Equipment | 334220 |
| Other Communications Equipment | 334290 |
| Audio and Video Equipment | 334310 |
| Fiber-Optic Cables | 335921 |
| Other Communication and Energy Wire Manufacturing | 335929 |
| **Semiconductors and Electronic Components** | |
| Semiconductor Machinery | 333295 |
| Electron Tubes | 334411 |
| Bare Printed Circuit Boards | 334412 |
| Semiconductor and Related Devices | 334413 |
| Electronic Capacitors | 334414 |
| Electronic Resistors | 334415 |
| Electronic Coils, Transformers, and Other Inductors | 334416 |
| Electronic Connectors | 334417 |
| Printed Circuit Assembly | 334418 |
| Other Electronic Components | 334419 |
| **Communications Services** | |
| Radio Networks | 513111 |
| Radio Stations | 513112 |
| Television Broadcasting | 513120 |
| Cable networks | 513210 |
| Cable and Other Program Distribution | 513220 |
| Wired Telecommunications Carriers | 513310 |
| Paging | 513321 |
| Cellular and Other Wireless Telecommunications | 513322 |
| Telecommunications Resellers | 513330 |
| Satellite Telecommunications | 513340 |
| Other Telecommunications | 513390 |
| **Software and Data Processing** | |
| Software Publishers | 511210 |
| On-Line Information Services | 514191 |
| All Other Information Services | 514199 |
| Data Processing Services | 514210 |
| Custom Computer Services | 541511 |
| Computer Systems Design Services | 541512 |
| Computer Facilities Management Services | 541513 |
| Other Computer-Related Services | 541519 |

**Table A-3: Embedded AC-IT NAICS Definition**

| NAICS Code Description | NAICS Code |
|---|---|
| **Navigation and Control Instruments** | |
| Electromedical Apparatus | 334510 |
| Search, Detection, Navigation, Guidance Systems, and Instruments | 334511 |
| Automatic Environmental Control | 334512 |
| Instruments for Measuring, Displaying, Controlling Ind. Process Variables | 334513 |
| Totalizing Fluid Meter and Counting Devices | 334514 |
| Electricity Measuring, Testing Instruments | 334515 |
| Analytical Laboratory Instrument | 334516 |
| Irradiation Apparatus | 334517 |
| Watch, Clock and Part Manufacturing | 334518 |
| Other Measuring and Controlling Devices | 334519 |
| **Aerospace Products and Parts** | |
| Aircraft Manufacturing | 336411 |
| Aircraft Engines and Engine Parts Manufacturing | 336412 |
| Other Aircraft Parts and Auxiliary Equipment Manufacturing | 336413 |
| Guided Missile and Space Vehicle Manufacturing | 336414 |
| Missile, Space Vehicle Propulsion Unit and Parts Manufacturing | 336415 |
| Other Missile, Space Vehicle Parts, and Auxiliary Equipment Manufacturing | 336419 |
| **Research, Development, and Engineering Services** | |
| Engineering Services | 541330 |
| R&D in Physical, Engineering, and Life Sciences | 541710 |
| **Strategic Office Centers** | |
| Corporate, Subsidiary, and Regional Managing Offices | 551114 |
| Telephone Call Centers/Telemarketing Bureaus | 561422 |

# Appendix B
# Detailed Benchmarking Case Studies

# California/San Diego

## STATE AND REGIONAL OVERVIEW

Home to a huge Navy complex, San Diego experienced heavy job losses from defense downsizing in the 1990s. However, unlike other regions similarly affected, San Diego also saw compensating, rapid growth in small, high-technology firms. This history has been studied extensively by the Small Business Administration[26] and the Council on Competitiveness.[27] There is wide agreement that the region's success was tightly tied to its emergence during World War II as a center of aircraft manufacture and the subsequent development—with the active support of Navy R&D laboratories housed at the base[28]—of an associated cluster in defense avionics.

As in all defense sectors, business is cyclical and opportunities regularly come up for entrepreneurs to pick up niches neglected by larger players. Alumni of giant contractors like General Atomics (itself founded in 1955 as a General Dynamics spin-off) were responsible for creation of current IT leaders like SAIC (founded in 1969) and Titan Corp. (1981). In 1966, a key event occurred: Irwin Jacobs, then a professor of computer science at UCSD, started Linkabit as a one-day-a-week faculty consultancy to the avionics sector. This fast-growing company was formally organized in 1968; by 1972, Jacobs had left UCSD to run it. He sold it in 1980 to M/ACOM, but not before Linkabit had developed the human resources for about 30 subsequent IT start-ups, including Qualcomm, which Jacobs himself co-founded in 1985.[29] The wireless communications sector *alone*—one of three IT-related clusters recognized by San Diego Regional Economic Development Corp.[30]—now accounts for more workers than the entire remaining defense/transportation sector and has attracted inward investment from global giants like Nokia and Ericcson. The region now claims twice as many employees in the wireless sector than the North Texas Telecom Corridor in Richardson (see note in Austin profile).

The region's receptivity to this process is widely credited to the efforts of Dr. Richard Atkinson, a former Stanford professor and director of the National Science Foundation who became chancellor of UCSD in 1980. His goal for the young campus (founded in 1960) was to grow it by increasing linkages to regional industry, much as he had observed in Silicon Valley. He brought to UCSD a model for university/industry collaboration he had championed at NSF, and decided to advance it as a way to build allies in his campaign for a full-fledged engineering school (not accomplished until 1994, and then named after Jacobs). Along the way, Atkinson championed an

[26] Innovation Associates Inc. (Diane Palmintera, author). *Developing High-Technology Communities: San Diego.* Washington, D.C.: U.S. Small Business Administration Office of Advocacy. April 2000. Available on-line from http://www.innovationassoc.com.
[27] Monitor Group (Prof. Michael Porter, author). *San Diego: Clusters of Innovation Initiative.* Washington, D.C.: Council on Competitiveness, May 2001. Available on-line from http://www.compete.org.
[28] Naval radio-electronics laboratories at Pt. Loma are now part of a much larger Space and Naval Warfare Systems Center, but date to 1906. See a history at: http://www.spawar.navy.mil/sandiego/.
[29] A genealogy of this spin-off process can be found in Table 15 of the Palmintera report referenced above.
[30] The others are software/internet and computer/electronics manufacturing.

unusual vehicle known UCSD CONNECT[31]—a networking organization that functions like an "incubator without walls" within the university's extension division. Together, these initiatives bound the interests of the university to those of the growing technology sector.

## STRATEGY ENVIRONMENT

California has never had a strong cluster-development effort at the state government level. The California Technology, Trade and Commerce Agency—actually eliminated in the current budget—is best known for its Regional Technology Alliance Program (profiled below), which attempts to support multiple clusters in each region. Instead, substantially all the state's cluster-development programming takes place within the University of California system, largely at the insistence of Atkinson, who led UCSD in the 1980s, moved to the system presidency in 1995, and just recently retired.

As UC System president, Atkinson adapted an existing incentive-grant program in micro-electronics run by the Berkeley campus to create a centralized, broadly based Industry/University Cooperative Research Program that provides incentives for UC faculty to collaborate with California industry. Also known as the **UC Discovery Grant**,[32] this program (profiled below) supports collaborations in seven fields, four of them IT-related.

Also funded through UC is a new initiative called the **California Institutes for Science and Innovation**,[33] Under this initiative, the state will pay the capital costs ($100 million each, to be matched at least 2:1) of four or five large, multidisciplinary research institutes. The Cal Institutes are in most respects like any other UC-organized research unit, but are explicitly targeted to assist in economic development. Each of the four currently funded Cal Institutes has an IT component:

- **California Institute for Bioengineering, Biotechnology, and Quantitative Biomedical Research**—a collaboration among UC San Francisco, Berkeley, and UC Santa Cruz
- **California Institute for Telecommunications and Information Technology** (further details on San Diego's institute below)
- **California Nanosystems Institute**—a collaboration among UCLA and UC Santa Barbara
- **Center for Information Technology Research in the Interest of Society**—a collaboration of the Berkeley, Davis, and Merced campuses.

## CENTERS OF EXCELLENCE

UCSD has leveraged the Cal Institutes program by successfully proposing a major center that weaves together strands of expertise in advanced computing, wireless telecommunications hardware, nanotechnology, and even bioscience:

- **California Institute of Telecommunications and Information Technology (Cal-[IT$^2$])**– This Cal Institute[34] is jointly operated by UCSD and UC Irvine. Its main focal points include

[31] See http://www.connect.org.
[32] See http://uc-industry.berkeley.edu/welcome.asp.
[33] See http://www.ucop.edu/california-institutes/about/about.htm.
[34] See http://www.cali2.net

Internet appliances, sensor arrays, embedded processors, and links to digital wireless. The state's $100 million capital contribution will pay for a 215,000-gross-square-foot building at UCSD housing new laboratory facilities for interdisciplinary teams. In all, there will be 200 faculty offices and hundreds of seats for collaborative activity. Included in the plans are ubiquitous wireless (G3) and optical networking, a computer arts virtual reality theater, a digital cinema auditorium, materials characterization and circuits laboratories, and clean rooms for nanotechnology and Bio-MEMS. Additional nanotechnology facilities are supported at UC Irvine. So far, the Institute claims matching support from dozens of IT and Internet companies, ranging from companies headquartered in the region to global giants with or without regional business presence.

CAL-(IT)$^2$ is really more an outgrowth of San Diego's success than an explanatory factor. Among the earlier resources that contributed to the credibility of this Center's charter was

- **San Diego Supercomputer Center**[35]—one of the original NSF-sponsored supercomputer centers that has survived by emphasizing development of applications in data management, biosciences, geosciences, grid computing, and visualization.

The campus also has reacted to growth of the wireless telecom cluster by creating its own targeted research collaboration, which is not a Cal Institute but enjoys heavy support from the regional industry base:

- **Center for Wireless Communications**[36] with membership from regional leaders like Ericcson and Qualcomm but also major multinational enterprises based elsewhere in the nation or the world.[37]

Finally, all these actors are interacting in ways that reinforce a state-level initiative:

- **Corporation for Education Network Initiatives in California** (CENIC)[38]—a state-owned high-bandwidth intercampus telecom network with three tiers: (1) a 2.5-gigabit per second (Gbps) backbone serving 140 institutions of higher education and 8,000 K-12 schools in 58 counties; (2) a 10-Gbps backbone serving more than 50 research institutions; and (3) an experimental backbone serving the Cal Institutes at 10 Gbps and additional dark fiber available.

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

UCSD faculty can leverage the UC Discovery Grant in the following IT fields:

- Communications and networking
- Digital media
- Electronics manufacturing and new materials
- Information technology for the life sciences
- Microelectronics (the original program).

[35] See http://www.sdsc.edu/Visitors/mission.html.
[36] See http://cwc.ucsd.edu/about.html.
[37] See http://cwc.ucsd.edu/members.html.
[38] See http://www.cenic.org/AboutC.html.

The program is now funded at more than $20 million annually, divided unevenly among the areas. Eligible applicants are principal investigators at any of the 10 UC campuses. Grants range from $50,000 to $250,000 annually for up to four years, with a requirement of 1:1 matching by companies based in California or with substantial R&D operations there. The Discovery Grant should be seen in the context of an overall UC operating budget of several billion dollars, within which about $300 million is targeted for "organized research units" and other strategic research activities under a "Partnership Agreement" between the system and the Governor that includes a specific focus on California competitiveness.[39]

Both UCSD spin-offs and other technology companies in the region are assisted in commercialization and financing by CONNECT, the UCSD-sponsored on-campus organization for networking. Founded in 1985, CONNECT mentors entrepreneurs, fosters strategic partnerships between start-ups and established businesses, provides in-depth entrepreneurial training, introduces early-stage companies to the world of finance and venture capital, and generally assures that the university's offerings are relevant to the needs of the high-tech employment base through a regular "meet the researchers" program.

Finally, UCSD has structured its Technology Transfer and Intellectual Property Services (TTIPS) office (a quasi-independent branch of the UC Office of Technology Transfer) so that it favors creation of locally based spin-offs over licensing to large companies. The TTIPS director has told Battelle that he has a "higher propensity" to accept equity in a start-up than other UC campuses, such as Berkeley, because UCSD has embraced a regional economic-development mission and wants to "grow technology companies" in the region rather than simply maximize royalty and fee revenue.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

Cluster leadership is provided by the San Diego Telecom Council[40] and the San Diego Software Industry Council.[41] The former also offers a mentoring program and the latter an entrepreneurs forum. Student-oriented entrepreneurship programs, including an internship program with local industry, are offered by the Entrepreneurial Management Center at San Diego State University.[42] Possibly the most innovative workforce initiative was creation of High Tech High, a 400-student regional magnet school on the grounds of a former naval training center.[43] The Telecom Council and others are deeply involved in fund-raising and support for the school.

The San Diego Workforce Partnership, the local Workforce Investment Board, has prepared specific strategic workforce plans for the following IT sectors: communications; computer and electronics manufacturing; software and computer services.[44]

[39] See http://budget.ucop.edu/NP.html#VII.%20Maintaining%20California%E2%80%99s
[40] See http://secure.sdtelecom.org/about/Industries.cfm.
[41] See http://www.sdsic.org/about-sdic.htm.
[42] See http://www-rohan.sdsu.edu/dept/emc/about/.
[43] See http://www.hightechhigh.org/about/
[44] All available on-line at http://jobs.sandiegoatwork.com/.

## ENTREPRENEURIAL INFRASTRUCTURE

In 1993 the state created the California Technology Investment Partnership (CalTIP) to be administered by a series of three Regional Technology Alliances (RTAs), now constituted as independent nonprofit corporations. Funded originally through "defense conversion" grants offered by federal agencies, CalTIP was conceived as a matching-grant program to provide incentives for California defense contractors to compete for and obtain federal awards that would allow them to transition to products not aimed at military markets. As such, the program offered by the San Diego RTA was used heavily.[45]

The state picked up the entire $6 million cost (including both the grants and the subsidy of the three RTAs). Since then, the focus has broadened to general-technology business development. In addition, the grantee base shifted from large defense contractors and university centers to small, technology-based businesses. Participants are now encouraged to spend their awards on activities not paid for by the federal contracting agency, such as business planning, market research, IP protection, etc. Three more RTAs were created to cover regions of the state that did not consider their needs addressed by San Diego, San Francisco Bay, and Los Angeles. However, as state funding began to look threatened, the RTAs have moved away from the CalTIP program and now serve essentially as think tanks for their regions on technology issues and as consultants to fast-growing technology firms. In some respects, the SDRTA competes with both CONNECT and the two telecom trade associations, but the multiple opportunities for networking seem to benefit the region.

The only current business incubator in San Diego belongs not to UCSD, but to San Diego City College and is manufacturing oriented.[46] However, the San Diego Regional Economic Development Corporation recently sponsored a study[47] that called for creation of a large (1,000-acre) Regional Technology Park aimed at production facilities for "the technology and biotechnology sectors" and also a network of smaller (200-acre) parks around the region. This recommendation was sized to fit an anticipated 5 percent annual growth rate in employment in these sectors, and to acknowledge minimal remaining developable land in the core of San Diego County. The report anticipates demand for R&D industrial space in IT-related sectors including computers, microelectronics, advanced materials, robotics, and telecommunications.

## VENTURE FUNDING AND INFRASTRUCTURE

California's public financing agencies do no work with technology-based business, except for export financing. The giant California Public Employees Retirement Fund has a $500 million "California Initiative" venture-capital program that necessarily benefits California disproportionately because of the high concentration of venture firms in-state, but without an exclusive focus on California or university-derived technologies.[48]

San Diego is now well supplied with formal venture capital, but this was not always so. Some years ago, CONNECT absorbed a Technology Financial Forum, an earlier experiment at

[45] See http://www.sdrta.org.
[46] See http://www.cact-sd.org/Technology_Incubator/technology_incubator.html.
[47] See http://www.sandiegobusiness.org/researchpublications.htm. j
[48] An excellent summary appears at: http://www.calpers.ca.gov/invest/investment-business-opportunities/ca-initiative-info-packet.pdf.

introducing local entrepreneurs to venture capitalists based in the Bay Area. CONNECT now operates what it calls its Springboard program to prepare entrepreneurs to meet venture investors, whether local or national. Other entrepreneurial resources in the region include a San Diego branch of the MIT Enterprise Forum[49] and a San Diego Venture Group.[50]

## BUSINESS CLIMATE

San Diego dramatically lowered its business taxes in the 1990s, established two city enterprise zones, and created both an advisory Science and Technology Council[51] and an ombudsman to assist high-technology businesses.[52]

## SUMMARY OF SUCCESS FACTORS

- Highly linked science and engineering programs
- Cohesive private sector with dense array of networking and mentoring opportunities
- Pipeline of IT workers through UCSD, San Diego State University, and City College
- Friendly local government
- Low cost of housing, high quality of life compared with Bay Area alternatives

[49] See http://www.sdmitforum.org/
[50] See http://www.sdvg.org/about/index.shtml
[51] See http://www.sannet.gov/city-clerk/boards-commissions/technology.shtml
[52] See http://www.sannet.gov/economic-development/business-assistance/small-business/

# Massachusetts/Boston

## STATE AND REGIONAL OVERVIEW

Long recognized as one of the two great technology centers of the nation, the greater Boston area traces its success not to any formal strategic planning, but rather to the federal government's massive investment in radar technology (the "Rad Lab") at MIT during World War II. A 1997 study by BankBoston[53] identified 4,000 then-active "MIT-related" companies nationwide.[54] About a quarter of these firms were actually headquartered in Massachusetts, accounting for 125,000 jobs (ranking second after the 162,000 MIT-related jobs in California). Examples of MIT-related firms that became regional technology giants include Raytheon, a small appliance company that leveraged MIT research to become a leading radar and defense contractor; Thermo-Electron (founded 1956); and Analog Devices (founded in 1965).

Following the war, basic research on radar was reabsorbed on the main MIT campus through formation of a Laboratory for Radio Electronics, which became a prototype for a series of world-renowned research laboratories in computer science, robotics, artificial intelligence, new media, and other application areas.[55] In 1951—the same year An Wang left Harvard to found the minicomputer pioneer Wang Laboratories (bankrupted in 1992)—MIT moved applied research on radar off-campus to the Lincoln Laboratory[56] at Hanscom Air Force Base. A wave of spin-offs followed. For example, in 1958, 485 employees of "Division 6" at Lincoln broke off at the request of the Air Force to form MITRE,[57] a not-for-profit research institute to do systems integration around the SAGE ground-based air-defense radar system invented at Lincoln. MITRE is now a major defense contractor and one of the few nonprofits to host a federal defense laboratory.

Lincoln Lab technology or personnel have accounted for 80 company formations in all, the best known of which is Digital Equipment Corp., founded in 1957 and a major force in the American computing industry until its acquisition by Compaq. More recent Lincoln-related start-ups include the display pioneer Kopin and the advanced optical networking company Sycamore. In 1973, MIT spun out its Instrumentation Lab into the Charles Stark Draper Laboratory,[58] another not-for-profit institute that provided a convenient home for classified engineering research that was no longer welcomed on campus. Though not active until recently in spin-formation, Draper recently formed a venture and commercialization arm.

Although "Route 128" has been compared unfavorably to Silicon Valley by scholars interested in entrepreneurial culture,[59] there can be no doubt that successive waves of spin-offs formed the basis for the Massachusetts Miracle that crested in the1980s. Massachusetts rode the Internet

[53] BankBoston. *MIT: The Impact of Innovation.* Boston: BankBoston, 1997. Available on-line at: http://web.mit.edu/newsoffice/founders/Founders2.pdf.
[54] Defined as those founded by persons formerly associated with the university as students or employees, and therefore counting many spin-offs from Lincoln, MITRE, and Draper as well as the main campus.
[55] See http://web.mit.edu/research/index.html.
[56] See http://www.ll.mit.edu/.
[57] See http://www.mitre.org/about/index.html.
[58] See http://www.draper.com/.
[59] Annalee Saxenian. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, Mass: Harvard University Press. Paperback edition 1996.

wave to a deeper and more sophisticated understanding of the role of cluster-based development, now showing in new initiatives in nanotechnology, optical networking, and photonics.

## STRATEGY ENVIRONMENT

Despite Route 128's success as an unplanned research park, the state has never had a strong strategy for technology-based economic development in communications/IT or any other sector. The high point of planning was achieved in the early 1980s in the second Dukakis administration, which created a series of four quasi-public corporations loosely attached to the Executive Office of Economic Development and linked to then-existing quasi-publics like the MassDevelopment financing agency:

- **Massachusetts Centers of Excellence Corporation**—which was charged with developing geographic technology clusters, but never operated university-based "centers of excellence" in the sense that most other states mean. This corporation was allowed to go inactive years ago.
- **Massachusetts Technology Park Corporation**—which was chartered originally to develop a research park in Westborough around a publicly subsidized semiconductor fab. The plant was subsequently leased to Kopin Corp., and MTPC was reinvented as the **Massachusetts Technology Collaborative**, a strategy steering group (see below).[60]
- **Massachusetts Technology Development Corporation**[61]—which still operates a publicly funded pre-seed investment fund, and has reinvested certain of its profits in a broadly based limited partnership with co-investment from regional banks and financial leaders.
- **Commonwealth Corporation**[62]—the third and current name for a workforce development agency first known as the Bay State Skills Corporation and then the Corporation for Business, Work and Learning.

In the 1990s, the state commissioned an explicitly cluster-based economic-development strategy from Harvard Business School professor Michael Porter,[63] but many of its recommendations went unimplemented. Strategy development rested with MTC, which created several cluster-based trade associations that did not then exist, and energized a "Route 495" initiative that served as a regional technology council. Under the board currently in place, MTC has dropped most of its broad-based cluster initiatives and is focusing mainly on its portfolio of alternative-energy research funded through the Massachusetts Renewable Energy Trust. It is nominally the home of a nanotechnology initiative and continues to publish annually its path-breaking and well-regarded innovation index of the state's economy.

[60] See http://www.mtpc.org/AgencyOverview/whatwedo.htm.
[61] See http://www.mtdc.com/role.html
[62] See http://www.commcorp.org/AboutUs/default.htm
[63] The Commonwealth of Massachusetts, Executive Office of Economic Affairs and the University of Massachusetts, *Choosing to Compete*, 1992. No longer available on-line.

## CENTERS OF EXCELLENCE

Massachusetts never supported centers of excellence in the sense meant by other states; though dozens of IT centers and institutes populate MIT and, to a lesser extent, UMass, Harvard, Boston University, and other smaller institutions. So diffident was the state that in 1990 Florida State University was able to pry a national high-field magnet user facility away from the much more qualified MIT by promising substantial state-provided matching funds. While this event shocked the Massachusetts technology community, no organized effort to build research capacity and retain it in state was ever funded at the state-government level.

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

MIT is well known for its Industrial Liaison Program,[64] the oldest and best elaborated such program in the nation. It was founded in 1948, when an alumnus became frustrated at his inability to connect his company efficiently with what he knew were the relevant technical resources at the university. This founder recruited an initial group of sponsors he knew would be willing to pay for the ability to reach into the university and always find the right resource. Today the ILP is a fee-for-service operation that employs 20 professionals and support staff. Members range from the largest global enterprises to smaller high-technology enterprises both within and outside New England. Each company joining the ILP gains access to otherwise tightly restricted information about research and technology at MIT, although no favored position with respect to research or licensing terms. Membership fees pay in part for assignment of an ILP staffer as a "Liaison officer"—a long-term relationship manager who identifies the needs of the member and ensures that all desired services are delivered or at least proposed if they cost extra. The ILP is completely independent of and does not interfere with those research efforts at MIT that have organized themselves as consortia or collaboratives.

Under the guidance of Mass Insight,[65] a public/private partnership based in Boston, effort is now coalescing to create a pool of state funds for university/industry matching grants and/or university-based centers of excellence.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

During the time in which MTC was largely responsible for overall technology strategy, it had identified the following IT sectors as important to the state's economy: factory automation; computer hardware; photonics; computer software; and telecommunications/internet.

The key cluster organization is the Massachusetts Telecom Council (founded in 1993).[66] The Telecom Council employs a broad definition of the field similar to that used by Battelle in the economic analysis.[67] According to a recent Council study, the state's largest IT/telecom sector is communications services, and the equipment manufacturing sector is shrinking. The public-sector

[64] See http://ilp.mit.edu/ilp/General/WhoWeAre.html.
[65] See http://www.massinsight.com/about.asp.
[66] See http://www.masstel.org/about/overview.html.
[67] Craig Moore. *The Telecommunications Industry in Massachusetts.* Waltham, Mass.: Massachusetts Telecommunications Council, November 2002. Available on-line at: http://www.masstel.org/pdf/research1102.pdf.

main initiatives recommended by the Telecom Council include broadband deployment, workforce development, R&D, and taxation reform.

A secondary cluster organization is the Massachusetts Software and Internet Council (founded in 1985 as the Software Council).[68] This organization was best known for a groundbreaking fellowship program that retrained the underemployed from other industries for software/internet jobs during the labor shortages of the late 1990s.

Likewise, the Commonwealth Corporation, one of the four quasi-public corporations formed in the 1980s, had extensive software training programs during the 1990s that are now largely dormant.

## ENTREPRENEURIAL INFRASTRUCTURE

With a weak state program, a good deal of entrepreneurial support activity rests within MIT itself. Known around the nation for the public-presentation format of its Enterprise Forum[69] (which has been replicated around the nation), the university also maintains the following relevant services:

- **Technology Capital Network**, an early angel-investor connection service[70]
- The student **Entrepreneurs Club** and its associated $50,000 business-plan competition,[71] which claims to be the world's leading university-based competition with 60 start-ups to its credit
- **Desphande Center**, which was endowed with $20 million to support $50,000 grants for pre-commercialization research and arrange industry partnerships to help commercialize MIT faculty inventions being handled by the Office of Technology Licensing.[72]

Smaller institutions also have played an important role. For example, Boston University operates a 23,500-square-foot "business accelerator"[73] associated with the university's Photonics Center, and Babson College, an undergraduate institution, has one of the nation's best-ranked entrepreneurial centers, now equipped with a "hatchery" incubator and a seed fund.[74]

## VENTURE FUNDING AND INFRASTRUCTURE

As noted above, the Massachusetts Technology Development Corporation has played an important role as "farm team" to formal venture capital by making seed-stage near-equity investments in technology companies throughout the state. Typical investments are in the $250,000 to $500,000 range, with follow-ups considered by an associated later-stage venture fund with private co-investors, the Commonwealth Investment Fund.

[68] See http://www.swcouncil.org/about_msic/default.asp.
[69] See http://www.mitforumcambridge.org/about/index.html.
[70] See http://www.tcnmit.org/.
[71] See http://50k.mit.edu/about/index.php.
[72] See http://web.mit.edu/deshpandecenter/grants.html.
[73] See http://www.bu.edu/photonics/business_accelerator.htm.
[74] See http://www3.babson.edu/ESHIP/resources/Seed-Fund.cfm.

One of the most interesting private venture initiatives is **Boston University's Community Technology Fund**,[75] an umbrella organization that operates the technology transfer function, manages a portfolio of venture-capital partnerships for the BU endowment, and makes its own direct investments in venture start-ups. While the CTF portfolio is not restricted to BU spin-offs, it has raised their visibility in the venture capital community by incurring reciprocal investment obligations. BU also operates **Beacon Technology Ventures,**[76] an early-stage venture fund associated with the Photonics Center incubator.

## BUSINESS CLIMATE

Massachusetts has made repeated tax cuts over the last several administrations and offers both an investment tax credit of 3 percent and a 10 percent in-state R&D credit (15 percent for basic research).

The state also has invested in broadband deployment in rural areas, through demand-aggregation experiments like Berkshire Connect.[77]

The eight research universities of greater Boston collaborated on an economic study[78] that credited them with $1.5 billion a year in research contracts, and direct and indirect economic impacts of $7.4 billion.

## SUMMARY OF SUCCESS FACTORS

- Increased regional focus on supporting an entrepreneurial culture and assisting start-ups
- Culture of venture investors and service providers who understand start-ups' needs
- Series of strong, value-added cluster networks developed and fostered

[75] See http://www.bu.edu/ctf/aboutus/aboutus.html.
[76] See http://btechventures.com/.
[77] See http://www.bconnect.org/index.htm.
[78] See http://www.masscolleges.org/Economic/default.asp.

# New Jersey/Central NJ

## STATE AND REGIONAL OVERVIEW

The historic center of telegraphy development in the 19th century, New Jersey spent much of the 20th century accumulating corporate assets in telephony, radio, and television electronics. The state entered the 1980s as host to some of the world's premier institutional laboratories in communications and electronics—AT&T Bell Labs in Murray Hill and Red Bank, RCA's Sarnoff Lab in Princeton, Exxon Research in multiple locations, and the U. S. Army's communications-electronics labs at Fort Monmouth. At that time, the state also still had a significant base of manufacturing in discrete electronic components and assembled systems. Still, some of the most promising postwar discoveries of these labs were never commercialized in New Jersey. The transistor (Bell) was developed in Silicon Valley, the VCR (Sarnoff) was licensed to Japanese manufacturers, Exxon failed in its office-automation ventures, and the Unix computer operating system (Bell) entered the public domain with little benefit to its owners.

Starting in the 1980s, this entire infrastructure collapsed before the state could ever learn to fully exploit it. First, the communications-equipment manufacturing sector entered an irreversible secular decline. The state had developed no mainframe, mini- or personal computer sector, and quickly lost what capacity it had in integrated circuits to California and Massachusetts or Asia. Next, a wave of downsizing and restructuring fragmented the corporate labs. After the AT&T breakup, Bell Labs was split among AT&T, Lucent, and a unit serving the regional Bell operating companies now owned by SAIC. Sarnoff was sold to SRI International after GE acquired RCA and declared the lab redundant with its facilities in New York State; Exxon essentially abandoned all research not directly related to oil; and the Army labs were consolidated in Maryland, with only certain functions remaining in New Jersey. The effect was to take away the labs' mandate for basic research and to make them short-cycle development shops for manufacturing that was done elsewhere.

It was in this environment that New Jersey began its efforts to build academic R&D capacity in a chronically under-invested university system, to promote academic/industrial collaboration, and to develop entrepreneurs. Although there were some early manufacturing losses to Pennsylvania and other states, a slow, steady climb has positioned New Jersey universities credibly to challenge those in California and Massachusetts for leadership in development of photonics technology at all levels—materials, systems, and devices.[79] Materials-science research remains very strong in the state, suggesting the potential to lead also in micro- and nano-scale electromechanical systems. Most of the new wave of photonics and materials companies are still small, but the best endorsement of the state's success is that the 1980s and 1990s saw the opening of a series of "listening post" laboratories by multinational enterprises—Siemens, NEC, and others. Eventually both AT&T and Lucent became minimally capable at formation of start-ups (although many did not survive the Internet boom and bust). The strongest spin-off engine in AC-IT is now the Sarnoff Corp. (operated by SRI as a for-profit subsidiary), which has yielded several private and public companies in the communications and bioinformatics space.[80]

[79] Examples include Universal Display, Emcore, Anadigics, PD-LD, Sensors Unlimited, and Epitaxx.
[80] See http://www.sarnoff.com/about/ventures/venture-list.asp.

## STRATEGY ENVIRONMENT

New Jersey, a heavily suburbanized state with only small and troubled cities at the periphery of the New York and Philadelphia metropolitan regions, developed and executed its strategy entirely at the state level, through the New Jersey Commission on Science and Technology,[81] established formally in 1985. After having invested more than half a billion dollars over a decade and a half, the Commission has been radically downsized in the current budget and now is under review for complete reinvention, loosely linked to a parallel attempt to reconfigure the public-university system.

From the outset, this Commission had identified both what it then called "telematics"[82] and advanced materials as research areas key to the state's economic future (along with bioscience and several other broad fields). The principal strategy of the Commission was to apply substantial capital and operating resources to development of centers for academic/industrial collaboration at Princeton, whose engineering programs were excellent but small and historically resistant to corporate interaction; Rutgers, the state university that was friendly to industry but historically underinvested; and two smaller technical universities, the public New Jersey Institute of Technology and the private Stevens Institute. The Commission allocated proceeds from bond issuances totaling nearly $125 million, creating "bricks and mortar" centers and largely equipping them to become competitive for industrial and federal research partnerships. At its peak, it had a $22 million annual grant budget, more than half of which was for communications or IT centers (see below).

## CENTERS OF EXCELLENCE

Among the full-scale "Advanced Technology Centers" that received both capital funding and operating grants until the program was reconfigured in the late 1990s were the following:

- **Center for Advanced Information Processing**[83]—a university/industry collaborative center at Rutgers focusing on development of new software-engineering approaches for massively parallel computation, with more than 20 corporate affiliates
- **Center for Photonics and Optoelectronic Materials**[84]—an industry-friendly research center at Princeton and the focal point for efforts to develop New Jersey as the "Gallium Garden," a play on the "Garden State" referring to the Gallium Arsenide optoelectronic material
- **Center for Surface Engineered Materials** (now defunct)—a consortial "center without walls" involving all four universities and the Sarnoff Corp., with research equipment or laboratory suites purchased for use by each participating member.

Centers that received funds to match major federal awards, but no capital support, included the following:

- **The John von Neumann Supercomputer Center**—one of the original five national supercomputer centers, owned by a national consortium but based in Princeton, and the only

[81] See http://www.state.nj.us/scitech/.
[82] From the French *télématique*, representing the convergence of computer and communication technologies.
[83] See http://www.caip.rutgers.edu/.
[84] See http://www.poem.princeton.edu/.

one to close when NSF pulled its funding. The regional network feeding the center was privatized and later absorbed into a national Internet Service Provider.

- **Wireless Information Network Laboratory**[85]—an NSF-sponsored Industry/University Cooperative Research Center at Rutgers, partnered with Virginia Tech, providing theoretical support for next-generation system development.
- **Center for Discrete Mathematics and Theoretical Computer Sciences**[86]—an NSF-sponsored Science and Technology Center pairing Rutgers and Princeton with Bell Labs and other corporate partners to match mathematicians' talent to practical applications in encryption, data mining, and computational biology.

Eventually, the centers program was disbanded in favor of an annual competition for "R&D Excellence" awards of up to $1 million over 5 years. These are intended to build research capacity to compete for federal and industry funding. This program reinforced efforts in optoelectronics and wireless communication and built new capability in multimedia, smart transportation systems, distributed and networked computing, and telemedicine.

Most recently, the Commission acted as agent for the Governor in arranging the newly formed New Jersey Nanotechnology Consortium to take control of a world-class micro- and nano-scale fabrication facility being surplused by Lucent.[87] It will be operated as a user facility open to academic and business users. Funding was $2 million from general appropriation and $2 million in a federal line item.[88]

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

Initially, the New Jersey Commission offered a matching-grant program intended to spur academic/industrial collaboration at the faculty level, with "telematics" being one of the primary fields for competition. This program was disbanded in favor of a "technology transfer merit program" that tried to become a commercialization fund but failed. In turn, it was replaced by the "Springboard" pre-seed fund that provided early-stage funds up to $250,000 for several IT/communications start-ups but no longer required any university involvement in the project. This final version of the program was defunded last year in the state's budget crisis.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

New Jersey is one of the few states with a Research and Development Council,[89] which represents the interests of research-intensive companies both large and small and the university sector. However, the R&D Council has never acted as a cluster organization. Instead, there is a separate New Jersey Technology Council that performs this function. Leadership in the AC-IT sector is provided through three industry "networks" maintained by the Council: communications; IT/software; and electronics/advanced manufacturing.[90]

[85] See http://www.winlab.rutgers.edu/pub/docs/about/about.html.
[86] See http://dimacs.rutgers.edu/.
[87] See http://www.njnano.org/about/index.shtml.
[88] See http://www.state.nj.us/cgi-bin/governor/njnewsline/view_article.pl?id=803.
[89] See http://www.rdnj.org/membercos.html.
[90] See http://www.njtc.org/industry/index.asp.

The state's separate Commission on Higher Education reacted to the Internet boom by making $15 million in competitive grants to New Jersey universities to promote the development of "nationally recognized" college curricula in four disciplines including computer science and IT, accompanied by $50 million in bond funding for purchase of computer, IT, and networking equipment and infrastructure. This program has not been renewed.

## ENTREPRENEURIAL INFRASTRUCTURE

The Science and Technology Commission sponsored (with start-up and annual grants) a series of more than a dozen technology-business incubators at various locales around the state, most oriented toward the software end of IT.[91] These are hosted variously by research universities, community colleges, DoD bases and laboratories, and other nonprofit entities. There also are two state-supported research parks, but both with bioscience orientation. With assistance from the Commission, the state's Small Business Development Center is one of the few to have developed expertise in technology start-ups,[92] a departure from that network's usual focus on retail and service providers.

Along with this effort, the Commission also funded a Washington-based consultant on the SBIR program to serve New Jersey companies, and placed a collateral deposit with a New Jersey commercial bank that enabled it to make "bridge loans" to SBIR companies between Phases I and II. The survival of all these programs is now in question, though elements of entrepreneurial infrastructure will remain.

## VENTURE FINANCING AND INFRASTRUCTURE

The state has been generally active in capital formation:

- During the 1990-91 recession, the New Jersey Economic Development Authority (NJEDA) used internally generated funds to buy a limited partnership interest in Edison Venture Fund, one of the state's largest and (although not an early-stage fund) committed to generating deal-flow by supporting various efforts to increase seed-stage capital. Edison deals throughout the Mid-Atlantic states nearly exclusively in software and IT and committed one-third of its investments to New Jersey as part of this deal.
- In 1996 NJEDA used appropriations from the Science and Technology Commission to buy an LP interest in Early Stage Enterprises, a Small Business Investment Company (SBIC) whose co-investors were major corporate citizens and banks in the state.[93] The fund focused on New Jersey in a mid-Atlantic context. ESE partners also are joining the recently announced Battelle Ventures.[94]
- In 1999 NJEDA committed to match 1:3 any funds raised privately as seed fund associated with the New Jersey Technology Council.[95] This fund raised $30 million, meaning

[91] For a representative sample, see the Web site of the New Jersey Business Incubation Network at: http://www.njbin.org/index.htm.
[92] See http://www.njsbdc.com/scitech/.
[93] See http://www.esevc.com/.
[94] See http://www.battelleventures.com/.
[95] See http://www.njtcvc.com/.

$40 million before SBIC leverage. This fund was designed in response to concern by NJTC members that only 10 percent of the venture funding managed in state is invested in state.

## BUSINESS CLIMATE

The state is well known for its aggressive incentive programs, including an innovative relocation grant that is scaled to the size of increased New Jersey income-tax withholding over a 10-year period and has been very effective in promoting relocation of companies from New York City to northern New Jersey. The NJEDA, which allocates these grants, also administers one of the nation's few programs under which start-up companies that cannot use net operating loss or R&D tax credits because they are not yet profitable and have no tax liability can sell them to those companies that can use them as a shelter.[96]

## SUMMARY OF SUCCESS FACTORS

- Significant public investment in university-based R&D capacity and industry collaboration
- Effort to steer corporate and federal lab outplacements into entrepreneurial ventures
- Vigorous efforts in business incubation and venture capital formation
- University commitment to photonics/optoelectronics cluster

[96] For both programs, see http://www.njeda.com/financingtypes.asp#small.

# New York/Rochester and Albany

## STATE AND REGIONAL OVERVIEW

New York State's leading AC-IT companies are clustered predominantly in two regions: Rochester—the historic home to Kodak and Xerox in western New York—and the Hudson Valley, where IBM is a dominant force in manufacturing and R&D. There also are other leaders such as the fiber-optics giant Corning in central New York; various telecom providers in Westchester County; and a range of software and hardware vendors that remain from the aerospace heritage of Long Island, once home to Grumman. Despite these impressive anchors, and the activity of a state-sponsored science and technology program with roots to the early 1960s, formation of entrepreneurial businesses has lagged. In part, business startups that would stand out in other states fade into insignificance when compared with the size and scope of the state's multinational enterprises.

Indeed, the most obvious success in developing the IT cluster has come in the form of large-company investments, such as IBM's agreement to invest $2.5 billion in a state-of-the-art, 300mm semiconductor wafer fab at East Fishkill, in the lower Hudson Valley. Heavy state investment in microelectronics and nanotechnology at the State University of New York (SUNY) at Albany has helped that campus grow its research budget 50-fold since 1992, with corresponding step-up in research investments by private firms. For example, shortly after the Fishkill plant was announced, the state was able to clinch the following additional investments: (1) a $300 million commitment by International Sematech of Austin to open a new 300mm facility to be shared with the university's faculty; (2) a $200 million commitment by Tokyo Electron, a Sematech member, to open its first major R&D facility outside Japan, also sharing this facility; and (3) a $100 million co-investment in this complex by IBM. The upper Hudson Valley has begun calling itself the "Tech Valley."

Progress in Rochester has been slower. Long known as a center of optics research and technology, the region targeted photonics as the next logical stage in its cluster development some time ago. During the 1990s, Rochester gained considerable visibility in IT as the locus for one of the few local telephone companies that was never part of the Bell System, and which had made early and large bets on fiber-based long-distance and Internet service. When a wave of consolidation and bankruptcy ended this dream, the region's software and hardware companies were still at an early stage of development. Rochester is still aiming to emerge as the technology center of an upstate "arc" of old-line manufacturing cities from Buffalo in the west, through Syracuse and Ithaca in Central New York, all the way to Albany.

## STRATEGY ENVIRONMENT

The New York State Office of Science, Technology and Academic Research,[97] created in 1999, replaces the New York State Science and Technology Foundation, created in 1963. The signature program of this agency and its predecessors since the 1980s has been the Centers for Advanced Technology—a series of academic/industrial research consortia in targeted fields, based at

[97] See http://www.nystar.state.ny.us.

universities around the state.[98] These centers are funded at about $1 million each annually, which the centers must match with contributions from New York State-based companies. By far, the majority of the 14 existing CATs have some relevance to either the software or hardware components of AC-IT. Subtracting the three centers with only bioscience orientations, the CATs cover the following fields:

- **Center for Advanced Ceramic Technology**[99]—at Alfred University, a private university with a state-sponsored or "statutory" college in ceramics.
- **Center for Ultrafast Photonic Materials & Applications**[100]—at City University of New York (a multicampus public system).
- **Center for Advanced Materials Processing**[101]—at Clarkson University, a private institution in the state's remote North Country.
- **Center for Advanced Information Management**[102]—at Columbia University, redesignated a CAT only after it was forced to reconfigure.
- **Center for Advanced Technology in Digital Multimedia**[103]—a collaboration of several departments at NYU, a private university. Often known as the "new media" CAT.
- **Center for Advanced Technology in Telecommunications**[104]—at Polytechnic University, a private university based in Brooklyn.
- **Center for Automation Technologies**[105]—specializing in micro- and nanomanufacturing, at Rensselaer Polytechnic Institute, a private institution in Troy.
- **Integrated Electronics Engineering Center**[106]**—**specializing in electronic packaging, at SUNY Binghamton.
- **CAT in Sensor Systems**[107]**—**Stony Brook's second CAT. Both will be jointly housed in the facility partly underwritten by the STAR grant referenced below.
- **Center for Computer Applications and Software Engineering**[108]**—**at Syracuse University, a private university.
- **Center for Advanced Thin Film Technology**[109]**—**at SUNY Albany, and the nucleus of the large Albany Nanotech program referenced above and below.
- **CAT in Electronic Imaging Systems**[110]**—**at University of Rochester (UR) and Rochester Institute of Technology (RIT) (both private institutions), intended to capitalize on the region's optics expertise.

[98] See http://www.nystar.state.ny.us/cats.htm.
[99] See http://cact.alfred.edu/.
[100] See http://www.cunyphotonics.com/.
[101] See http://www.clarkson.edu/camp/.
[102] See http://www.cat.columbia.edu/
[103] See http://cat.nyu.edu/current/.
[104] See http://cat.nyu.edu/current/.
[105] See http://cat.nyu.edu/current/.
[106] See http://www.ieec.binghamton.edu/ieec/.
[107] See http://www.sensorcat.sunysb.edu/.
[108] See http://www.case.syr.edu/.
[109] See http://www.albanynanotech.org/centers_programs/thin_film.cfm.
[110] See http://www.ceis.rochester.edu/.

Three years ago, NYSTAR was allocated some $95 million in capital funding to complement its operating grants with one-time investments in research buildings and large scientific equipment. These grants likewise have been distributed across fields and around the state and are not made to the CATs. Also using one-time bond funding from the state financing agency, the Governor committed 2 years ago to creation of five Centers of Excellence that are modeled on the Cal Institutes. About $250 million is to be made available in awards of $35 million to $50 million to each of five centers, predominantly for capital needs and with some undetermined amount set aside for seeding center operations. The program is intended to leverage between two and three times that amount in private commitments of various kinds (capital, in-kind contributions, and operating grants). The state therefore portrays the total size of the effort at approximately $1 billion. The two centers with an IT focus happen to be in Rochester and Albany, as described immediately below.

## CENTERS OF EXCELLENCE

### Rochester

- **Infotonics**, the informal name for a Center of Excellence in Photonics and Microsystems,[111] is unique among the five centers as an off-campus, free-standing nonprofit corporation. Though it involves heavy cooperation from the UR and the RIT, its main private funders and true leaders are Kodak, Xerox, and Corning. In fact, it is based outside Rochester at a 123,000-square-foot former Xerox inkjet manufacturing line in Canandaigua. The Infotonics facility includes 22,000 square feet of clean room space, about half at class 100. Its annual grant budget is about $4.5 million, distributed last year across 17 participating universities and colleges statewide. The programs of Infotonics focus on MEMS and MOEMS (micro-optical electromechanical devices) with priority given to projects that could lead to pilot fabrication runs in the Center clean rooms. The Center also offers K-12 programming and targets small firms with SBIR and commercialization assistance. The total Center commitment is listed as $75 million, of which $30 million will come from the state over time.

As noted above, Rochester also hosts the Center for Electronic Imaging Systems, a joint UR/RIT CAT that has historically been used as a way to strengthen the optics research offerings of both institutions and their partners at Kodak, Xerox, and Bausch & Lomb. Recently, this Center received an "enhanced CAT" award to expand into microelectronics design, which presumably enhances the capability of these institutions to compete for awards from Infotonics. In addition, several of the region's universities also received a one-time "STAR" capital award of $14 million to construct an Information Technology Collaboratory. The goal is to integrate the work of the CAT with information technology applications. Again, this award is consistent with and reinforces the Infotonics effort.

[111] See http://www.infotonics.org/AboutInfotonics/History.asp.

### Albany

- **Center of Excellence in Nanoelectronics**[112] is the state's capstone investment in the Nanotech complex at SUNY Albany and a key part of the deal to attract International Sematech and Tokyo Electron. The campus already had a substantial installed base of 200mm semiconductor and thin-film equipment thanks to earlier state support to the Thin Film CAT and the SRC-sponsored Focus Center on Interconnects.[113] The Center of Excellence takes the campus's microelectronics total investment to $500 million, counting both capital grants and cumulative operating support over the next several years from both the state and its industry partners, Sematech, TEL, and IBM. The facilities include nearly 60,000 square feet of 300mm clean rooms spread over two buildings (136,000 and 228,000 square feet)—the largest such facility at an American academic site. These facilities are being shared among researchers from both academia and industry.

At the same time, the state is renovating a nearby 350-acre former government campus to serve as a research park to house smaller companies collaborating with Nanotech or emerging from SUNY intellectual property.

### Other Regions

On Long Island, the IT center of excellence is

- **Center of Excellence in Wireless Internet and Information Technology**[114]—a collaboration of SUNY Stony Brook, Symbol Technologies, Computer Associates, and Reuters. The Center places emphasis on cyber-security, concurrency and verification, file systems and storage, and other applications. State support will purchase a 100,000-square-foot building near campus, with facilities for visualization, networking, etc. The original state commitment of $35 million was expanded to $50 million to match federal grants in cyber-security.

On a statewide basis, New York State retains from the days of the NSF supercomputer center at Cornell a statewide, high-bandwidth network. NYSERNet[115] is in the process of expanding its base of clients from research universities to other educational and cultural institutions and has a major fiber-laying program under way in New York City. NYSTAR also supports a young-investigator award, a senior-faculty development award, a program involving teaching colleges, and a Science and Technology Law center to provide legal advice to both start-up businesses and university technology transfer offices.[116]

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

Legislation in 2000 gave NYSTAR authority and temporary funding to operate an industry matching-grant program of the kind that several of the CATs already offer internally. The Technology Transfer Incentive Program[117] supports applied or precommercialization research

[112] See http://www.albanynanotech.org/centers_programs/NanoTech_centers.cfm.
[113] See http://www.albanynanotech.org/centers_programs/focus_center.cfm.
[114] See http://lina.tns.sunysb.edu:8080/indexnew.htm.
[115] See network diagram at: http://www.nysernet.org/gif/net5aa.jpg.
[116] For the roster of statewide programs see http://www.nystar.state.ny.us/initiatives.htm.
[117] See http://www.nystar.state.ny.us/ttip.htm.

conducted by faculty in conjunction with one or more New York State-based industrial partners who are willing to provide matching support. These projects typically could not attract peer-reviewed federal grants precisely because of their applied and commercial orientation. Awards from a $7.5 million pool were offered in amounts up to $500,000 over several years.

The 64-campus SUNY system (including large university centers, specialized campuses, teaching colleges, and community colleges) has recently a Vice Chancellor for Business and Industry Relations.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

There is no statewide trade association in IT or advanced communications, and NYSTAR has been only minimally involved in cluster formation. Such initiatives have been left largely to the NYSTAR-supported network of Regional Technology Development Centers (RTDCs), which operate the MEP program and provide commercialization counseling to high-tech businesses.[118]

For example, the RTDC known as High Tech Rochester (HTR)[119] is closely affiliated with a regional High Technology Business Council (HTBC)[120] that is stressing photonics, IT/software, and life sciences. In the software space, the HTBC faces competition from a grass-roots organization that calls itself Digital Rochester.[121] Because of fragmentation among all the region's economic-development and cluster initiatives, business leaders have backed an umbrella organization, the Greater Rochester Enterprise,[122] which has placed initial emphasis on a fuel-cell initiative. In Albany, the RTDC is the Center for Economic Growth, which likewise sponsors a regional Technology Council.[123]

In New York City, the City University of New York (CUNY) houses an internship program run jointly with the New York [City] Software Industry Association (NYSIA).[124] This program selects the most highly accomplished computer science students in the CUNY system and reimburses employers who are NYSIA members 50 percent of their salary up to a maximum of $1,000 per semester. Interns must be paid at least $10 per hour for up to 20 hours a week. Employers who are not NYSIA members may receive placements but are not eligible for the subsidy.

## ENTREPRENEURIAL INFRASTRUCTURE

### Rochester

There are three principal elements of the region's technology infrastructure, none of which is strongly supported by the state.

[118] See http://www.nystar.state.ny.us/rtdcs.htm.
[119] See http://www.htr.org/.
[120] See http://www.htbc.org/.
[121] See http://www.digitalrochester.com/.
[122] See http://greaterrochesterenterprise.com.
[123] See http://www.ceg.org/about/TechnologyCouncil.htm.
[124] See http://www.cisdd.org/nysiaintern.html.

- The **Lenox Tech Enterprise Center (TEC)**[125] is a 50,000-square-foot office and "dry-lab" incubator operated by HTR and located in RIT's 81-acre Business and Technology Park[126] adjacent to the RIT campus, in suburban West Henrietta. There are 18 to 20 firms in residence at any one time, and the TEC just graduated its 51st company. This is widely considered a strong success in the technology community.
- A short distance away, on the main campus, RIT has opened its own **High Technology Incubator**[127] of similar size. It is thought likely that RIT will contract with HTR to manage business incubation services at this facility so that the two do not end up competing based on who can offer the lowest rent. Both incubators are in state Empire Zones.
- **Rochester Technology Park**[128] is a 500-acre mixed use technology-industrial park (full buildout target of 5 million square feet) being developed by a California real-estate firm on the site of a former Kodak facility in Rochester. Anchored by the North American headquarters of Heidelberg Digital, the park is targeting a broad range of technology and non-technology uses (including life sciences) and is also designated an Empire Zone.

### Albany

The building in which Albany Nanotech is being constructed has long doubled as an incubator for SUNY Albany, but the major infrastructure elements in the region belong to Rensselaer Polytechnic Institute, which operates an on-campus incubator[129] and an off-campus research park.[130] IT is one of RPI's institutional priorities. Its Entrepreneurial Center also is active in supporting regional business formation.

## VENTURE FUNDING AND INFRASTRUCTURE

The Empire State Development Corporation now operates the Small Business Technology Investment Fund, the quasi-public venture fund begun under the Science and Technology Foundation.[131] In addition, the state Insurance Department is authorized by law to grant CAPCO credits,[132] and the state Comptroller—the sole fiduciary of the giant state Common Retirement Fund—has invested $90 million of an overall $1.1 billion venture-capital allocation in New York State-domiciled venture partnerships.[133] There is, however, no evidence that this latter program has resulted in any incremental funding being made available to New York-based start-up companies, as the selected venture partnerships have been conservative in their approach and oriented to a wide geographic region.

[125] See http://www.htr.org/Pages/tec/tec_core2.htm.
[126] See http://park.rit.edu/pi_location.shtml.
[127] See http://www.rithi.org/.
[128] See http://www.rochestertechpark.com/.
[129] See http://www.rpi.edu/dept/incubator/homepage/.
[130] http://www.rpi.edu/dept/rtp/.
[131] See http://www.banking.state.ny.us/sbusines/nys-stf.htm.
[132] See http://www.ins.state.ny.us/acrobat/annrpt02.pdf, p. 40.
[133] See http://nysosc3.osc.state.ny.us/press/venturecapmanagers.htm.

## BUSINESS CLIMATE

New York State's business climate is high-cost, but countervailing initiatives[134] include the following:

- A network of low-tax Empire Zones
- Employment and capital investment tax credits applied to "emerging technology" firms, as defined under statute or with R&D-to-sales ratios exceeding the 3.6 percent national average
- An R&D tax credit.

## SUMMARY OF SUCCESS FACTORS

- Significant public investments in R&D capacity coordinated with attraction strategy (Albany)
- Involvement of major corporations in efforts to stimulate start-ups (Rochester, Hudson Valley)
- Diverse, well-funded state technology program with heavy IT emphasis and reach into all major universities

[134] See http://www.nylovesbiz.com/default.asp.

# Texas/Austin

## STATE AND REGIONAL OVERVIEW

Although Dallas and the nearby "Telecom Corridor" dominated by Texas Instruments and its peers have traditionally ranked higher in measures of IT employment, it is Austin that first awakened American regions to the importance of technology-based development. In 1983 this then-sleepy college town unexpectedly won the competition among 57 cities to host the Micro-electronics and Computer Technology Corp. (MCC), a private consortium of computer-related firms.[135] Six years later, Austin triumphed over 100 other cities to host the federally sponsored Sematech consortium, which now has 500 employees and a $150 million annual budget.[136] Both victories were secured when business leaders organized to woo the selection committees and successfully lobbied the state not only for direct incentives but also to promise targeted investments in senior faculty positions in electrical engineering and computer science at UT Austin.[137] Although Austin already had one major technology company that was generating spin-offs (Tracor), access to technical and managerial talent that rotated through these two consortia was key to Austin's subsequent success in attracting and growing IT companies.

Most of the employment was in microelectronics branch plants. However, it was also in the 1980s that Michael Dell began the business that became Dell Computer, the sole Fortune 500 head-quartered in the region, which, despite rapid growth, is still dominated by state government and the university campus. Among the semiconductor giants with investments in Austin include IBM,[138] Motorola, Samsung, AMD, Applied Materials, 3M, DuPont Photomasks, and Cypress semiconductor. Recycled wealth from Dell and other start-ups[139] propelled Austin to high venture-backed start-up ranking in the late 1990s Internet boom. Most recently, Austin again had to mobilize to retain Sematech in the face of major incentives provided by New York State for creation of a northern branch (see New York State profile). Ultimately Governor Perry provided $40 million through the Texas Enterprise Fund, a state economic-development incentive fund.[140] The state also is investing heavily to boost the R&D capacity of UT Dallas in partnership with a $3 billion 300mm fab investment being made locally by TI.

## STRATEGY ENVIRONMENT

With historically weak leadership at the state level,[141] Austin's development strategy has been propelled since the 1970s mainly by the Greater Austin Chamber of Commerce, whose role in lobbying the state for research support and pushing American Airlines to add service to Silicon

[135] At its peak MCC had a $150 million budget from its members. It reorganized into a for-profit commercialization company in 2000. See http://www.mcc.com/09jun00pr.htm.
[136] Now called International Sematech. See http://www.sematech.org/public/index.htm.
[137] Then in the process of building its engineering programs to compete with Texas A&M.
[138] IBM started its local presence with a typewriter plant in 1967, but now supports one of eight worldwide research centers in Austin.
[139] Such as Tivoli, sold to IBM and merged with Indianapolis-based Software Artistry.
[140] See http://www.governor.state.tx.us/divisions/press/initiatives/sots/enterprise.
[141] Only at the height of the Internet boom did the state create a Governor's Science and Technology Council, which focused on workforce issues and has since gone largely inactive.

Valley is well documented, and the more recent Austin Technology Council (see below). Both played a role in the recent Sematech retention package.

Start-up and growth-company strategy has been steered mainly by the quasi-independent IC$^2$ Institute (originally known as the Institute for Constructive Capitalism), created by the late, charismatic UT business dean George Kozmetsky to channel the energies of the campus's entrepreneurial faculty and students, at a time when this was not yet a well-accepted role for the university.

Since Kozmetsky's death, UT has moved to reintegrate IC$^2$ into the mainstream of the business college, where it meshes with existing activities such as Moot Corp., a 21-year-old effort which bills itself as " the super bowl of world business plan competition."[142] UT also has created a campus-based Texas Alliance for Technology Commercialization that embraces the engineering college.[143]

## CENTERS OF EXCELLENCE

Already strong in the natural sciences and engineering, but lacking a medical school, UT Austin has emphasized building its R&D base in microelectronics and allied sciences. Among the assets the UT accrued through state and federal line-item support targeted at MCC or Sematech were the following:

- Thirty-two endowed chairs in engineering and science, at $1 million each, financed by $16 million in local philanthropic donations matched by allocations from the Texas Permanent University Fund[144]
- The $30 million laboratory that was leased to MCC for $2 a year following UT investment of $14 million
- A 275,000-square-foot Sematech manufacturing plant at UT's 92-acre off-campus research park (where it also collocated the university's Microelectronics Research Center).

UT has continued its own investment program in the same areas. Major additions include the following:

- **Texas Advanced Computing Center**,[145] launched at the UT research campus with more than $25 million in university funds
- The **Institute for Computational Sciences and Engineering**,[146] a $38 million initiative at the main campus
- Advanced materials programs (including in nanotechnology manufacturing)[147] that will expand the campus's historic strengths in micro-scale manufacturing into the nanometer realm.

[142] See http://www.mootcorp.org/.
[143] See http://www.texalliance.org/news/index.cfm.
[144] See http://www.utimco.org/scripts/internet/fundsdetail.asp?fnd=2.
[145] See http://www.tacc.utexas.edu/.
[146] See http://www.ticam.utexas.edu/.
[147] See http://www.utexas.edu/academic/tmi/about.shtml and http://www.cm.utexas.edu/cnm/.

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

For many years, the Texas Higher Education Coordinating Board has offered grants for both research capacity-building and university/industry partnerships through its **Advanced Research Program/Advanced Technology Program**.[148] In the most recent competition, about $20 million was made available for the ATP, which is open to both public and private institutions, including a 20 percent setaside for joint university/industry commercialization projects. The ARP was unfunded, in part because the Legislature had funded many other research-capacity initiatives on a line-item basis. Both programs have always targeted large shares to IT-relevant disciplines.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

Kozmetsky, a co-founder of the Silicon Valley giant Teledyne, also played a role in mentoring Michael Dell and many later startup entrepreneurs in Austin. At his insistence, $IC^2$ incubated in 1992 and then spun out in 1998 a cluster organization that became first the Austin Software Council and then the Austin Technology Council.[149]

Austin also hosts the Technology Business Network, a national membership organization, which also runs regional industry forums in several sectors, including "NxGen Communications" and "Information Management and Security."[150]

Paralleling recent statewide organization in the biosciences, interested companies have recently created an informal, voluntary Texas Nanotechnology Initiative that rotates its meetings among Austin, Houston, and Richardson (heart of the Dallas/North Texas telecom corridor).[151]

What was originally a local E-commerce association has turned into an Austin council of a statewide Texas Ecom.[152] However, Austin retains its own Multimedia Alliance,[153] which is more a professional association than a cluster initiative.

Most of the more imaginative IT workforce initiatives in Texas are actually near Dallas. For example, an entire UT branch campus (Arlington) exists largely to serve the educational needs of TI, though the company has recently signed on to state efforts to upgrade the research-oriented UT campus at Dallas. One other outcome of the brief state-level interest in IT workforce issues was creation of the Texas Telecommunications Engineering Consortium, based at Texas A&M in College Station.[154]

The main initiative in Austin is the Capital Area Training Foundation, a Chamber of Commerce subsidiary that, in addition to its work with the community college, has partnered with AMD on programs to enrich the training of K-12 science and math teachers in areas considered of importance to high-technology employers.[155]

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[148] See http://www.arpatp.com.
[149] See http://www.austinsoftwarecouncil.org/.
[150] See http://www.techbiz.com under "programs."
[151] See http://www.texasnano.org/faqs.html.
[152] See http://www.texasecomm.org/.
[153] See http://www.aama.org/.
[154] See http://www.txtec.org/
[155] See http://www.austinchamber.org/The_Chamber/About_The_Chamber/What_We_Do/Workforce_Development/CATF/Services_Products/HTEN/.

## ENTREPRENEURIAL INFRASTRUCTURE

Two of the cornerstones of Austin's entrepreneurial infrastructure are the Austin Technology Incubator,[156] based at the MCC building since 1989, and the Texas Capital Network, an angel investor connecting service that now has national ambitions as "The Capital Network."[157]

The 45,000-square-foot ATI incubator, cosponsored by the Chamber of Commerce and the city, asks 1 percent equity stakes from its tenants. It claims 60 graduates since 1989, including five that have gone public, creating more than 2,000 jobs and generating $900 million in annual revenue. TCN makes analogous claims.

## VENTURE FINANCING AND INFRASTRUCTURE

Austin has long been amply supplied with later-stage venture capital; the largest local firm, Austin Ventures, dates to pre-MCC days (1979), and, once the Chamber had begun focusing on air service, many Silicon Valley firms opened Austin offices. Recently, UTIMCO, UT's captive endowment-management firm, announced that it would hold aside a share of its existing asset allocation to venture capital for venture partnerships that commit to focusing on financing early-stage spin-offs from the UT system (both life science and materials science).[158] This program has not yet taken shape. The Legislature also has created two seed-stage funds[159] to be housed in the Comptroller's office; but, they are focused mainly on life science, and legal issues have interfered with their timely start-up.

## SUMMARY OF SUCCESS FACTORS

- Active role of mainstream business community in recruitment of anchors
- Public participation in building university R&D capacity
- Visionary leadership of entrepreneurial programs
- Successful connections with headquarters operations in Silicon Valley

[156] See http://ati.ic2.org/.
[157] See http://www.thecapitalnetwork.com/.
[158] See http://www.utimco.org/pressreleases/11132003_PressRelease.htm.
[159] The $25 million Product Development Fund and the $20 million Small Business Incubator Fund.

# Virginia/Northern VA and DC

## State and Regional Overview

Virginia has multiple mid-sized technology poles, one around each of its major research institutions. The state's strongest IT research programs are unquestionably at Virginia Tech, at Blacksburg in the rural, far southwestern corner of the state. However, it is the Washington, D.C., suburbs of northern Virginia that have emerged as the center of the state's AC-IT sector, despite the relatively modest research budget of its resident public university, George Mason.

The sector actually has its roots in the Washington Beltway's defense and technology contractors. In 1968, William McGowan emerged from this community to found Microwave Communications of America, which eventually became MCI. By the mid 1980s, MCI was a fast-growing long-distance provider based in Washington, and its alumni played an important role in seeding the region's telecom start-ups. There were other sources of talent as well. In 1987, seeing the emergence of a publicly accessible but privately operated Internet on the horizon, key employees of DoD's ARPANET initiative and its private contractors left to found UUNET, a critical Internet backbone service provider that was eventually folded into MCI/Worldcom and remained based in the region throughout.

At about the same time, Steve Case founded Quantum Computer Systems, an on-line gaming system that ultimately transformed into America On Line, based in the town of Vienna. As AOL interconnected its proprietary telecom network with the emerging public Internet, northern Virginia became one of the most "wired" spots on the world, ultimately hosting four of the nation's top 10 ISPs and billing itself by the late 1990s as home to half the world's Internet traffic. All this activity attracted in turn the attention of several hardware manufacturers. After the successful opening of a semiconductor fab by Motorola and Siemens in Richmond (now operated by Infineon), IBM and Toshiba followed with a similar facility in the northern Virginia town of Manassas (later sold to Micron). Although Motorola later canceled its announced plans to build its own, separate $3 billion 300mm fab, and although there have been layoffs and canceled expansion plans at both the existing fabs, the state had clearly emerged as a secondary center of fabrication.

Development activity climaxed in the late 1990s with a major new operations center for MCI/Worldcom in Loudoun County and AOL's half-billion-dollar technology center in Prince William County. In choosing Virginia, AOL was said to have walked away from a larger incentive package offered by Georgia in order to retain its historic roots (this was before its takeover of Time Warner).

## Strategy Environment

Virginia's technology efforts are led by the Center for Innovative Technology (CIT), a nonprofit public/private partnership created in 1984. From 1986 to 1992, CIT funded 13 university-hosted Technology Development Centers (TDCs), 11 of them now self-supporting. These are structured as university/industry research consortia. In 1998, the centers program was recast as Technology Innovation Centers (TICs), which are aimed more directly at product commercialization. CIT describes them as umbrellas or joint ventures among the state, the colleges and universities,

federal laboratories, and other R&D organizations. Their goal is to operate as full-service centers for particular technology sectors. CIT also has made a variety of seeding and discretionary awards, described below.

Among CIT's key board members is the Virginia Secretary of Technology—a position created by then-Governor Gilmore during the Internet boom to serve as the state's CIO and cheerleader for development of the sector. State appropriations for CIT have waxed and waned over the years, due in part to the fact that Virginia's governors are limited to one term, and the leadership of CIT has changed with each transition. CIT does host the Virginia Research and Technology Advisory Commission, [160] a group that advises the Governor on the direction of state S&T policy.

## CENTERS OF EXCELLENCE

Two of the earliest TDCs supported by CIT were in the IT field, but neither is based in northern Virginia. Both are well established and long independent of state support, with corporate sponsorship that is both regional and national:

- **Fiber & Electro-Optics Research Center** [161]—based at Virginia Tech, in Blacksburg
- **Center for Wireless Telecommunications**,[162] also at Virginia Tech.

Two of the three TICs are IT-oriented, but again neither is based in the region:

- **Center for Plasma and Photon Processing**, a multiuniversity collaboration hosted by the Jefferson National Accelerator Laboratory in Newport News[163]
- **Internet Technical Innovation Center,** a virtual consortium of several of the state's universities with no physical headquarters in any of the regions.[164]

Through its research or technology programs, CIT also made seeding "Innovation Awards" to various IT initiatives including two in the region:

- AOL's On-line Home of the 21st Century Lab (a testbed for Internet appliances) at George Washington University's Loudoun County campus
- Optical networking research at George Mason University.

Outside the region, CIT also made several IT-related awards to the University of Virginia that tracked the interests of the semiconductor manufacturers, especially in integrated and nanoscale systems.

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

In 2000, at the height of the state's Internet boom, the state created the Commonwealth Technology Research Fund, intended as an incentive award to help increase the flow of public and private research funding to the state's universities, in both IT and other disciplines. Originally

[160] See http://www.cit.org/vrtac/.
[161] See http://www.ee.vt.edu/~feorc/index.htm.
[162] See http://www.cwt.vt.edu/about/default.htm.
[163] See http://www.jlab.org/ARC/.
[164] See http://www.internettic.org/aboutus.shtml.

created in the Department of Planning and Budget, the program was moved to CIT in FY 2004, but apparently without current appropriation.[165] At its peak, it was funded at about $25 million per year and had made multiple IT-related awards in fields such as bioinformatics, information security, and advanced printed-circuit-board design.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

Although Virginia does not have a specific IT cluster organization, it is home to the World Information Technology and Services Alliance, an entity with global ambitions.[166] Created with support from CIT, the Northern Virginia Technology Council[167] is a regional multisector technology council. Given the employment base of the region, it does place heavy emphasis on the IT, software, Internet, telecom, and nanotechnology sectors.

At one time, the Northern Virginia Economic Development Coalition—one of 19 regional partnerships sponsored by the state development agency—offered significant programs in IT workforce preparedness, but these have been discontinued.

## ENTREPRENEURIAL INFRASTRUCTURE

CIT sponsors five entrepreneurship centers, one each at George Mason, Old Dominion, Virginia Commonwealth, Virginia Tech, and the College of William and Mary. Staffed by university personnel, these "incubators without walls" focus on business-advisory services and connecting entrepreneurs through CIT's Capital Access Program with the many sources of investment available in the state. A similar virtual service offered directly by CIT is "Innovation Avenue," a Web portal.[168] The service provides access to resources on entrepreneurship, legal issues, and finance and sales expertise. Specially aimed at counseling small firms using e-commerce, the Virginia Electronic Commerce Technology Center[169] is based in the Hampton Roads region, an outgrowth of the Southeastern Virginia Network, a regional broadband network serving government, small business, and educational institutions in the Hampton Roads region.[170]

There is a formal incubator associated with the Jefferson Lab in Newport News,[171] and with the research parks at Virginia Tech (Blacksburg)[172] and Virginia Commonwealth (Richmond).[173] University of Virginia (Charlottesville) has two research parks, but no formal incubator.[174]

[165] See http://www.cit.org/ctrf-main.asp.
[166] See http://www.witsa.org/about/.
[167] See http://www.nvtc.org/about.
[168] See http://www.innovationavenue.com/.
[169] See http://www.vectec.org.
[170] See http://www.seva.net/.
[171] See http://www.jlab.org/ARC/.
[172] See http://www.vtcrc.com/.
[173] See http://www.vabiotech.com/.
[174] See http://www.uvafoundation.com/researchparks/.

## VENTURE FINANCING AND INFRASTRUCTURE

CIT also operates a "Growth Acceleration Program" (GAP)[175] that makes pre-seed investments of up to $100,000, which must be matched one-to-one by other investors. CIT also will introduce IT entrepreneurs to a series of regional angel investment clubs and venture-capital forums.

## BUSINESS CLIMATE

The Secretary of Technology, now responsible for Virginia Information Technologies Agency, made substantial progress in bringing state government services on-line, improving the regulatory environment through privacy and e-signature initiatives, and raising the profile of the state in national debates over Internet taxation.

The main incentive aimed at IT firms is the Virginia "technology zone" program modeled on its existing enterprise zone program. Some 13 zones have been created around the state.

## SUMMARY OF SUCCESS FACTORS

- Accident of corporate lineage, leading to dense telecom networking capacity
- Public investment in university R&D capacity
- Heavy involvement of public universities in research parks, incubators
- State's decision to take a high profile in IT public policy development

[175] See http://www.cit.org/gap-04.asp.

# Ireland

## OVERVIEW

During the past 25 years, the Republic of Ireland has leveraged its highly educated workforce to hone a reputation as the preferred low-cost platform for global IT and telecom enterprises that are targeting the European markets. A range of multinational companies operate facilities ranging from assembly plants to semiconductor fabs and R&D laboratories. Like many branch-plant economies, Ireland has seen this strong flow of inward investment as an opportunity to jump-start its community of technology-based SMEs.[176] Enterprise Ireland, the agency responsible for this job, is currently executing what it calls "ITS 2007," a formal strategy to develop an internationally traded sector in informatics services.[177]

## STRATEGY ENVIRONMENT

The Irish government has spent the last decade reconfiguring its traditional economic-development and research agencies to better address the needs of its targeted technology clusters (biosciences and IT), effectively implementing the Irish analogue to the UK's well-regarded "foresight" program. An umbrella development agency once known as Forbairt was split in two parts: (1) IDA Ireland,[178] which now focuses only on promoting inward investment, and (2) Enterprise Ireland, the agency charged to promote the indigenous SME sector. Forfás—an advisory board that housed a Council on Science Technology and Innovation[179]—lost some of its programmatic responsibilities but spawned an entirely new statutory agency, the Science Foundation of Ireland (SFI).[180] SFI's research programs are less applied than those of Enterprise Ireland but more strategic and collaborative in approach than those of the traditional research funders, the Higher Education Authority and several associated Research Councils. SFI and Enterprise Ireland are partners in implementing the nation's IT strategy.

## CENTERS OF EXCELLENCE

Ireland' earliest and best-known IT center of excellence, which pre-dates all current government programs, is the **National Microelectronics Research Centre**,[181] established in 1981. Based in Cork, the NMRC has programmatic interactions with all "third-level" Irish research institutions, including the major public universities, private colleges, and the training-oriented Institutes of Technology. It has capability in the communications applications of optoelectronics and is adding a user facility in nanotechnology.

In 1989, building on this perceived success, the government leveraged EU funds to establish a series of **Technology Centres** at Irish universities. Most focused on the traditional manufacturing sectors, but a few (for example, industrial control, surface and interface analysis, avionics)

[176] Small and Medium-sized Enterprises, the preferred European term for entrepreneurial firms.
[177] Plan available on-line at: http://www.nsd.ie/htm/links_pub/pdf/ITS-brochure-npcover.pdf.
[178] See http://www.ida.ie/home/index.asp.
[179] See http://www.forfas.ie/profile/role.htm.
[180] See http://www.sfi.ie.
[181] See http://www.nmrc.ie/profile/index.html.

touched on IT sectors. This initiative ultimately faded in favor of the government's later **Programmes in Advanced Technology** (PATs)—decentralized and industry-driven grant programs for smaller-scale university-based research projects. [182] Of the five PATs, four were IT-related areas: informatics,[183] power electronics,[184] materials, and optronics. Research projects seeded by the PATs remain in operation at many of Ireland's universities. Several were "adopted" by Enterprise Ireland, while others have developed direct industrial support or relationships with similar programs offered through the European Union.

Currently, the Science Foundation of Ireland is offering to support university-based, industry-driven **Centres for Science, Engineering and Technology**. Awards will be made at up to €5 million per year for up to 5 years.[185] The program is new and has no track record that can be evaluated.

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

Additional collaborative programs below the scale of a center of excellence are offered by Enterprise Ireland:

- **Research Technology and Innovation Competitive Grants Scheme**[186]—which encourages companies to conduct research in collaboration with Irish universities, with up to €650,000 in combined grants and loans (higher proportion of outright grants for SMEs)
- **Campus Companies Program**—which provides half the cost of pre-commercialization research up to €38,000 for academic entrepreneurs preparing university spin-offs
- **Research and Development Capability Initiative**—which underwrites up to 45 percent of eligible investment by Ireland-based companies in building R&D capacity.

In addition, three universities in the western counties of Ireland have banded together to offer what they call a Technology Transfer Initiative—in reality, an industrial liaison "gateway" to their R&D programs.[187]

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

The Irish Software Association, which dates back two decades,[188] was joined by an Irish Nanotechnology Association[189] spun off by Enterprise Ireland in 2002 and managed on its behalf by the Materials PAT.

Based on a "future skills" expert group convened by Forfás at the height of the global IT boom, a number of training initiatives were also developed. The National College of Ireland launched the School of Informatics in 1998. Somewhat less conventionally, Enterprise Ireland operates an IT Systems Programme that provides a subsidy grant to companies employing young graduates in

[182] See http://www.enterprise-ireland.com/industry-programmes.asp.
[183] See http://www.enterprise-ireland.com/documents/uploaded/informatics_2003.pdf.
[184] See http://www.pei-tech.ie/.
[185] See http://www.sfi.ie/content/content.asp?section_id=189&language_id=1.
[186] See http://www.enterprise-ireland.com/cat5.asp.
[187] See http://www.technologytransfer.ie/about.html.
[188] See http://www.software.ie/.
[189] See http://www.nanotechireland.com/aboutus.html.

IT. For a time the agency also subsidized the development of software products for large IT firms by Irish SMEs, which retained development rights in other fields of use.

## ENTREPRENEURIAL INFRASTRUCTURE

Enterprise Ireland supports a series of college-based business incubators and also offers the following direct-investment programs:

- **Commercialization Fund—**a three-stage grant aimed at commercializing discoveries emerging from university-based programs. It provides up to €90,000 over 18 months for proof of concept, up to €350,000 over 36 months for technology development, and half the cost up to €38,000 for business development.
- **Enterprise Platform Fund**—1-year full-time professional training for entrepreneurs at half current salary, up to €550 per month.

Shannon Development, which for historic reasons targets the Shannon region independent of Enterprise Ireland,[190] also has supported two research and technology parks equipped with business incubators and/or commercialization counseling:

- **National Technology Park** in Limerick,[191] a 1.5-million-square-foot research park with 3,000 employees from 80 organizations
- **Kerry Technology Park** in Tralee,[192] a 113-acre park with a target employment level of 1,000 by 2007, also housing the Enterprise House incubator.

## VENTURE FINANCING AND INFRASTRUCTURE

Aside from the pre-seed-stage direct investment programs described above, Enterprise Ireland has invested €95 million of public funds in a series of 15 privately managed venture capital funds, leveraging a total of €400 million in private capital.[193] Most of these funds are either open to IT or focused specially on IT opportunities.

## SUMMARY OF SUCCESS FACTORS

- Inward attraction tactics based on low-cost, highly educated workforce
- Heavy public investment in industry-driven R&D centers and grant programs
- Strategy to leverage global firms' participation in these centers to stimulate SME sector

[190] See http://www.shannondev.ie/background/history.htm.
[191] See http://www.shannondev.ie/ntp/info_1.html.
[192] See http://www.shannondev.ie/ktp/overview.html.
[193] See http://www.enterprise-ireland.ie/solutions-finance.asp.

# Singapore

## OVERVIEW

Acting through a dense array of government agencies and quasi-public entities, Singapore has steadily moved itself from a center of low-end electronics assembly to a full-service hub for the global communications and information technology business. Sectors now represented include fully integrated semiconductor fabrication; data-storage and display components; integration of telecom and computer systems; and, increasingly, software development and services. The IT industry in Singapore encompasses direct investments by many U.S. and Japanese multinational firms, but also a number of domestic joint-venture partners, including SMEs that government strategy targets to move up the value chain and become export leaders. Singapore by no means disdains economic-development subsidies; but, unlike some of its neighbors, its development strategy also has emphasized development of "intellectual capital." A sequence of "National IT plans" stretching back at least to 1980 has guided the computerization of government and education of the populace for IT jobs. More recently, there has been strong emphasis on an increasingly sophisticated R&D infrastructure.

## STRATEGY ENVIRONMENT

Development strategy is coordinated by the Ministry of Trade and Industry,[194] in close partnership with nine quasi-public agencies, including most prominently the Economic Development Board, created in 1961.[195] EDB and the other boards—including the Agency for Science, Technology and Research[196]—collectively control billions of dollars in resources that are applied to a range of Ministry-sponsored strategic development plans including those with the following titles:

- Building World-Class Companies
- Strengthening base of SMEs
- Productivity Action 21
- Thinking Schools and Nation
- Technopreneurship 21
- National Science and Technology Plan 2000
- Industry 21
- Leveraging Science, Technology and Innovation
- Manufacturing Services as Twin Engines
- Manpower 21
- SME 21.

[194] See http://www.mti.gov.sg/public/MTI/frm_MTI_Default.asp?sid=15.
[195] See http://www.sedb.com/edbcorp/sg/en_uk/index/about_edb/edb_history0.html.
[196] See http://www.nstb.gov.sg/astar/about/action/about_astar.do.

## CENTERS OF EXCELLENCE

A*STAR (formerly known as the National Science and Technology Board) comprises a Science and Engineering Research Council, a biomedical counterpart, and a commercialization arm. Through a $4 billion action plan launched in 1996, A*STAR has created a series of nearly a dozen "public research institutes" that are loosely linked to Singapore's main universities and which attempt to involve industry significantly in joint R&D partnerships. Among the institutes relevant to the communications and IT sectors are the following:

- **Data Storage Institute**[197]—from conventional magnetic heads to advanced storage networking and to nano-spin electronics research
- **Institute for Infocomm Research**[198]—including cyber-security, data mining, human-computer interfaces, distributed computing, and mobile/satellite telecom
- **Institute of Materials Research and Engineering**[199]**—**similar to a nanotechnology institute in the biomedical segment but focused more on the engineering and electronics sectors
- **Institute of High Performance Computing**[200]—including applications in nanomechanics and other disciplines relevant to processing
- **Institute of Microelectronics**[201]—including packaging, design, MEMS/nano innovation.

The main IT initiative inside the university structure is a new, interdisciplinary School of Computing at National University.[202]

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

A*STAR's Exploit Technologies Pte provides funding for commercialization of discoveries emerging from the research institutes, offering one way for SMEs to exploit their subcontractor relationships with the multinational IT base. In addition, A*STAR participates in three multiagency subsidy programs:

- **Growing Enterprises with Technology Upgrade** (GET-UP), intended to connect companies with the capabilities of research institutes
- **Technology for Enterprise Capability Upgrading** (T-UP), a program that finances scientists from the research institutes to spend time in local industry
- **Operation and Technology Roadmapping**, which provides funding for development of modernization plans in concert with the institutes.

[197] See http://www.dsi.a-star.edu.sg/.
[198] See http://www.i2r.a-star.edu.sg/.
[199] See http://www.ices.a-star.edu.sg/.
[200] See http://www.ihpc.a-star.edu.sg/.
[201] See http://www.ime.a-star.edu.sg/.
[202] See http://www.comp.nus.edu.sg/aboutsoc/brief_overview.htm.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

A*STAR's R&D initiatives are paralleled and reinforced by cluster-development programs at the EDB. Among the entities that have been seeded are the Singapore Infocomm Technology Federation[203] and the Photonics Association of Singapore,[204] soon to sponsor its own center of excellence in photonics R&D. These programs are also reinforced by activities of the Infocomm Development Authority.[205]

Aimed at making Singapore a hub for e-commerce and finance throughout Asia, workforce strategy aims at universal IT competency. Among the programs sponsored by EDB are training for existing staff, pre-placement training, and graduate programs at both the National University and Nanyang Technological University. Additional training comes from Spring Singapore, a national productivity agency.[206]

## ENTREPRENEURIAL INFRASTRUCTURE

Singapore Science Park, founded in 1980, now encompasses three campuses totaling 65 hectares.[207] The first two campuses are IT-oriented (the third is targeted at life sciences). The Science Park hosts many of Singapore's multinational IT enterprises, as well as the headquarters of A*STAR (and some but not all of its institutes), the Defense Science and Technology Authority and defense R&D laboratories, and CINTECH. Science Park hosts one of a network of seven EDB-sponsored "HOTSpots" (incubators known as "Hubs of Technopreneurs").[208] Again, the majority are IT-oriented.

## VENTURE FINANCING AND INFRASTRUCTURE

Two of the government's interlocking "schemes" address capital-access: SEEDS (Startup Enterprise Development Scheme) and the Technopreneur Investment Incentive Scheme. Under the former program, EDB makes pre-seed investments up to S$300,000 provided they are matched by qualifying third-party investors of at least S$75,000 each.[209] The vast majority of the investments made have been in IT market segments.

Under the second program, EDB qualifies certain start-ups to issue their investors loss-insurance certificates up to S$3 million. In the event of a financial loss, investors may use these certificates to offset certain tax liabilities that would not otherwise be possible.[210]

At an even earlier stage, EDB offers individuals or small companies limited funding for professional and official fees involved in filing patent applications.

[203] See http://www.sitf.org.sg/index.aspx.
[204] See http://www.singoptics.org/.
[205] See http://www.ida.gov.sg/idaweb/aboutida/index.jsp.
[206] See http://www.spring.gov.sg/portal/aboutus/spring/springprofile.html.
[207] See http://www.sciencepark.com.sg/abtscipk/abtscipk.htm.
[208] See http://www.sedb.com/edbcorp/sg/en_uk/index/startups/incubators.html.
[209] See http://www.sedb.com/edbcorp/sg/en_uk/index/startups/financing/startup_enterprise.html.
[210] See http://www.sedb.com/edbcorp/sg/en_uk/index/startups/financing/technopreneur_investment.html.

EDB also manages a Web-based and personal referral program to members of the local venture association and angel investors network. EDB believes that S$16 billion is under management of Singapore-based venture firms.

## SUMMARY OF SUCCESS FACTORS

- Asian hub strategy predicated on intellectual capital, not just locational subsidy
- Heavy public investment in research capacity and collaborative R&D
- Steady efforts to boost SMEs as joint venture partners of global manufacturers

# Sweden

## OVERVIEW

With a history of excellence in industrial automation, Sweden has been investing in university-based information technology research since the 1960s. A combination of dispersed geography, a population disposed to adopt new technology, and lucky accident (local electronics firm Ericsson's runaway success in the global market for wireless handsets) led to the country's emergence as one of the most "wired" jurisdictions on the planet. Recent household penetration rates are 80 percent for wireless/mobile phones and 12 percent for broadband Internet connections, and government subsidies for computer and network deployment are driving these statistics steadily higher.

Leveraging the presence of domestic giants Ericsson and Telia, Sweden positioned itself as an ideal testbed for the convergence of mobile and Internet technologies, stressing development and market trials of Bluetooth (invented at Ericsson), WLAN, advanced fiber optics, and 3G wireless built on both European and American standards. With IT programs at every major university except the specialized medical institutions, Sweden has succeeded both in attracting significant inward investment from global telecom companies and at stimulating entrepreneurial enterprise. The Ministry of Industry and Trade and its Invest in Sweden Agency stress an "Information and Communications Technology" (ICT) strategy that involves applications in commercial, industrial, medical, and residential sectors. In fact, the government maps and "brands" these approaches by region:

- Mobile Valley (Stockholm/Kista), where ICT strategy emphasizes corporate R&D facilities and dense wireless coverage
- Telematics Valley (Göteborg), where researchers serve the nation's automotive center with intelligent vehicle technology
- Øresund (Lund), emphasizing the human interface
- Telecom City (Karlskrona), a wireless testbed
- Homecom (Linköping), emphasizing residential uses
- Internet Bay (the sparsely populated northern region around Luleå), emphasizing distance-spanning technology.

Other recognized elements of the ICT cluster include photonics, fiber optics, systems-on-chip, etc. There also are new efforts in micro- and nano-electronics and software products, but these strategies are less well developed.

## STRATEGY ENVIRONMENT

Sweden's university system has long received direct appropriations for research, including in ICT-related disciplines; and additional basic-research support is available through the Swedish Research Council,[211] created in 2001 to consolidate several pre-existing independent councils.

[211] See http://www.vr.se/english/index.asp.

However, more targeted and strategic research is the domain of several agencies or quasi-public foundations created by separate parliamentary action. Among the entities with relevance to the ICT sector are the following:

- **Vinnova, the Swedish Agency for Innovation Systems** (founded 2001), which serves the SME sector. With an annual budget of SEK 1 billion, Vinnova finances needs-driven research in both industry and academia, including development and demonstration of advanced technology in ICT and five other sectors. Vinnova developed the regional ICT strategies that ISA has branded (see above).
- **Swedish Foundation for Strategic Research** (founded in 1994),[212] which supports research in natural science, engineering, and medicine considered likely to enhance the nation's competitiveness. Spending at a rate of SEK 700 million annually, the Foundation will make its SEK 6 billion endowment last through the 2020s. The foundation supports individual faculty, on-campus research centers, off-campus institutes, and strategic reorientations of entire schools and institutions. Among its several focal areas are IT and microelectronics, and it supports both basic and applied projects.
- **Knowledge Foundation** (founded in 1994),[213] which emphasizes a similar role in Sweden's 18 "new universities" and university colleges. It focuses on building applied research of a high standard sufficient to attract industrial partnership, developing industry-tailored training programs, and applying IT to instructional needs. The Foundation is currently expending about SEK 275 million annually and has a permanent endowment.

## CENTERS OF EXCELLENCE

Sweden is densely supplied with ICT research centers, most university based and funded through university budgets or one or more of the entities noted above. Examples include the following:

- Stringent (Strategic Integrated Electronic Systems Research), a joint venture of two departments at the University of Linköping and billed as the largest single electronics research center in the nation[214]
- CCCD (Competence Center for Circuit Design), an academic/industrial center at Lund University, formed with support from Vinnova[215]
- Scint,[216] the Swedish Center for Internet Technologies, founded with support from Vinnova at IT University In Kista.

However, one of the most influential centers in the ICT space is outside the academic sector. Acreo,[217] a stand-alone contract research institute, was created in 1999 through merger of the former Institute for Industrial Microelectronics and Institute of Optical Research. Acreo is 60 percent owned by an industrial consortium and 40 percent by a state-owned company. It has a permanent staff of about 200, with head offices in Kista and branch facilities in four other cities.

[212] See http://www.stratresearch.se/eindex.htm.
[213] See http://www.kks.se/aboutus/.
[214] See http://www.ida.liu.se/~eslab/stringent/.
[215] See http://www.es.lth.se/cccd/.
[216] See http://www.scint.org.
[217] See http://www.acreo.se.

Acreo lists its core competencies as IC design, microelectronic process technologies, optical components and systems, packaging and interconnect technologies, robust electronics, sensor technologies, visual interfaces, and SME services. Either on industrial funds or in combination with government funding provided by one of the agencies above, Acreo has created the following notable centers of excellence, often with facilities distributed across Stockholm, Lund, and other multinational technology centers:

- **Kista Photonics Research Center** [218]—a joint effort with the Royal Institute of Technology, stressing both basic research and applications.
- **Socware Design Cluster**[219]—a cluster initiative co-sponsored by Invest In Sweden Agency and aimed mainly at global semiconductor firms. This 5-year project is budgeted at $60 million.
- **Center for Organic Informatics**[220]—a joint venture with Linköping University
- A 40-Gpbs optical network testbed in the Stockholm region
- **PAELLA**[221]—a consortium of Nordic industrial companies interested in adding electronic functions to paper.

One or more government agencies have co-funded several additional "industrial" research institutes, including Interactive Institute,[222] Mäkitalo (Wireless) Research Center,[223] Swedish Institute of Computer Science,[224] Swedish Research Institute for Information Technology,[225] Viktoria Institute,[226] and Wireless@KTH.[227]

## OTHER UNIVERSITY/INDUSTRY COLLABORATION

One of Vinnova's principal mechanisms is the "active industrial collaboration," which funds half the cost (up to SEK 3 million from Vinnova) of collaborative projects among one or two research or academic institutions and about a dozen companies. Vinnova also has built a network of "certified technology brokers" who connect SMEs to university sources of technology.

## CLUSTER SUPPORT AND WORKFORCE INITIATIVES

The Swedish government recognizes a nonprofit photonics cluster organization. Significant resources have been directed to curricular development at the universities and Institutes of Technology. A notable example is the IT University at Kista, a joint venture of the Royal Institute of Technology, Stockholm University, and others.

[218] See http://www.kprc.se/.
[219] See http://www.socware.com/socware.asp?ID=77&category=3.
[220] See http://www.coin.acreo.se/.
[221] See http://www.acreo.se/acreo-rd/smpage.fwx?page=1&url=page%3D313.
[222] See http://www.interactiveinstitute.se.
[223] See http://www.makitaloresearch.com.
[224] See http://www.sics.se.
[225] See http://www.siti.se.
[226] See http://www.viktoria.se.
[227] See http://www.wireless.kth.se.

## ENTREPRENEURIAL INFRASTRUCTURE

Swedish university researchers have the legal right to commercialize their own discoveries unless specific arrangements to the contrary are made with research sponsors. Since the 1990s, there has been a surge of spin-off companies, encouraged in part by the seven regional Technology Bridge Foundations created by the Ministry of Industry and Trade in 1994.

These foundations—the Stockholm Foundation of Technology Transfer[228] is one example—have unabashedly embraced technology-based economic development as a key driver of regional development strategy. Partly as a result of their work, there are now publicly supported research and technology parks associated with universities or technical institutes in virtually every significant population center. Most prominent in the ICT sector is the huge Kista Science City that spans four municipalities in the Stockholm region.[229] There also are university-linked technology parks in Göteborg,[230] Linköping,[231] Luleå,[232] Lund,[233] Umeå,[234] and Vasterås.[235] All together, the government estimates that 1,700 companies with 50,000 employees populate the nation's science parks (including both large companies and start-ups).

In fact, most of these parks also include incubators targeted at faculty spin-offs. The incubators are owned by holding companies created by the universities. In like manner, the holding companies are creating seed funds. Two already exist (at Stockholm and Lund), and the model will be replicated. These funds will take place among the estimated 120 venture capital firms operating nationwide in both the private and public sectors.

## VENTURE FINANCING AND INFRASTRUCTURE

Several Swedish government agencies offer direct financing relevant to the needs of IT start-ups:

- Nordic Industrial Fund offers companies (not necessarily in university partnerships) R&D grants up to SEK 5.9 million for up to 50 percent of project costs.[236]
- NUTEK, the Business Development Agency,[237] which makes royalty-payback loans up to SEK 2 million for up to 50 percent of project-development costs.
- Norrlandsfonden, the Norrland Fund,[238] which provides start-up loans up to 25 percent of total capital and focuses on technology-growth companies in the five northernmost counties. It is one of several similar funds that target rural and under-developed areas.
- ALMI, a government-owned company with a series of 21 regional affiliates, which takes 20 to 50 percent of commercial term-loan packages for small start-up companies.[239]

[228] See http://www.tbs.a.se/index.php?dnode=17.
[229] See http://www.kistasciencepark.org/index.html?lang=en&.
[230] See http://www.chalmersciencepark.com/ and http://www.lindholmensciencepark.se/ext/index_en.php.
[231] See http://www.mjardevi.se/english.php.
[232] See http://www.aurorum.se/.
[233] See http://www.center.ideon.se/eng/frameset.asp.
[234] See http://www.uminovacenter.se/eng/ (an agricultural sciences park).
[235] See http://www.vasteras.se/evab/eng/default.asp.
[236] See http://www.nordicinnovation.net.
[237] See http://www.nutek.se.
[238] See http://www.norrlandsfonden.se/bin/view.cgi?English.
[239] See http://www.almi.se/almi_in_english.html.

In addition, as in the case of research funding, the Swedish government has deeply intertwined its operations with those of private companies. In the case of capital formation, the vehicle is the Industrifonden, the Industrial Development Fund. In addition to its direct investments of up to 50 percent of projects costs over SEK 4 million, Industrifonden has invested public funds in 11 privately managed venture capital partnerships with private investors. The funds are categorized as seed-stage, regionally focused, or sectorally focused. Several make or target IT investments.[240] In addition, Vinnova intends to expand its presence in the seed capital markets.

## SUMMARY OF SUCCESS FACTORS

- Anchor companies that truly achieved global status
- Entrepreneur-friendly university policies and infrastructure
- Frequent co-funding by government and large industry of research centers that benefit SMEs

[240] See http://www.industrifonden.se/ny/english/investments/ventcap.asp.

# Appendix C
# Summary of Arizona's University and Military AC-IT R&D Assets

## UNIVERSITY OF ARIZONA

### Electronics and Optics

The UA's optics and electronics assets are centered in the Department of Electrical and Computer Engineering (ECE) and the Optical Sciences Center (OSC). ECE-based assets featured here include four significant research centers, including an NSF-funded Engineering Research Center focused on environmentally oriented design and manufacture of semiconductors. Both this ERC and the Center for Microcontamination Control have an explicit focus on manufacturing capabilities. One center, the Center for Low Power Electronics, is a joint effort with ASU. The OSC is ranked number one in the United States and is home to the Center for Optoelectronic Devices, Interconnects, and Packaging, a former NSF-funded Industry/University Cooperative Research Center. OSC faculty are leveraging these capabilities to propose to NSF an Engineering Research Center for Intelligent Optical Networks. This proposal is part of a larger, longer-term effort to create a statewide Photonics Research Center that will encompass the three universities in research on integrating wireless and wireline communications.

- **Center for Low Power Electronics (CLPE)** http://clpe.ece.arizona.edu/

  The CLPE is a collaborative effort led by the UA in partnership with ASU. Research at CLPE addresses fundamental, industry-relevant research problems in the design of ultra-low power microelectronic systems. The CLPE was formed initially under the State/Industry/University Cooperative Research Center (SIUCRC) initiative of the NSF. The Center focuses its efforts on designing ultra-low power systems aimed at solving the issues created by the high demand for portable electronic devices, such as laptop computers and cellular phones. Seven faculty from Electrical Engineering at ASU and ECE at UA participate in the Center. The Center's four industry members include Intel, Raytheon, National Semiconductor, and Western Design Center.

- **Center for Electronic Packaging Research (CEPR)**
  http://www.ece.arizona.edu/~cepr/

  The drive for continued miniaturization requires that greater numbers of smaller interconnections among devices and components in electronic packages be designed and manufactured. Powerful simulation tools are needed to enable this drive. The CEPR is developing new simulation tools for high-speed interconnect systems needed for integrated electronic packages. The centerpiece of this effort is the development of the Multichip Module (MCM) design/simulations/modeling system. This effort builds on CEPR studies of electrical and thermal/mechanical characteristics of electronic device packages and interconnected devices. The Center's research involves four faculty researchers and a postdoctoral fellow. Faculty researchers include two from ECE and two from Aerospace and Mechanical Engineering.

- **NSF/SRC Engineering Research Center for Environmentally Benign Semiconductor Manufacturing** http://www.erc.arizona.edu/

  The ERC is developing a methodology for incorporating environmental, safety, and health factors as design parameters in the development of new processes, tools, and protocols for semiconductor manufacturing. The emphasis is on an "integrated approach," where interactions among processes are considered, and on "process optimization" for waste minimization, rather than relying on abatement and "end-of-the-pipe" treatments. The Center's interdisciplinary research efforts involve six universities, and about 30 professors, 30 undergraduates, and 50 graduate students in 11 different academic disciplines. Forty-three companies participate through their membership in the Semiconductor Research Corporation, which provides a substantial portion of the Center's support.

- **NSF Center for Microcontamination Control**
  http://www.ece.arizona.edu/%7Ecmc/

  The Center is an Industry/University Cooperative Research Center led by the UA, including Northeastern and RPI as partner institutions. The Center's research seeks to reduce defects and improve yields in semiconductor manufacturing. The Center looks at all forms of contamination—solid, liquid, gaseous, and biological—as well as on-yield enhancement methods. Center research focuses on thin oxide quality, particle and film nucleation and growth, electronic characterization of ultra-thin oxide films, and chemical mechanical planarization improvements. Four faculty researchers and 10 students participate in Center research. Fifteen industry members participate in the Center.

- **The Optical Sciences Center** http://www.optics.arizona.edu/default.htm#

  The Optical Sciences Center is not a focused research center, but a university unit (under the Provost) devoted broadly to optics education and research. The Center offers a range of degree programs in optics. The Center hosts collaborative research engaging faculty from a range of university departments. The Center is home to three specialized facilities: Microfabrication and Clean Room, Thin Film Physics Laboratory, and Optical Fabrication. Fifty-four companies participate in the Center through three different types of membership.

- **Center for Optoelectronic Devices, Interconnects, and Packaging (COEDIP)**
  http://www.eng.nsf.gov/iucrc/directory/iucrc_a.htm

  COEDIP is located in the Optical Sciences Center. COEDIP was originally established as an NSF-supported Industry/University Cooperative Research Center, receiving its initial support in 1984. Center activities include modeling, fabrication, and packaging of optoelectronic components. State-of-the-art fabrication facilities allow the fabrication of optoelectronic devices and interconnect subsystems, with packaging occupying center stage from inception to completion of the device/subsystem. Companies participate in the Center through two levels of membership, paying $25,000 and $50,000 per year, respectively.

**Computer Modeling and Simulation**

The UA's computer modeling and simulation assets are centered in the ECE Department, including a series of labs and a major research center, all with commitments to the development and application of modeling and simulation capabilities. Another asset, the Arizona Center for Integrative Modeling and Simulation, is located in the business school and involves a partnership with ASU.

- **Computer Engineering Research Laboratory** (CERL)
  http://www.ece.arizona.edu/%7Ecerl/

  CERL research focuses on Internet gateway protocols and developments; distributed computing environments; multimedia distributed collaborative systems; and high-speed optical networks for medical imaging, picture archiving and communications systems, health and medical informatics systems, distance learning, and telemedicine systems.

- **Laboratory for Analysis and Processing of Images and Signals (LAPIS)**
  http://www.ece.arizona.edu/~lapis/

  LAPIS research focuses on developing new techniques for use in the processing and analysis of digital signals and images for a variety of applications such as automated classification of biomedical cells, content-based image retrieval for digital image libraries, hardware design for signal processing applications, and image enhancement and segmentation.

- **High Performance Distributed Computing Laboratory (HPDC)**
  http://www.ece.arizona.edu/%7Ehpdc/

  HPDC provides networking and computing resources for student research. Facilities include HPDC Testbed, Internet Teaching Testbed, Intel Multimedia Testbed, and an AOL Connectivity Testbed.

- **Center for Advanced Telesysmatics (CAT)**
  http://www.ece.arizona.edu/~hpdc/cat/summary.html

  CAT research aims to combine telecommunications and advanced networks with distributed information systems and information theory. Research is focused on enabling technologies including (a) software tools to assist in the design and analysis of network-centric systems and their services; (b) active agent technologies that can be dynamically programmed to implement any desired control and management functions; (c) hardware and software subsystems to allow real-time monitoring and management at very high transmission rates (terabit/gigabit per second); (d) mobile, global, wireless Internet access. Nine faculty members participate in research at the CAT.

- **Optical Computing and Processing Laboratory** http://www.ece.arizona.edu/~ocpl/

  Center research is focused on developing optical devices, systems, and algorithms in support of optical and optoelectronic information processing. Since 1991, research projects have been conducted in the general areas of volume optical storage, pattern recognition, and optoelectronic devices/systems.

- **Arizona Center for Integrative Modeling and Simulation (with ASU)**
  http://www.acims.arizona.edu/

  Center research is focused on enterprise modeling and modeling of manufacturing processes.

**Assets Unclassified by Core Competency Area**

- **Internet Technology Commerce and Design Institute**
  http://web.cfa.arizona.edu/itcdi/about.html

  The primary goal of ITCDI is to create a unique multidisciplinary culture for training a new breed of Internet technology and commerce leaders; establishing theoretical foundations for the practical understanding of Internet technology and commerce; developing Internet enabling hardware and software technologies to design, optimize, and manage Internet systems and their services; facilitating technology transfer between university and local industry constituents; and creating the stimulus for the growth of Internet-related businesses, educational initiatives, workforce development, and university research opportunities.

- **Center for the Management of Information** http://www.cmi.arizona.edu/

  The CMI is located in the business school. CMI researchers investigate collaboration processes and technologies from both behavioral and technological perspectives. Researchers use quantitative and qualitative approaches to develop experiments and field studies to examine collaboration.

## ARIZONA STATE UNIVERSITY

**Electronics and Optics**

Assets in electronics at ASU are centered on telecommunications technology solid state electronics. The Telecommunication Research Center is home to a broad array of research groups. The Center is also home to ConnectionOne, a new NSF Industry/University Cooperative Research Center. The Center for Solid State Electronics research is a major research enterprise cutting across departments. ASU also participates in the Center for Low Power Electronics led by the UA.

- **Telecommunication Research Center**
  http://www.fulton.asu.edu/~trc/

  The Telecommunication Research Center is home to an array of related research groups. Faculty conduct research across seven areas: information technology; wireless and wireline communications; networking; antennas; radio frequency; mixed-signal analog/digital electronics; embedded systems; and multimedia and bioinformatics. Thirty-one faculty participate across these research areas.

- **ConnectionOne: Communication Circuits and Systems Research**
  http://www.connectionone.org/about/

  Located in the Telecommunication Research Center, ConnectionOne is an Industry/ University Cooperative Research Center (awarded by NSF in 2002). The Center's

mission is to enable the development of a small, portable, all-in-one communication device. The Center's takes a "system-on-a-chip" approach. Researchers are employing a new circuit technique for the higher integration of complex RF, analog, and digital systems, combined with novel communication protocols, algorithms, and embedded system designs. ConnectionOne maintains strong links to CEINT. Fifteen faculty members participate in ConnectionOne. ConnectionOne has 12 industry members.

- **Consortium for Embedded and Inter-Networking Technology (CEINT)**
  http://www.eas.asu.edu/embedded/

  CEINT is a nonprofit consortium of ASU and industry (Intel, Motorola) that supports research and education in embedded systems. Support is provided for research by faculty and students, for visiting faculty, student internships, and curriculum development. The focus of support is guided by a "Target Technologies" roadmap revised annually by a Board of Directors, which includes representatives from Motorola and Intel. Target technologies are defined as "all areas of study and research that develop and advance the state of the art in technologies required to implement dedicated computing systems and their application in inter-networking and communications applications."

- **Center for Solid State Electronics Research**
  http://ceaspub.eas.asu.edu/csser/

  The CSSER aims to develop broad leadership in the field of solid state electronics. The Center maintains five main cross-disciplinary research efforts; Nanostructures; Molecular Beam Epitaxy and Optoelectronics; Materials and Process Fundamentals; Low Power Electronics; and Bio and Molecular Electronics. Special facilities are available for electron beam lithography, surface chemical analysis, transport measurements, and chemically enhanced vapor etching patterning. Thirty-eight faculty members, 15 postdoctoral researchers, and more than 80 students participate in CSSER research efforts. They are drawn from various disciplines including biochemistry, bioengineering, chemistry, chemical engineering, electrical engineering, materials science, mechanical engineering, industrial engineering, and physics.

- **Center for Low Power Electronics Research** (CLPE)
  http://clpe.ece.arizona.edu/

  The ASU participates in the UA-led research program to address fundamental, industry-relevant research problems in the design of ultra-low power microelectronic systems. The CLPE was initially formed under the SIUCRC initiative of the NSF. The Center focuses its efforts on designing ultra-low power systems aimed at solving the issues created by the high demand for portable electronic devices, such as laptop computers and cellular phones. Seven faculty from Electrical Engineering at ASU and ECE at UA participate in the Center. The Center's three industry members include Intel, Raytheon, and National Semiconductor.

**Computer Modeling and Simulation**

A defining effort in this area is the effort by ASU to institutionalize collaboration among researchers in computer science and research groups in departments across the university where computer science and IT capabilities as well as modeling and simulation may be developed and applied. This effort is centered in the Institute for Computer and Information Science and Engineering (InCISE).

- **The Institute for Computer and Information Science and Engineering (InCISE)** http://incise.asu.edu/

  InCISE is supported by the Vice President for Research and Economic Development and the Ira A. Fulton School of Engineering. The mission of InCISE is to foster computer science and applications of data storage, security, modeling visualization, analysis and interpretation on interdisciplinary research, education, and entrepreneurship. Three core research groups are the Center for Cognitive Ubiquitous Computing, Intelligent Information Integration, and Information Assurance. InCISE is affiliated with five other research centers: CEINT; PRISM; the Arts, Media, and Engineering Research Center; the Center for Advancing Business through IT; and the Software Factory.

- **Collaborative Program for Ubiquitous Computing**

  This program undertakes interdisciplinary research on mobile computing, bioinformatics, and e-commerce applications in a ubiquitous computing environment.

- **Partnership for Research in Stereo Modeling (PRISM)** http://prism.asu.edu/

  Research at PRISM focuses on developing 3-D software tools to record, manipulate, and recreate three-dimensional data. Six faculty researchers participate in PRISM.

- **Information Science and Engineering Center**

  The ISEC will integrate systems-scale research and training in data systems, algorithms, multimedia, and other software-based interests.

**Chemistry and Materials**

- **Computational Materials Science Group**

  Computer simulation of properties and structure of materials on atomic scale. Research areas include semiconductor processing, catalysis, adhesion to metal-ceramic interfaces, nanotribology, and GW approximation. The Group includes two participating faculty.

- **Goldwater Materials Science Laboratories**

  Part of the Center for Solid State Science, extensive facilities for materials synthesis and processing, as well as computer modeling and visualization. The facilities include Furnaces and Thermal Processing Equipment, Facility for High Pressure Research, Thin Film Deposition Equipment, Thermal Analysis Methods and Equipment, Auxiliary Materials Processing and Analysis Equipment, and Microscopy Sample Preparation.

- **The Computational Materials Science Group**

  Research is focused on computer simulation of structure, properties, and processing of materials at the atomic scale.

- **The Laboratories for Growth of Novel Materials**

  Research is focused on high-temperature engineered microsystems based on GaN, III-N semiconductor growth, and development of superconductor devices for photonic applications.

- **The Nanostructures Research Group** http://www.eas.asu.edu/~nano/index.html

  The Nanostructures Research Group is a collection of faculty, staff, and students working on research in the regime of ultrasmall semiconductor devices. The work focuses upon nanolithography, the physics of nanostructures and ultrasmall semiconductor devices, the modeling of these structures and devices, and the study of VLSI implementations of novel device architectures. The Nanostructures Research Group is a part of the College of Engineering's Center for Solid State Electronics Research.

**Assets Unclassified by Core Competency Area**

- **Software Factory** http://sf.asu.edu/

  Gathers part-time student programmers in a common facility, puts them under professional management and mentorship, and uses sound software engineering techniques in the development of software for university research. Researchers get well-designed, documented, and tested software. Students get experience working in a professional software development organization. ASU gets a reliable software development capability that will enhance bids for research funding.

- **CAPS** http://www.capsresearch.org/

  Created by ASU's W. P. Carey School of Business' Supply Chain Management MBA program and the Institute for Supply Management, CAPS Research is a nonprofit, independent research organization. CAPS Research examines how technologies such as the Internet and Web applications have changed the global economy and the ways in which organizations conduct business. CAPS Research's e-Supply Chain/e-Sourcing Project examines the impact of these applications on purchasing and supply. It seeks to identify how organizations are harnessing the connectivity and information exchange made possible by the Internet including the value propositions of e-markets, dynamic pricing, industry portals, buying process automation, and supply decision support systems.

- **Technology Based Learning and Research (TBLR)**
  http://tblr.ed.asu.edu/AboutTBLR/TBLRDescription/?w=1256

  The TBLR provides a unified structure to coordinate various technology-based R&D projects. As an integral part of the College of Education, TBLR focuses on research and large-scale delivery of educational materials as well as technology training and integration using computers and other information and communication technologies.

## NORTHERN ARIZONA UNIVERSITY

**Electronics and Optics**

- **The Wireless Networks Laboratory** http://www.cet.nau.edu/Projects/WNRL/

  The focus of WNL is on integrating cutting-edge low-cost circuit and system technology into a wireless environmental sensing network—WISARDNet—based on evolvable architecture that will meet an immediate and critical need to dramatically improve coverage and spatial density while greatly reducing the total cost. This first-generation network will also serve as an experimental testbed for fundamental research in wireless sensor networking that targets the unique characteristics of environmental monitoring applications.

- **The Advanced Microelectronics Laboratory**

  The Advanced Microelectronics Lab is a facility for designing and fabricating integrated circuits using micro-manufacturing processes, with support from Honeywell, Intel, and Raytheon.

## MILITARY-BASED ASSETS

**Fort Huachuca, Sierra Vista,** http://www.teamhua.hqisec.army.mil/index.htm

Fort Huachuca is home to a complex of facilities including the following:

- **U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH)**

  USAIC is the focal point of R&D relationships with universities.

- **U.S. Network Enterprise Technology Command (NETCOM)** http://138.27.190.13/default.cfm

  Formerly the U.S. Army Signal Command (USASC), the U.S. Army Network Enterprise Technology Command/9th Army Signal Command is the Army's single authority for information management. It is a service-based organization that provides centralized technical control over all functions associated with network operations, management, and defense. It ensures secure, dependable, and timely communications across the Army.

- **U.S. Army Communications-Electronics Command**

  The Communications Security Logistics Agency (CSLA) is the Army Wholesale Commodity Manager of Information Systems Security (INFOSEC) and Communications Security (COMSEC) Equipment and Materiel. CSLA develops the Army's Information Systems Security Program (ISSP) that identifies all COMSEC/INFOSEC requirements in the Army. CSLA is responsible for the acquisition, distribution, and logistics support to all field users of INFOSEC/ COMSEC and Information Assurance (IA) equipment and encryption materiel.

- **Joint Interoperability Test Command (JITC)**

  The JITC is responsible for the testing and evaluation of all new communications equipment for all three services. JITC enumerates its responsibilities as follows:

  - Being an independent operational test and evaluation/assessor of Defensive Information Systems Agency and other DoD C4I acquisitions
  - Identifying and solving C4I and Combat Support Systems interoperability deficiencies
  - Providing C4I joint and combined interoperability testing, evaluation, and certification
  - Bringing C4I interoperability support, operational field assessments, and technical assistance to the Combatant Commands, Services, and Agencies
  - Providing training on C4I systems, as appropriate.

- **Electronic Proving Ground (EPG)**

  The mission of EPG is to support developers by planning, conducting, and reporting technical tests of new electronic systems. Fort Huachuca's grounds are unique in the continental United States in the quality of the signal environment. The relative freedom from signal interference is unparalleled. The systems tested include C4I systems, EW systems, UAV systems, and the GPS. EPG provides quality services to developers throughout the acquisition development cycle; EPG answers many questions through the use of modeling and simulation.

  Facilities include C4I test-related facilities—the Electromagnetic Environmental Test Facility, an Instrumented Test Range, an Antenna Test Facility, Electromagnetic Interference/Compatibility (EMI/EMC)/TEMPEST Test Facility, and the GPS Test Facility. EPG also has a number of test beds to include the Communications Test Bed, the Satellite Test Bed, and the Distributed Systems Test Bed Operational Test Command (formerly TEXCOM).

### Other Military Facilities

- **Warfighter Training Research Division (AFRL/HEA),** Human Effectiveness Directorate, Mesa, Arizona, http://www.mesa.afmc.af.mil/Default.htm

  Formerly the Williams Air Force Base, the AFRL/HEA supports two of the Air Force's primary research and development objectives by advancing warfighter training system technology and by evaluating the training effectiveness of that technology. This is accomplished by developing and evaluating new training methodologies and engineering concepts that can provide increased warfighter training at lower cost. A major focus of projects is modeling and simulation for training purposes.

- **U.S. Army Yuma Proving Ground (USAYPG)**, Yuma Arizona, http://www.yuma.army.mil/

  USAYPG is a general-purpose facility for testing weapon systems of all types and sizes in a joint environment. The proving ground conducts tests on medium- and long-range artillery, aircraft target acquisition equipment and armament, armored and wheeled vehicles, a variety of munitions, and personnel and supply parachute systems. Services include prototype combat vehicle and field artillery testing; testing of all types of military hardware, from tents to tanks; testing of new and improved types of conventional munitions; testing of developmental Army aircraft and aircraft weapon systems; joint testing with the Air Force and Navy of position location systems; joint Army and Air Force testing of personnel and cargo airdrop systems; and management of Army desert, tropical, and cold weather environmental testing.