# Measuring Technological Innovation

Over the past two decades of the 20th century, there has been a fundamental shift in the economic and social landscape. This dramatic change has been led by the rise of global markets, the fast pace of technological development, alterations in lifestyles and demographic changes.

No longer is the U.S. the unchallenged leader in the world economy. Regions in the U.S. once insulated from international competition today stand toe-to-toe with regions in other nations that are competing successfully for virtually every good and service we produce.

At one time, firms competed based on factor costs (e.g., labor, raw materials, capital, and infrastructure), and the firm with the lowest factor costs won. The changing nature of competition has superseded this model. Globalization allows firms to source factors such as raw materials, capital, and even generic scientific knowledge from international markets, and to locate selective activities overseas to take advantage of low-cost labor or capital. At the same time, technological change and innovation have given firms the ability to eliminate, nullify, or circumvent weaknesses in local factors. For example, high product quality and meeting extraordinary technical standards can offset high wages.

Thinking on regional competitiveness is undergoing a transition. Historical efforts to enhance competitiveness were tied to lowering the cost of inputs as regions focused on holding down wages, reducing taxes, and recruiting new companies using financial incentives. This model has been recognized as self-defeating. Prosperity comes from the ability to utilize a region's inputs more productively than other regions in the production of goods and services. Low wages do not yield fundamental competitiveness, but they hold down the standard of living. Financial incentives are easily matched by competing regions, and erode the tax base needed to invest in education and local infrastructure[65].

A study from the Council on Competitiveness "Clusters of Innovation Initiative: San Diego", authored by Harvard economist Michael Porter, makes the following points when discussing the determinants of regional prosperity.

> "The most important sources of regional prosperity are created, not inherited. Inherited competitive advantages such as natural resources, location or a supply of labor are becoming less important in determining prosperity, especially in advanced economies. Globalization has expanded the supply of natural resources, and technology has created new substitutes for them as well as bringing distant locations into the economy. A supply of labor is no longer an advantage in a world where low-skilled workers are plentiful. Prosperity depends not on inherited inputs themselves, but on creating the conditions that allow firms operating in the region to be highly productive in the use of inputs".

American businesses are winning in today's marketplace, not by demanding protection in the form of import tariffs, but by constantly innovating – by repeatedly creating and improving products and services, inventing more efficient production systems and technologies, identifying and penetrating new markets, and where appropriate, collaborating both nationally and internationally for mutual benefit. Under the new terms of global competition, businesses need to draw on essential services and resources found in their local regions – from skilled workers to technology to venture capital to efficient and high quality physical infrastructure. Increasingly, efficient management of well-developed local resources has become the determinant of a region's economic, social and environmental well being.

---

[65] "Clusters of Innovation: Regional Foundations of U.S. Competitiveness", Council on Competitiveness, October 2001.

Clearly, the paradigm that determines competitiveness for regions has shifted. The competitive advantage today is driven by the ability of firms to continuously innovate and upgrade. And, innovation is the driving force behind improvements in productivity, a key component of competitiveness in nearly all firms. Although, industries producing enabling technologies such as computers, computer chips, software, communication devices, and medical research, drugs and instruments have received much of the attention, opportunities to apply advanced technology are present in nearly all fields of business. As pointed out in the report from the Council on Competitiveness, there are no low-tech industries, only low-tech companies that fail to incorporate new ideas and methods in their products and services, failing to innovate and improve productivity. Indeed, innovation stretches beyond the better-known science and technology and into all aspects of production, distribution and service.

In response, the San Diego region is transforming itself by creating a new economy. Today, we're attracting attention as an international model for strategic economic development in technology oriented industry clusters. What is the new economy? According to the San Diego Regional Economic Development Corporation it is a set of fast-moving, knowledge based industry clusters that will enjoy their strongest growth in the 21st century. It is made up of the kind of companies that every region wants – companies that pay high wages, are internationally oriented, and are engines of sustained growth[66].

San Diego's economic history is characterized by waves of technological innovation: defense, aircraft and aerospace, pharmaceutical research, medical devices and instruments, wireless communications, and software. Much less known are the benefits from the technological advances in drip irrigation systems to our horticultural and avocado industries. Each wave has been or will be interrupted or altered by a competitive or external shock. But each wave built the technological innovation networks of talent, suppliers and financial service providers necessary to make the next wave of technological innovation possible. In this way, a salient feature of technologically innovative companies is that they are self-regenerating.

One measure of the technological innovation that drives competitiveness is the level of patenting in a region[67]. Patents are a way of registering an entirely new product, a new way of producing, or a change to an established process. A patent protects the economic rights or value of the innovative idea.

## Patent Activity 1990-1999

The US Patent and Trademark Office [US PTO] awarded 10.984 utility patents to organizations, companies and individuals in San Diego between 1990 and 1999. Of that total, 2,800 patents or 25.5% were awarded to individuals leaving 8,184 utility patents awarded to 1,463 organizations that could be organized by industry using the Standard Industrial Classification [SIC] coding system. In addition to utility patents, the US PTO awarded 125 plant patents to organizations, companies and individuals in San Diego between 1990 and 1999. Of the total, 33 patents or 26.4% were awarded to individuals leaving 92 plant patents awarded to 8 organizations.

Our research targeted organizations that received 10 or more patents between 1990 and 1999, ultimately matching 275 organizations to SIC codes – about 18% of the total. These 275 organizations were awarded over 66%, or 5,512 to the utility and plant patents awarded to organizations. Of the remaining organizations not matched to a SIC code about 44% were awarded only one patent, while another 11% were awarded two patents. Further research will attempt to assign the SIC does to all companies with 10 or more patents and will take a sample of

[66] "Partnership for the New Economy", San Diego Regional Economic Development Corporation.
[67] "Clusters of Innovation: Regional Foundations of U.S. Competitiveness", Council on Competitiveness, October 2001.

the organizations with less than 10 patents to determine the distribution of their patents by SIC code.

## Patent Activity by Industrial Cluster

One way to assess our region's potential *future* competitiveness is to identify the industries, organizations and companies that are annually awarded the largest number of patents. To evaluate this, companies are assigned to clusters and the ratio of the number of patents per 1,000 employees is estimated for each of the 11 clusters than contain companies receiving utility or plant patents[68]. Patents are a measure of early stage innovation and, our future prosperity rests upon these industries providing the region with the capacity for continuous technological innovation.

In 1999, the most recent year for which data are available, inventors in San Diego were awarded 1,749 utility patents, ranking the region fourth compared to 20 other US regions. San Diego produced 12.9 patents per 10,000 workers, more than twice the national average of 6.3, but well behind competitor regions like Boston (20.9) and Austin (22.2). Between 1990 and 1999 San Diego's annual patent growth rate per 10,000 employees of about 13% was nearly double the national rate (7.7%), faster than Boston (8.5%) but significantly slower than Austin (34.4%)[69].

The largest share of patents awarded between 1990 and 1999 went to organizations in the Biotechnology and Pharmaceutical cluster (34.3%). Organizations in this cluster receiving the largest number of patents include Scripps Research Institute, University of California, San Diego, Isis Pharmaceuticals, and Salk Institute. The second largest number of patents awarded was in the Defense and Transportation cluster (20.4%). Organizations in this cluster receiving the largest number of patents include the U.S. Navy, Hughes Aircraft and General Atomic. Other clusters registering a large number of patents include the Computer and Electronics Manufacturing cluster, the Communications cluster and the Biomedical cluster [see Figure 110].

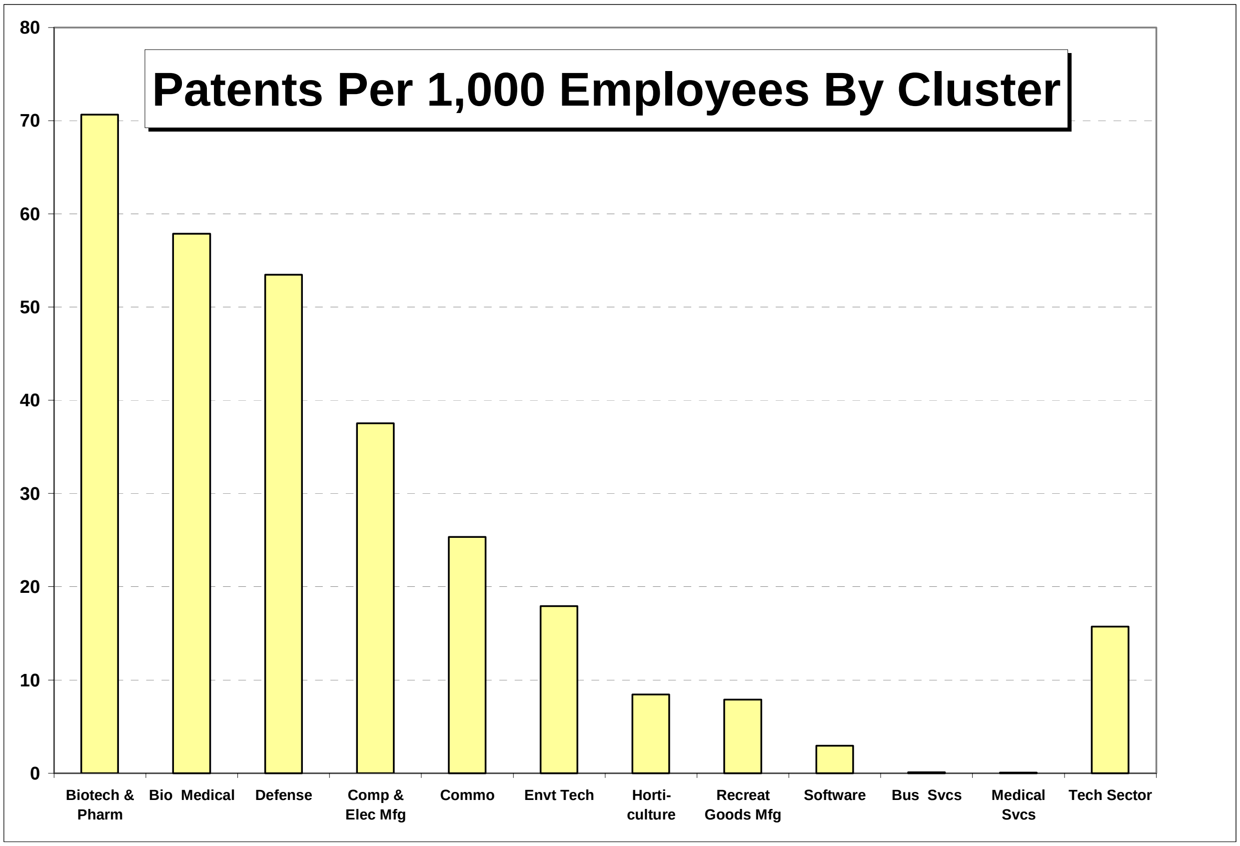
**Figure 110**
**Patents Awarded in San Diego by Cluster, 1990 – 1999[70]**

| Rank | Clusters with SIC Codes | Number | Shares |
|---|---|---|---|
| | | | |
| 1 | Biotechnology & Pharmaceuticals | 1,629 | 34.3% |
| 2 | Defense & Transportation Manufacturing | 970 | 20.4% |
| 3 | Computer & Electronics Manufacturing | 907 | 19.1% |
| 4 | Communications | 631 | 13.3% |
| 5 | Biomedical Products | 362 | 7.6% |
| 6 | Environmental Technology | 82 | 1.7% |
| 7 | Software & Computer Services | 63 | 1.3% |
| 8 | Horticulture | 56 | 1.2% |
| 9 | Recreational Goods Manufacturing | 39 | 0.8% |
| 10 | Business Services | 10 | 0.2% |
| 11 | Medical Services | 5 | 0.1% |
| | **Total Patents in Clusters Using Company SIC Code** | **4,754** | **100.0%** |

[68] The methodology for assigning company patents to the clusters is detailed in the Methodology.
[69] "San Diego Clusters of Innovation Initiative", Council on Competitiveness, May 2001, page 12.
[70] The SIC codes contained in each cluster are enumerated in the glossary.

Regarding patents per 1,000 employees, the range of data varies from about 71 patents per 1,000 employees in the Biotechnology and Pharmaceuticals cluster to 0.1 patents per 1,000 employees for Medical Services. The Software Cluster has a relatively low ratio of 3 patents per 1,000 employees, however, most software is protected by Copyright and this cluster is included in the analysis due to this fact. The Business Services and Medical Services clusters were found to be least important to sustaining the region's edge in technological innovation based on a review of the patents awarded over the last 10 year, thus, these two clusters are dropped from the analysis.

**Figure 111**




Therefore, our most *technologically innovative clusters* are the following:

1. Biomedical Products
2. Biotechnology and Pharmaceuticals
3. Communications
4. Computer and Electronic Manufacturing
5. Defense and Transportation Manufacturing
6. Environmental Technology
7. Horticulture
8. Recreational Goods Manufacturing
9. Software and Computer Services

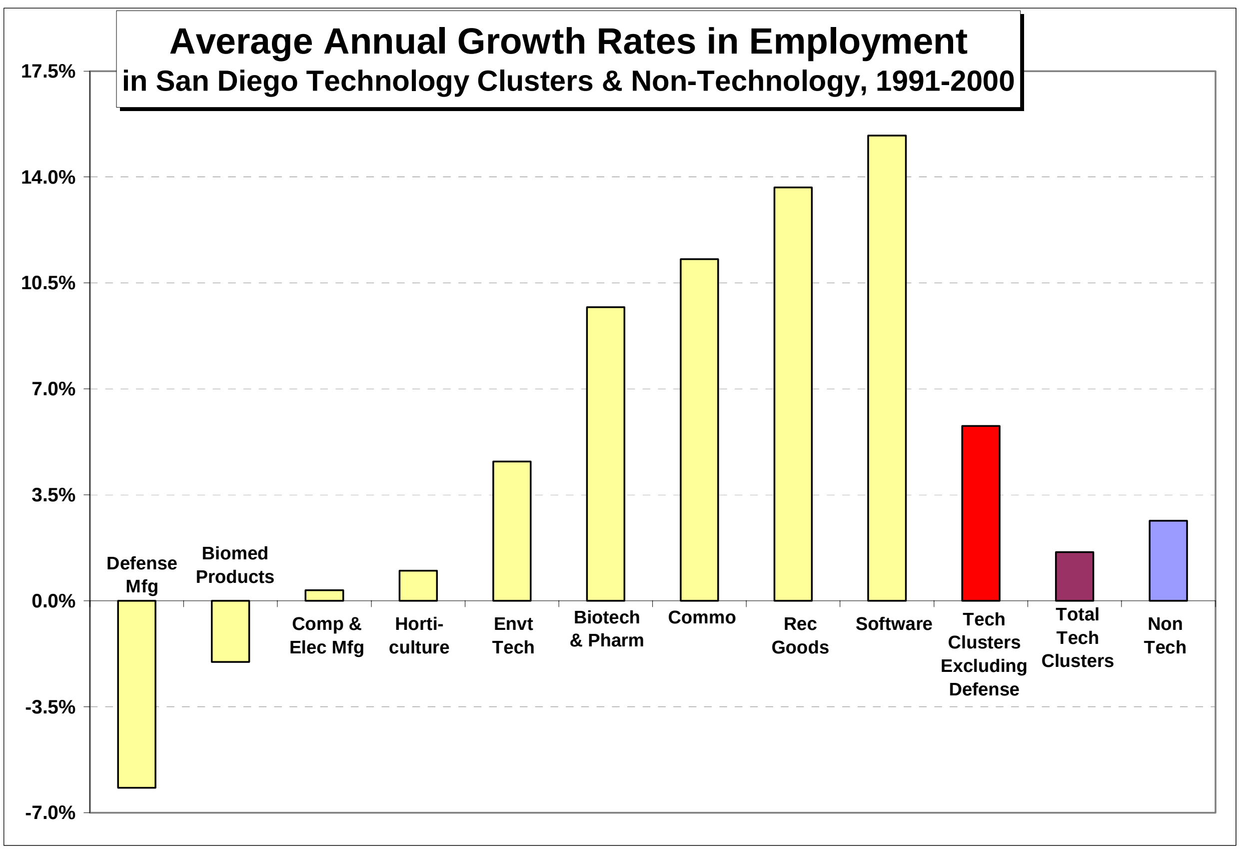
The focus of our work is to understand major trends while building on established concepts. Compiling patent data to represent innovation and aligning those data with cluster information provides insights on the impact of innovation on the San Diego economy. This is not perfect as 14% of the patents for which we have SIC codes do not fall within the region's industry clusters [754 / 5,512]. However, the vast majority of the patents are assigned to clusters and the major trends outlined in the following analysis are intended to indicate the manner in which the innovative firms impact the economy.

## Economic Impact of the Technologically Innovative Clusters

Employment

Total employment in our most technologically innovative clusters grew at an average annual rate of 1.6% between 1991 and 2000. By contrast, growth outside these innovative clusters grew at an average annual rate of 2.6%. Thus, the share of total employment in these technology clusters decreased from 12% in 1991 to 11.3% in 2000. The primary reason the technology sector did not grow faster was the contraction in the defense cluster. During the early 1990s there was a significant contraction in the defense cluster, and employment declined at an average annual rate of about 6.2% between 1991 and 2000. Excluding the Defense cluster, employment in the remaining technology clusters grew an average of 5.8% per year between 1991 and 2000 [see Figure 112].

**Figure 112**




Between 1991 and 1994 employment in the Defense and Transportation cluster contracted at an annual rate of 14.6% per year while employment at the Recreational Goods Manufacturing cluster expanded at an average annual rate of 23.4%. During this same time period employment in the Biotechnology cluster expanded at an annual average rate of 10.9% while the Software cluster expanded at an annual average rate of 9.3%.

After the 1990-1994 recession ended, the Software cluster continued to grow at an annual average rate of 14.4% per year, while the Communications cluster expanded at a rate of 11.5% per year. Also between 1994 and 2000 the Defense cluster continued to shrink as its employment declined 3.5% per year and the Biomedical Products contracted at an annual rate of 2.0%.

These changes in growth rates mean that the number of employees in each cluster changed dramatically and the distribution of employees by cluster also changed. In 1991 there was a high concentration of employment in one cluster as about 34% of all technology employment was in the defense cluster. By 2000 the defense cluster share shrank to about 13.5%. While defense was shrinking, other clusters were expanding – and expanding rapidly. Software, the fastest growing technology cluster, accounted for 7.6% of the technology sector employment in 1991 and about 16% in 2000. The Communication cluster grew from 10.5% of the technology sector in 1991 to 18.6% in 2000. The Biotechnology & Pharmaceuticals cluster grew from about 10.5% of the technology sector in 1991 to about 17% in 2000.

**Figure 113**

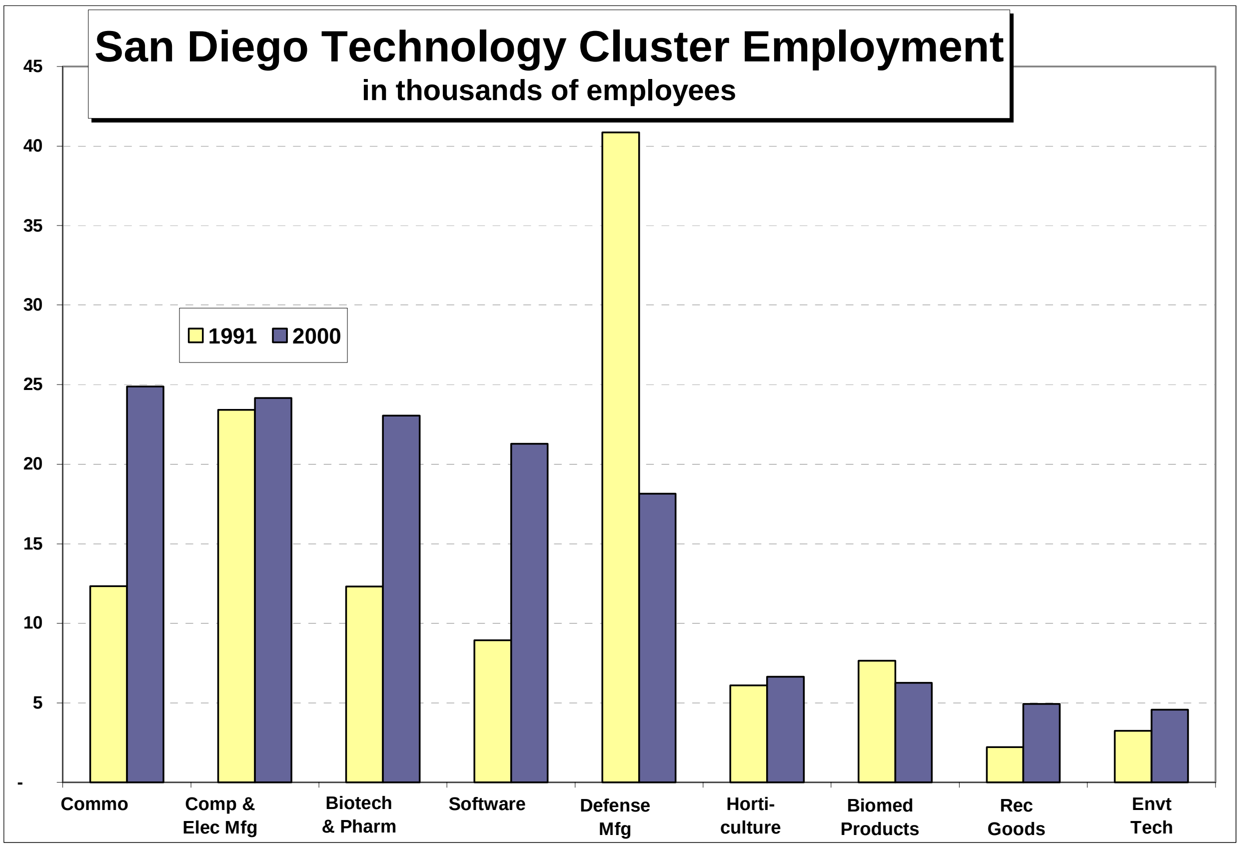
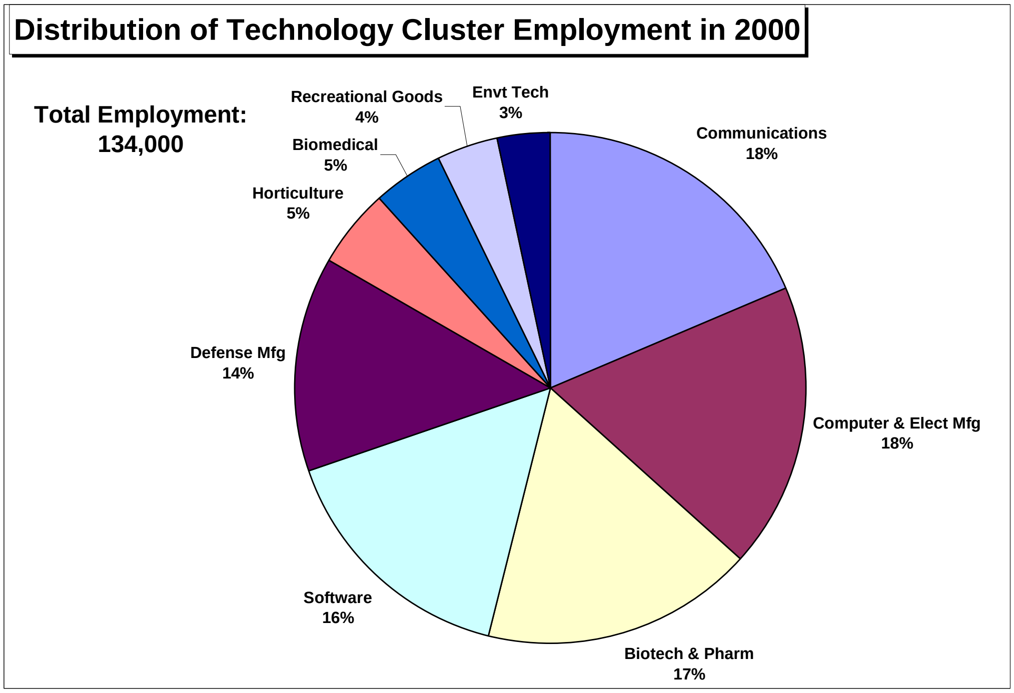
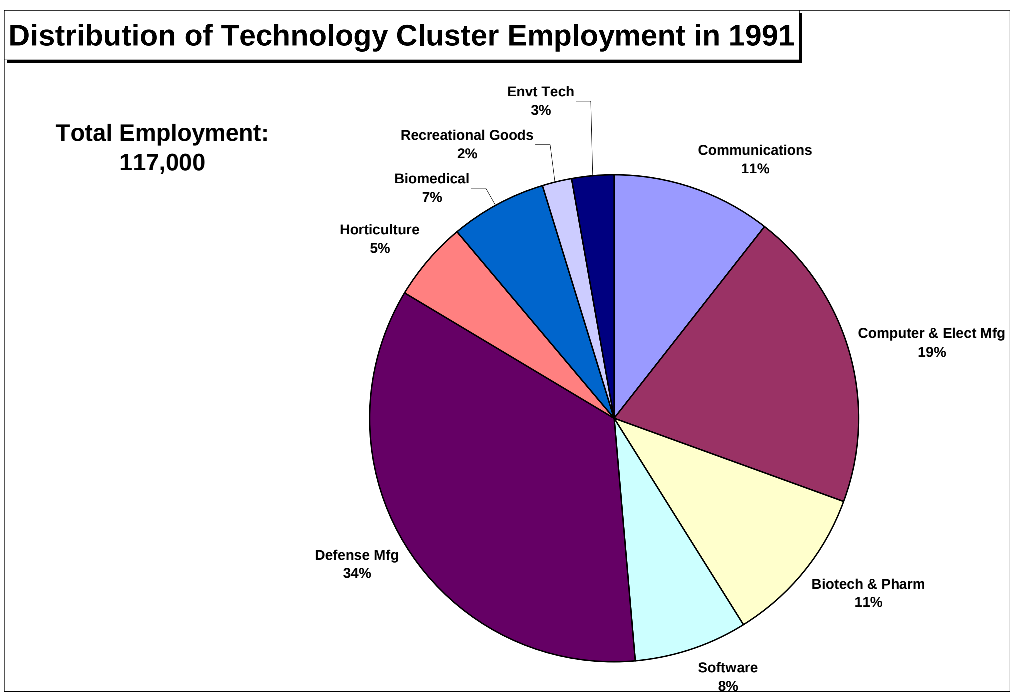


**Figure 114**




Today's employment distribution in the technology sector is far less concentrated than that observed in 1991 [see Figures 114 and 115]. In 2000, the technology cluster with the most employees is Communications with about 24,900 employees or about 19% of the technology total. Computer and Electronics Manufacturing is a close 2nd with about 24,200 employees or about 18% of the total. Ranked 3rd is Biotechnology and Pharmaceuticals with about 23,000 employees or about 17% of the total.

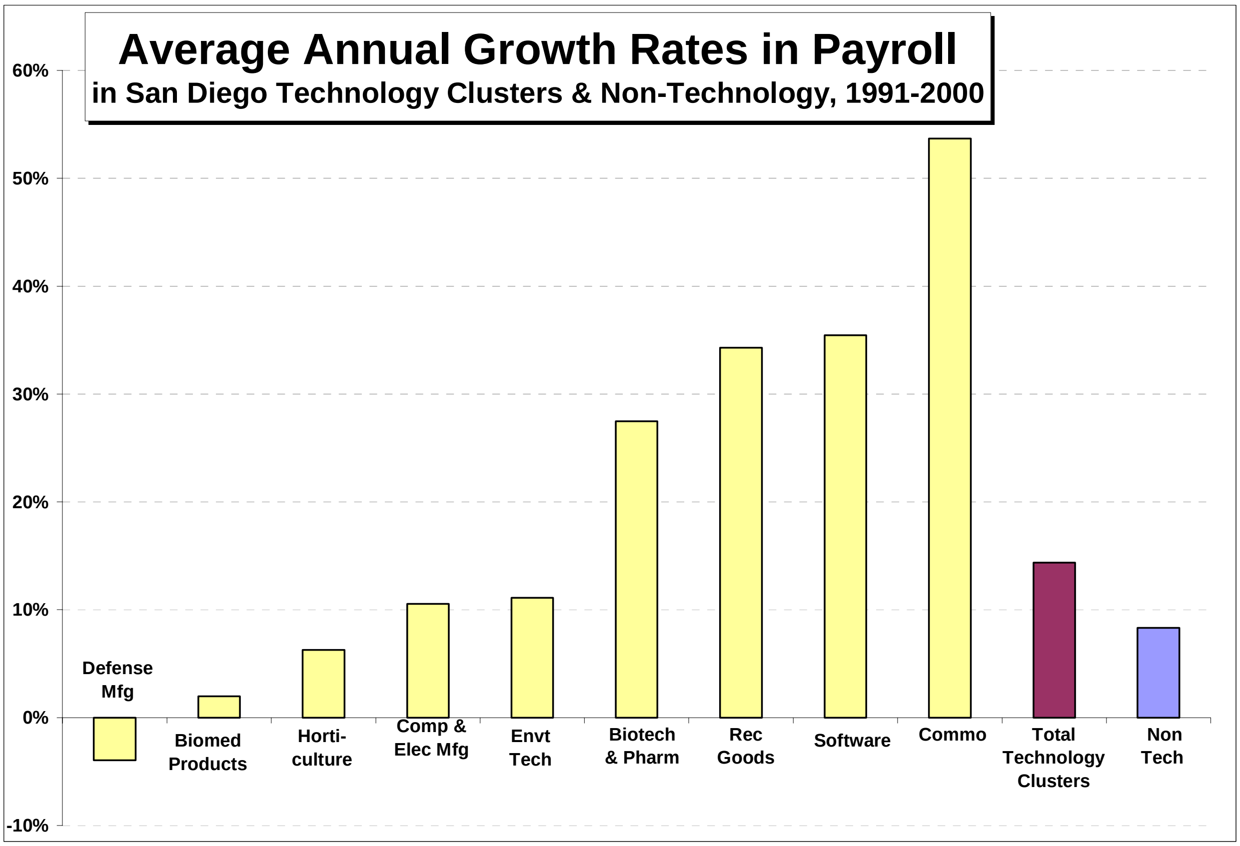
**Figure 115**



Payroll

"Payroll" represents total wages and salaries paid to employees[71]. The payroll data shows that technology cluster employees have a disproportionate share of the region's payroll. The technology cluster accounts for 11.2% of regional employment in 2000 and 21.7% of regional payroll. Not only is payroll disproportionately higher, it has grown faster during the last decade. Payroll in the technology clusters grew an average of 14.4% per year between 1991 and 2000. Part of the significant rise in payroll is explained by employee "stock options". These options allow employees to purchase company stock at a price set by management at the time the option is granted [called the strike price]. The option has value if the market price is higher than the strike price. For some technology cluster employees, 1999 and 2000 were years when stock options were exercised.

**Figure 116**



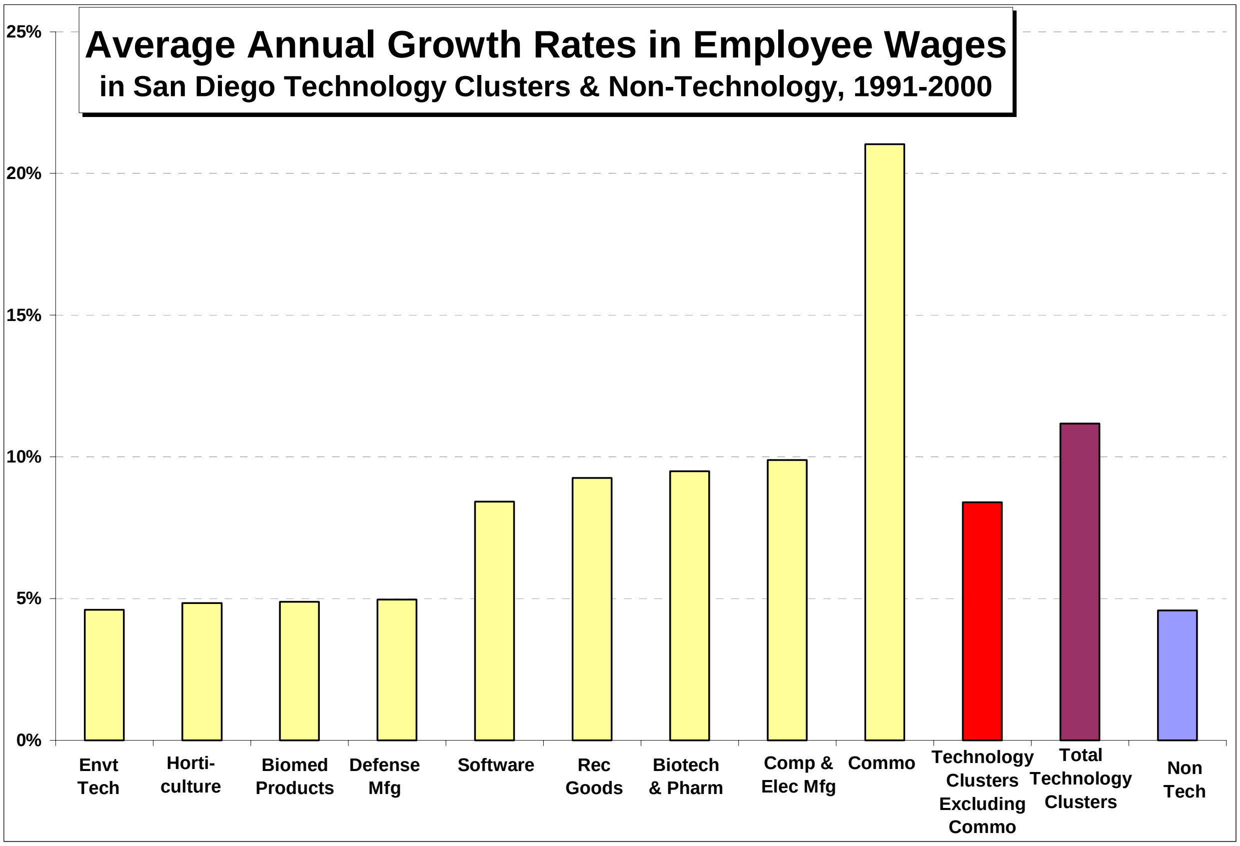

Wages per Employee

Dividing payroll by employment provides average annual wages and this statistic highlights the importance of the technology sector to the region. In 2000, the average wage for all employees in the technology clusters is $72,978. For employees outside of the technology sector the average wage is $33,115. Thus, wages for employees in the technology sector are more than double the average for employees outside the technology sector.

Between 1991 and 2000 wages grew fastest in the Communications cluster where they increased an average of 21.0% per year. Ranked 2nd is the Computer and Electronics Manufacturing Cluster where wages grew an average of 9.9% per year. The Defense cluster, which experienced substantial declines in employment, experienced wage increases averaging 5.0% per year between 1991 and 2000 [see Figure 117 following page].

[71] Includes monies from exercising stock options.

Figure 117




Because employee stock options for Qualcomm and other communications firms were exercised in 1999 and 2000, the annual growth rate for the Communication cluster is extremely high. In fact, the average wage for employees in the Communications cluster is about $116,300 for 2000. To see how fast technology wages grew excluding the Communications cluster, this cluster was removed from the data set. After this adjustment, technology, excluding Communications, had annual wages of about $63,100 in 2000 – about 90% higher than non-technology wages. Further, the growth rate between 1991 and 2000 is about 8.4% – significantly higher than the growth rate of non-technology wages.

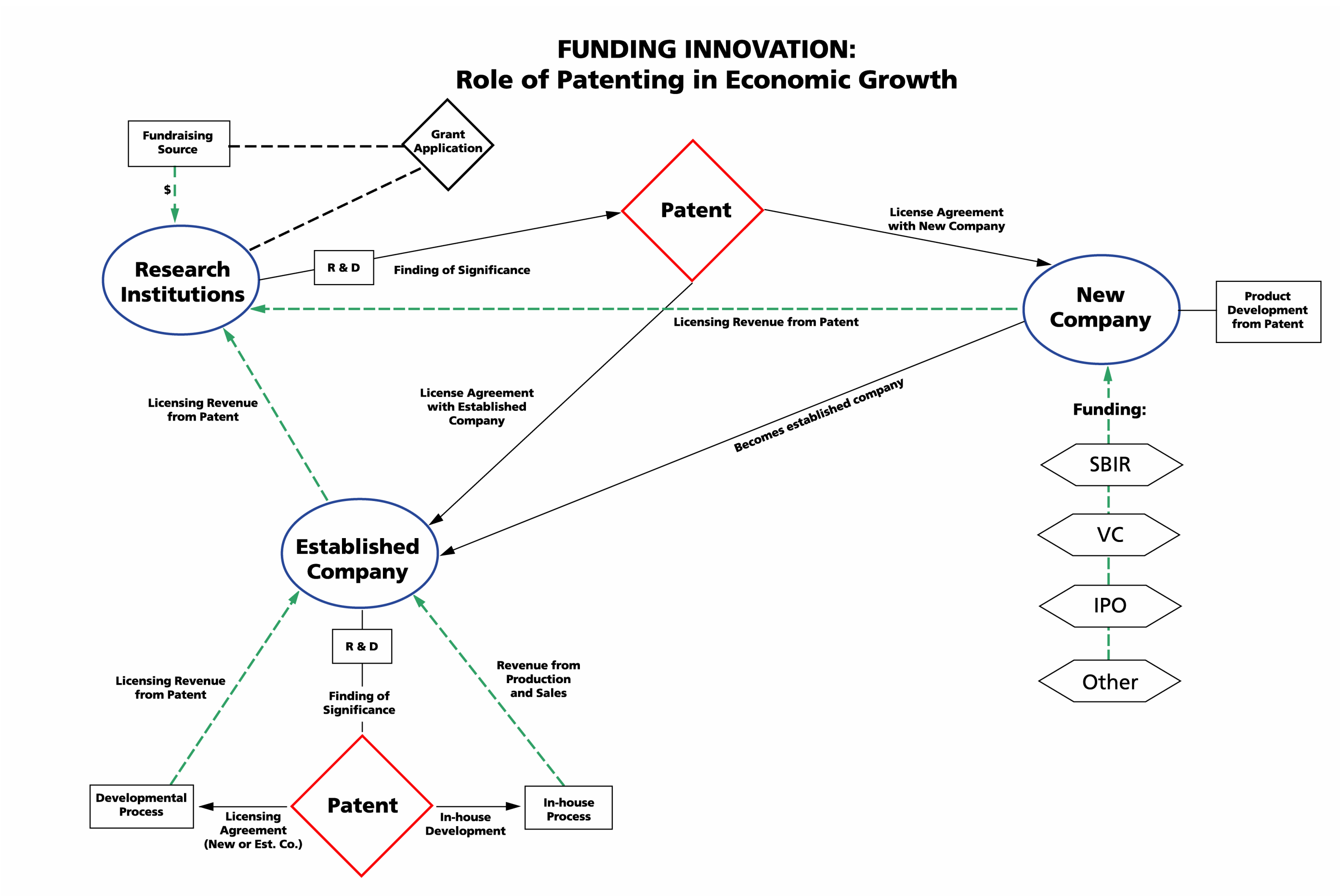
It is important to remember that only 11.2% of San Diego employment in 2000 is in the technology sector. Targeted efforts by regional organizations such as the San Diego Workforce Partnership and the San Diego Regional Technology Alliance attempt to increase the share of regional employment in the technology sector. Such efforts seek to increase the region's standard of living by increasing the number of employees in the technology sector.

Looking forward, recent events with terrorism and the military build up imply that the defense sector might be an area of growth. Another possible area of growth would be the area of bio-terrorism – and for that work, the Biotechnology cluster is well positioned. Thus, there is a good chance that there will be faster growth in the San Diego technology clusters than in the rest of the region's economy. Whether or not average wages continue to increase at the rapid rate seen in the past will likely be determined by the ability of the technology clusters to produce new products and services and sell them in the marketplace. Likely the region will not see a repeat of the "stock options" that dramatically raised wages in the Communications cluster. Although, technology clusters do have that potential, so there is always a chance.

## Funding Innovation

The graphic presented in this section is a simplification of part of the process that funds technological innovation. The process is circular and for this discussion we start with research institutions in San Diego [see Figure 118]. In San Diego County about $6.1 billion was spent on Research and Development [R&D] between 1993 and 1999 that was funded from federal government grants[72]. Of that total, about 39% or approximately $2.4 billion was spent by research institutions that are public educational institutions or non-profit non-educational institutions [for example, the Salk Institute]. The average size of these grants is about $160,000 and the appendix contains data on R&D expenditures by types of organizations. To describe the process, we select the University of California at San Diego [UCSD] where research is an on-going effort. UCSD is currently undertaking research from grants already received. R&D Expenditures from all sources at UCSD grew from about $237 million in 1990 to about $462 million in 1999 – a compound annual growth rate of about 7.7%.

**Figure 118**




At some point, the University has a finding of significance – at which time it would file a patent application with the US PTO. The US PTO would grant a patent assuming the application meets all the requirements. In 1995 UCSD filed 107 patent applications and this total grew to 150 in 2001 – an annual growth rate of about 5.8%. Patents awarded to UCSD by the US PTO grew from six in 1990, to 59 in 2001 – an annual growth rate of 27.1%.

---

72 Lee & Walshok, "A County Level Analysis of California's R&D activity", April 2002.

Having received a patent, UCSD may not want to undertake its commercial application. Rather, it may pursue the commercial development by signing a licensing agreement with a company – either (1) an established company or (2) a new company that UCSD helps create. At UCSD, licensing revenue increased from about $2.97 million in 1995 to about $8.35 million in 2001 – a compound annual growth rate of about 19%.

If the University opts to sign a licensing agreement with a new company, it will work with the company founders to help develop a business plan to commercialize a product for which UCSD holds the patent. According to the California Healthcare Institute, there have been 64 biotechnology companies that have spun off from UCSD[73]. Other non-profit research organizations, such as Scripps Research Institute and the Salk Institute follow a similar process where research leads to findings of significance and eventually a firm may be spun off to develop the commercial application of the finding. For Scripps Research Institute there have been 26 such spin-offs, while there have been 15 such spin-offs at the Salk Institute[74].

Although patents can measure technological innovation, this does not necessarily mean that a region is fully benefiting from the opportunities presented by this innovation. A region must work to capture the economic value of the productivity generated by the innovative technology. The ability of a region to commercialize new ideas and technologies will determine its ability to improve its prosperity and standard of living. Some regions, like San Diego, have high levels of R&D investments, numerous specialized research centers, and high levels of patenting activity; however, they still lag behind other regions in terms of commercialization. The reason: knowledge is not effectively or rapidly transferred to companies, or the companies receiving the patents do not have production facilities in the region.

In the San Diego region, the linkage between UCSD and local technology companies is one way as companies commercialize technological innovation. Recent literature on this topic provides details for the San Diego region and the success with which this linkage has been achieved[75]. At UCSD, there is an organization called "UCSD CONNECT" whose purpose is to link academics [who have the ideas], with entrepreneurs, business service providers and venture capitalists. In other words, UCSD CONNECT facilitates the process of creating a new functioning business selling a product or service, where the product or service is based on the idea protected by the patent. CONNECT is fully funded by over 1,000 companies and sponsors more than 80 events per year.

For new companies, obtaining finance and guidance early in their existence is critical for success. The evolution of San Diego's technology sector could not have taken place without the assistance of economic development organizations that addressed these needs. Such organizations are designed to nurture young businesses and provide hands-on management assistance, as well as access to financing, marketing, consultants, technical assistance, and networking opportunities. UCSD has been a prime mover in revitalizing the San Diego region.

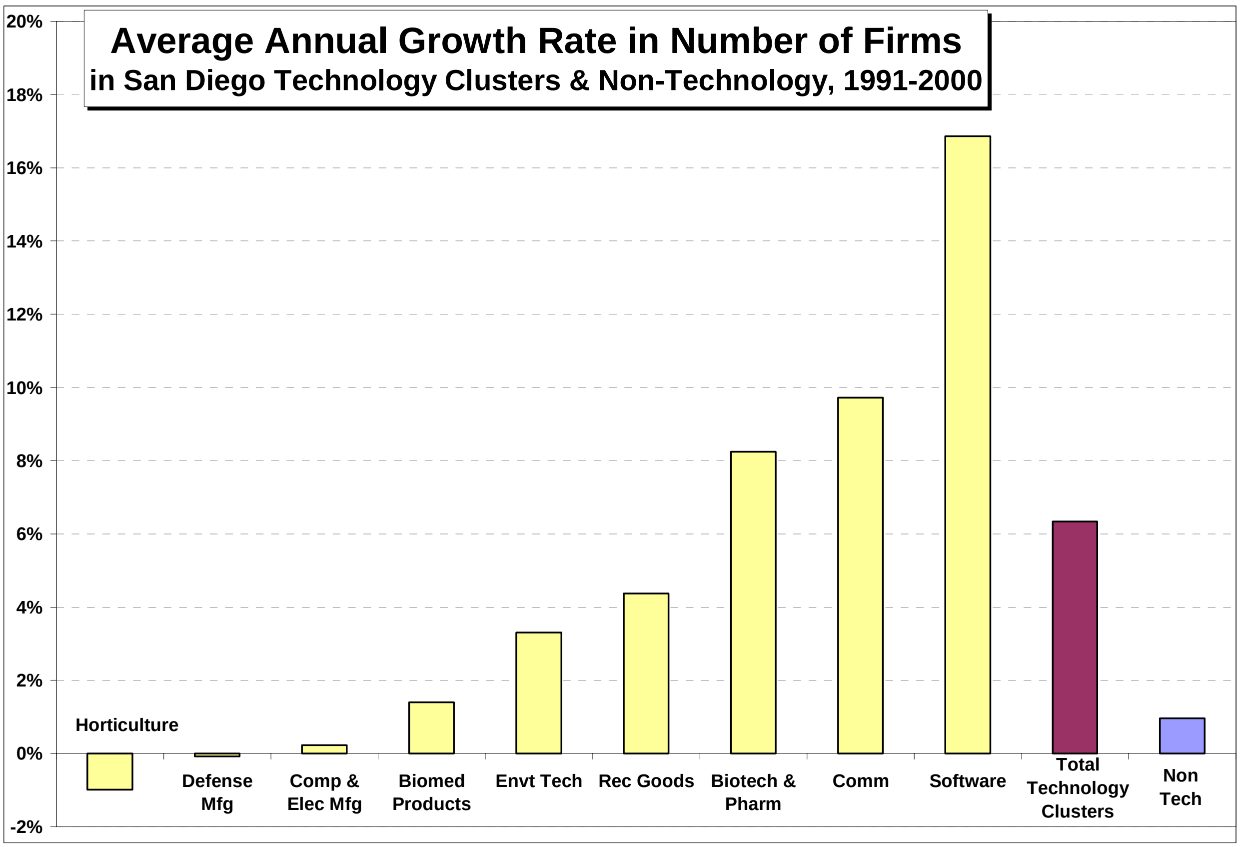
In addition to UCSD CONNECT, economic development organizations such as the San Diego MIT Enterprise Forum, the San Diego Regional Technology Alliance, and industry-specific organizations such as BIOCOM and the San Diego Telecom Council have played a key role in the growth of the technology sector. These organizations offer seminars and events that guide entrepreneurs in commercialization and growing their businesses, while providing opportunities for firms, service providers, and suppliers to interact.

---

[73] Walshok, Furtek, Lee & Winkham, "Networks of Innovation: Contributions to San Diego's Telecommunications and Biotechnology Clusters", UCSD, CONNECT, Final Report, May, 2001, page 27.
[74] Ibid., page 28.
[75] Walshok, Furtek, Lee & Winkham, "Building Regional Innovation Capacity", *Industry and Higher Education*, Volume 16, No. 1, February 2002, pp 27-42, forthcoming.

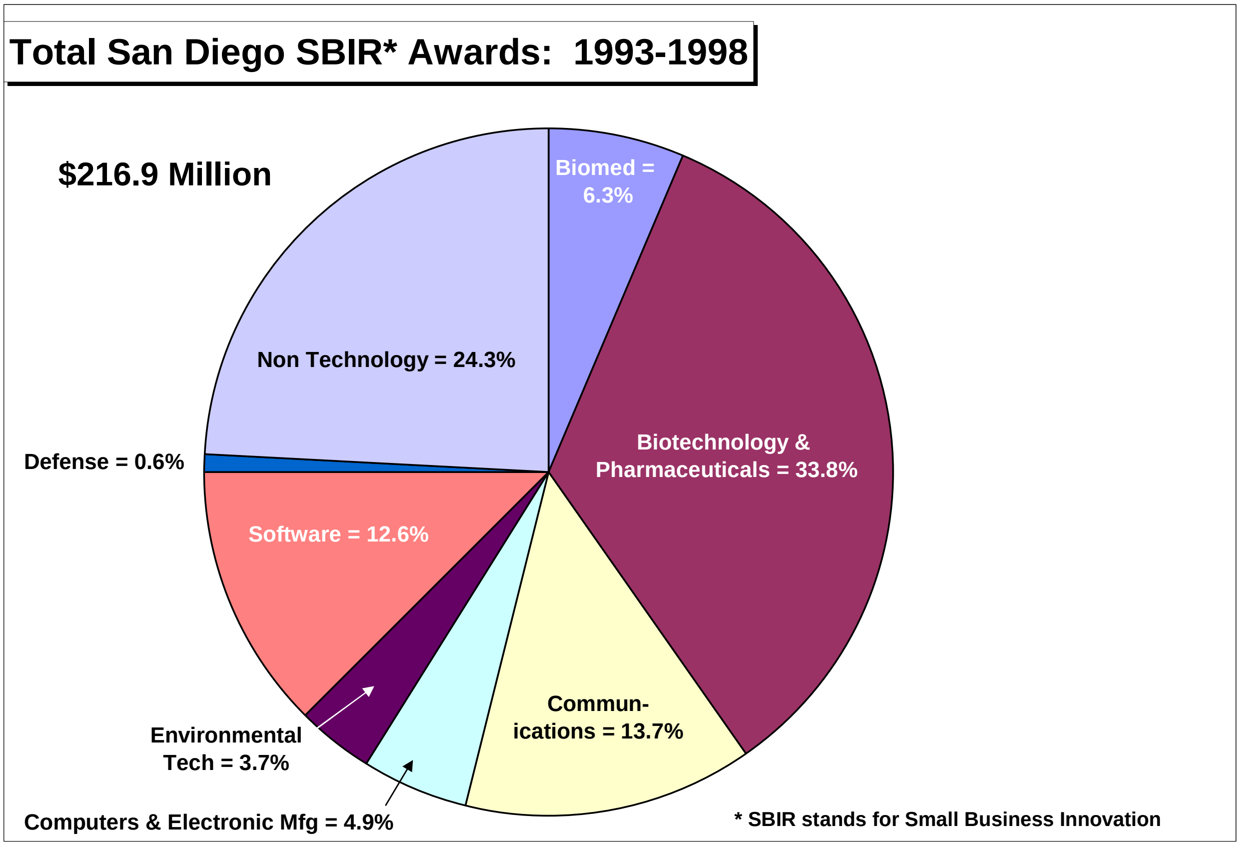
The San Diego region appears to have the critical mass of service providers to help new technology firms succeed. This fact is supported when examining new company formation in San Diego. In the technology clusters, the number of companies increased from 2,412 in 1991 to 3,788 in 2000, a growth rate that averages 6.3% per year. In the San Diego economy outside the technology sector, the growth rate of new companies averages 1.0% per year for the same time period [see Figure 119]. In short, within the technology sector there is a process in place to convert ideas to products and services and establish companies that will develop and market those products.

**Figure 119**



For new businesses to grow they need access to capital and one avenue open to a business in the high technology arena is the Small Business Innovation Research Program [SBIR]. In San Diego this program awarded about $216.9 million to 1,010 companies between 1993 and 1998. Our research shows that about 76% of the monies awarded went to 711 firms in 7 of the technology clusters. In fact, the only technology clusters to not receive SBIR awards are Horticulture and Recreational Goods Manufacturing. The technology cluster receiving the largest amount of SBIR funding is Biotechnology and Pharmaceuticals with about $73.3 million or 34% of the total [see Figure 120]. Ranked 2nd is Communications with about $30 million or 13.7% and ranked 3rd is Biomedical Products with about $13.8 million or 6.3% see Figure 120].

**Figure 120**

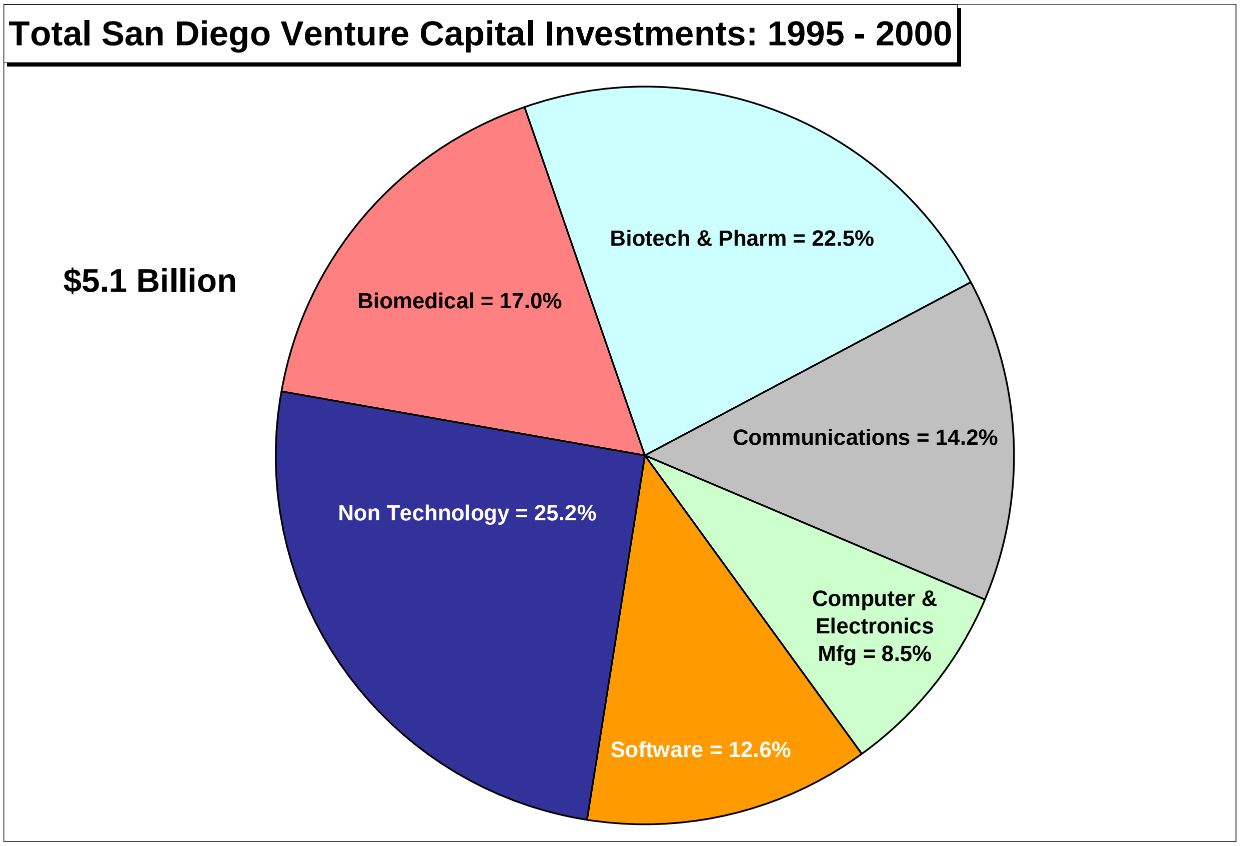



Another way new firms can obtain funds is in the form of Venture Capital [VC]. As pointed out in the Monitoring Our Progress section, the amount of dollars companies received from VC increased fifteen-fold between 1990 and 2000 and San Diego does well compared to other regions. Analysis of the VC data reveals that about 75% of the funds distributed to companies in San Diego went to technology start-ups.[76].

[76]The allocation of VC dollars by industry receiving the VC $ is classified by PriceWaterhouseCooper [PWC] in their MoneyTree analysis of Venture Capital. Those categories are compared to the 9 San Diego technology clusters. Though not identical, there is a great deal of similarity in some of the categories and certain categories defined by PWC are used as technology clusters for this study. Appendix C contains the data.

Between 1995 and 2000, about $5.1 billion was invested by Venture Capitalists in San Diego. Of that total, five technology clusters received about $3.8 billion with the balance [about $1.28 billion or 25.2%] going to non-technology firms. The technology cluster receiving the largest portion is Biotechnology & Pharmaceuticals with about $1.15 billion or about 22.5% of the total. Ranked 2nd is Biomedical Products with about $0.87 billion or 17% of the total and ranked 3rd is Communications with about $0.72 billion or about 14.2% of the total [see Figure 121].

**Figure 121**

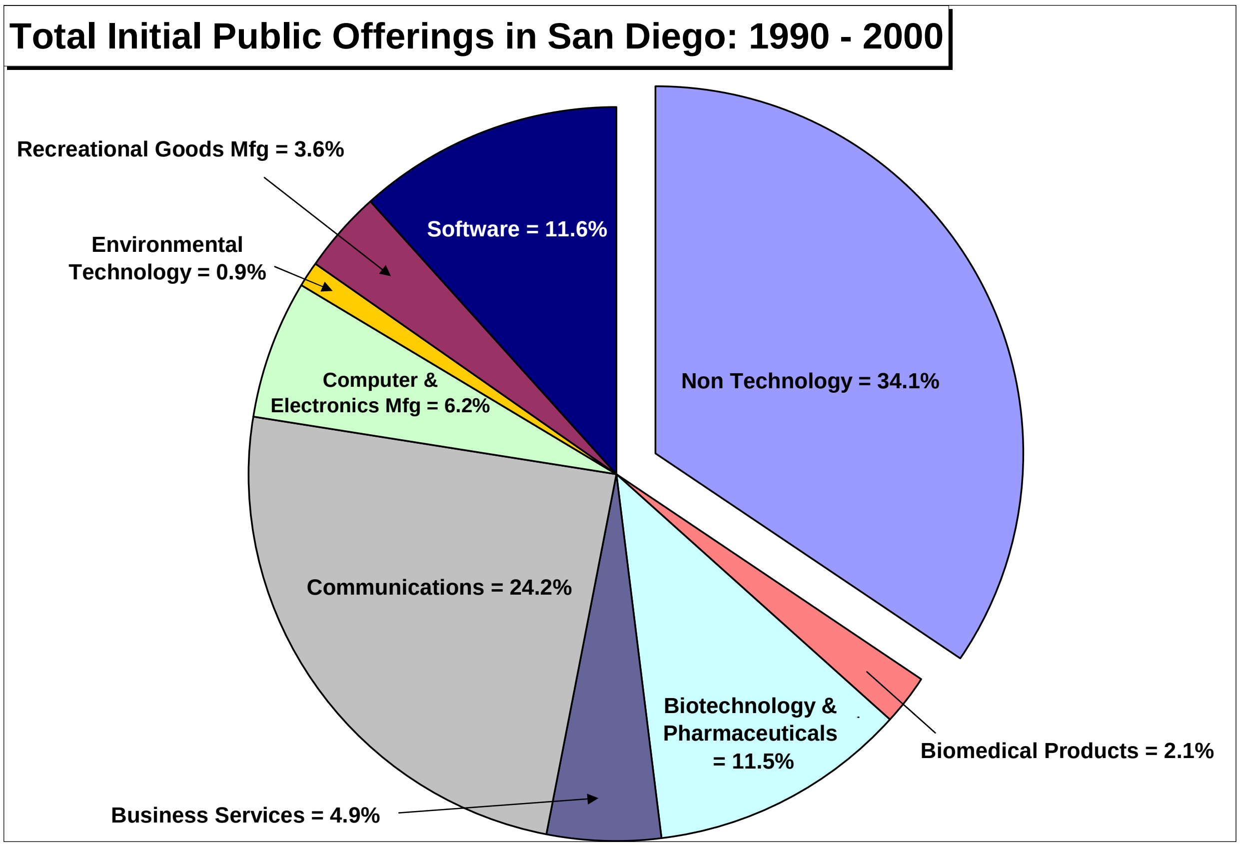



Preliminary results for 2001 indicate the amount of money received by San Diego firms from Venture Capital declined about 33% from about $2.1 billion in 2000 to about $1.4 billion in 2001. Surveys[77] indicate that less money is going into telecommunications and network equipment and more into biotechnology, medical devices and healthcare services. Further, it also appears more money is going to maintaining companies rather than funding new start-ups.

[77] PWC MoneyTree and GrowThink [a Los Angeles market research firm].

Another way for firms to raise capital is by selling shares of their stock to the public. The first time a company does this it is referred to as an Initial Public Offering or IPO. Going public usually occurs after a firm has proven its business model. As noted earlier in this report, there was about a 300-fold increase in the dollars raised from San Diego IPOs in the 1990s. Our research shows that about 60% of the money raised from IPOs went to companies in the technology sector with Communications ranked 1st with about 24% of the total [see Figure 122]. Ranked 2nd is Software and Computer Services with about 11.6% of the total and ranked 3rd is Biotechnology and Pharmaceuticals with about 11.5% of the total.

**Figure 122**




Initial results for 2001 reveal three companies went public in San Diego and they raised about $390 million – a 60% drop from the $981 million raised from IPOs in San Diego in 2000. One of the IPOs in 2001 was in the technology sector – in the Biomedical Products cluster while the other two were outside the technology sector.

## Looking Forward

The technology sector is vibrant in San Diego and appears to be leading the regional economy toward improved prosperity. The recession in the early 1990s saw the Defense and Transportation cluster shrink dramatically. Today, the technology sector is poised to grow and is more balanced now than it was in the early 1990s when the defense cluster accounted for about 34% of all technology sector employment. Today there are five technology clusters each having 14% or more of the technology sector employment. Well-established research capabilities, a fully developed network to *incubate* new businesses, an ability to attract SBIR funds and venture capital from investors all point to an opportunity for future prosperity.

The University of California at San Diego and other research institutions have well-established research programs that are continually awarded research grants. This links well to the Biotechnology and Pharmaceuticals cluster, which is well positioned to take advantage of all sorts of new discoveries in the new millennium. Likewise, the Communications cluster is well established and continues to make inroads internationally with its products[78]. The terrorist events of September 11 have increased federal government expenditures on the military, so the Defense and Transportation cluster may actually see employment growth in the coming years. In addition, efforts to counter bio-terrorism may utilize some of the research facilities already in place in San Diego – and this could also add a boost to the Biotechnology and Pharmaceuticals cluster.

If there is a negative, it is that future growth in employee compensation in the technology sector may not be as fast as that experienced in the previous decade. A significant portion of employee compensation in the late 1990s in the technology clusters [especially in the Communications cluster] was derived from stock options, not the commercialization of products and resulting growth in the middle income jobs that support product production. However, wage growth in the technology clusters is likely to out-pace the average for the regional economy.

[78]Recent articles in the San Diego Union Tribune highlight Qualcomm's ability to penetrate the Chinese mobile phone market.

## Methodology – Identifying the Relationship Between Innovation, Technology and Prosperity

There is a five-step process to defining companies that are most innovative.

- Step 1 – Identify organizations that were awarded patents between 1990 and 1999
- Step 2 – Assign the Standard Industrial Classification code to organizations awarded patents
- Step 3 – Distribute patents among the SIC codes based on the organization's SIC code
- Step 4 – Allocate patents to the San Diego clusters based on the organization's SIC code.
- Step 5 – Evaluate the clusters to determine which are most innovative.

Step 1 – Identify organizations awarded patents between 1990 and 1999.

This was accomplished by obtaining a list of organizations awarded patents from the US PTO. There are a total of 10,984 utility patents awarded between 1990 and 1999. Of the total, 2,800 patents or 25.5% are awarded to individuals leaving 8,184 utility patents awarded to 1,463 organizations. For plant patents, there are a total of 125 awarded between 1990 and 1999. Of the total, 33 patents or 26.4% were awarded to individuals leaving 92 plant patents awarded to 8 companies.

Step 2 - Assign SIC codes to organizations awarded utility and plant patents.

By using information from the California Employment Development Department, Securities and Exchange Commission listings, organization web sites, information from the San Diego Economic Development Corporation, and the SIC manual, SIC codes are assigned to 275 organizations [about 18% of all organizations receiving patents]. Complicating this process is the fact that some companies merge or get purchased and their SIC code changes, or some companies go out of business. Nevertheless, these 275 companies account for over 66% of all patents awarded to organizations.

Step 3 – Distribute patents among SIC codes based on the organization's SIC code.

Another complexity is found with multifunction organizations where different parts of the organization operate in different clusters. For example, Scripps Clinic and Research Foundation was awarded 43 patents and operates in two SIC codes – one dealing with the provision of medical services and one dealing with research in biotechnology & pharmaceuticals. Its patents are all allocated to the SIC code associated with research in biotechnology & pharmaceutical because its research is done in biotechnology while most of the work in the medical services field is in providing services to clients – not undertaking research. For the US Navy, there are at least four SIC codes to which its 345 patents could be assigned. Rather than attempting to allocate its patents amongst the various SIC codes, it was decided to allocate all of them to a category called defense.

Step 4 – Allocate patents to the San Diego clusters based on the organization's SIC codes.

Of the 5,512 patents for which we obtained data, about 86% were assigned to 11 San Diego clusters. A difficult aspect in assigning company patents to clusters is that a firm may operate in more than one cluster. Judgments were made regarding the cluster to which the company's patents were assigned. These judgments were based on information about the individual firm from the company's web page, the Securities and Exchange's web page for the company involved, and other relevant information. In most cases it was relatively straightforward to distribute the patents among the appropriate clusters. For a small number of organizations [seven companies with 20 patents] this was not possible. These firms had been assigned SIC code 8731 and there was relatively little information about them, in fact, three had gone out of business. Their 20 patents are distributed to three clusters [the Biotechnology & Pharmaceuticals cluster, the Software Computer Services cluster, and the Communications cluster], based on the relative share of employees in each of the three clusters. Definitions of the clusters using the SIC codes are contained in the glossary.

Step 5 – Evaluate the clusters to determine which clusters are most innovative.

To evaluate if patenting is an on-going part of a cluster's work, the number of patents awarded per thousand employees is calculated for each cluster. Those clusters with a ratio of patents per thousand employees that is significantly lower than the average are dropped from the clusters considered most innovative. An exception was made for the Software and Computer Services cluster since software firms protect their ideas via the Copyright system. This step yields nine clusters that are considered the most innovative.

**Pages 138 through 149 intentionally left blank.**