As has been the case nationally, southwestern Pennsylvania’s technology clusters have had to navigate a long, hard path since the economic downturn of 2001. The investment boom of the late 1990s was followed by an investment bust, which was felt more acutely in the technology-related industries. Symptomatic of this investment bust were sharp declines in business spending on technology and the availability of venture capital funding. As a result, southwestern Pennsylvania’s technology industries, which had been one of the fastest growing segments of the region’s economy, were faced with a challenging business environment between 2001 and 2003.

Over the second half of 2003, however, signs of a turnaround began to emerge. Robust U.S. economic growth fostered improving business and investor confidence. After a three-year slump, business investment spending began to rise, with notable strength in spending on technology equipment designed to enhance worker productivity. While still well below the peak levels seen during the height of the investment boom, venture capital funding has stabilized and begun to edge higher. Moreover, improved stock market conditions will ultimately lead to a rebirth in IPO activity.

As a result, we look for a solid rebound in technology-related industries in 2004, both nationally and in southwestern Pennsylvania. Our region will see a resumption of growth in its main technology-related industry clusters, which include information technology, biotechnology, advanced manufacturing, advanced materials and environmental technology, as well as growth in a host of emerging clusters. Over the next several years, clusters such as cybersecurity, robotics, data storage, fuel cells and tissue engineering offer potential for further growth, and each of these clusters already has
established a foundation here in southwestern Pennsylvania. Indeed, the diversity of our region’s technology industries is one factor that helped mitigate the adverse impact of the recent downturn.

Other regions of the country whose fortunes have been largely tied up with one industry cluster, such as telecommunications, were hit much harder and will be longer in recovering than is the case in southwestern Pennsylvania.

Another factor that will facilitate our region’s technology rebound is the presence of highly regarded research institutions, most notably the University of Pittsburgh and Carnegie Mellon University. Armed with ample research and development budgets and the ability to draw top-flight research talent to southwestern Pennsylvania, these institutions will continue to have a significant impact on the growth of technology firms in the region. This impact will become more pronounced, given the growing importance of developing commercial applications for academic research and development. Moreover, the presence of quality research institutions provides our region with a pool of trained graduates, more of whom will be likely to remain in the region when presented the job opportunities afforded by a diverse and growing range of technology industries.

In summary, having weathered the worst of the recent economic downturn and collapse of business investment spending, southwestern Pennsylvania’s technology industries find themselves well-positioned to benefit from the rebound in technology industries that we expect for 2004. Moreover, given its diverse mix of technology clusters and the presence of world-class research institutions, the region will realize continued growth in its technology-related industries well beyond 2004.
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- Data Storage in the Pittsburgh Region
- Electro-Optics in the Pittsburgh Region
- Fuel Cells in the Pittsburgh Region
- Manufacturing in the Pittsburgh Region
- Nanotechnology and MEMS in the Pittsburgh Region
- Robotics in the Pittsburgh Region
- System-on-a-Chip in the Pittsburgh Region
- Tissue Engineering in the Pittsburgh Region
- U.S. Government-funded Research and Development in the Pittsburgh Region
- Wage Increases in the Pittsburgh Region

For optimal viewing, set your screen resolution to 1024 and millions of colors. The text within this document is searchable. For Mac users, type Cmd + F; Windows users type Ctrl + F. To find again, type Cmd (or Ctrl) + G.
PURPOSE OF THIS REPORT

The State of the Industry Report is the fifth in a series of benchmark studies compiled by the Pittsburgh Technology Council.

As in past years, the primary goal of this annual report is to quantify the impact and draw attention to the region’s significant technological resources, thereby engendering a deeper, more current understanding of this sector’s contribution to the southwestern Pennsylvania economy. The intent is that this report will continue the process of redefining the region’s assets and help to identify resources and tactics that will strengthen them.

In addition to the macro-level regional analysis, this report features analyses of five of the region’s key technology industry clusters. They are:

- information technology
- life sciences
- advanced manufacturing
- advanced materials
- environmental technology

Beyond these five industry clusters, this year’s report also will provide a deeper examination of the emerging technology clusters, including:

- system-on-a-chip
- data storage
- nanotechnology and micro-electro-mechanical systems (MEMS)
• cybersecurity
• tissue engineering and regenerative medicine
• electro-optics
• robotics
• fuel cells

Although the five main industry clusters and emerging technology clusters play an important role in innovation and growth within the region’s borders, they do not provide a complete picture. In addition to basic industry statistics on wages and employment over the measured period, data also was collected that focused on supporting activities, including business incorporations, venture capital, initial public offerings, university technology transfer activity and many other indicators.
WHY IS TECHNOLOGY IMPORTANT?

Some might ask why technology deserves the focus of an analysis separate from other economic sectors. There are several important reasons:

- Despite economic downturns in certain geographic markets and industry sectors, technology industries are growing globally and are forecast for continued growth with new and expanding markets.

- Technology industries are knowledge- or human capital-based, and they create a greater share of high-paying, high-quality jobs.

- On average, technology industries generate higher added value per worker than other non-technology industries.

- Technology industries create products that are prime export commodities, thereby bringing new wealth into the region.

- Many startup companies are defined within the technology sector, and a disproportionate share of high-growth, innovative businesses emerge from technology industries.

- Technology startup successes draw venture capital into the region; they also have been the source of the region’s most promising initial public offerings.

- Technology industries share a natural synergy with the region’s existing base of world-class research universities.

- Finally, a region’s ability to serve as a competitive platform for technology also exponentially affects other businesses, like financial, legal and marketing services.
A key challenge in compiling such a report is defining what is meant by the “technology industry.” Numerous national and regional studies have been conducted, often with unique definitions.

Further, to maximize the consistency of data, the methodology used for this report is consistent with other published data sources, which can allow comparisons with other regions.
Industry Categories

For more than 60 years, the Standard Industrial Classification (SIC) system has served as the structure for the collection, aggregation, presentation and analysis of the U.S. economy. An industry consists of a group of establishments primarily engaged in producing or handling the same product or group of products or in rendering the same services. Because the SIC was used by many other federal government statistical programs, it was possible for users to assemble a comprehensive statistical picture of an industry.

The SIC system was developed in the 1930s at a time when manufacturing dominated the U.S. economy. Over the last 60 years, there have been numerous revisions to the SIC system, reflecting the economy’s changing industrial composition. However, despite these revisions, the system has received increasing criticism about its ability to handle rapid changes in the economy. Recent developments in information services, new forms of health care provision, expansion of services and advanced manufacturing are examples of industrial changes that could not be studied under the SIC system.

Introducing NAICS

Developed in cooperation with Canada and Mexico, the North American Industry Classification System (NAICS) represents one of the most profound changes for statistical programs focusing on emerging economic activities. NAICS was developed using a production-oriented conceptual framework, and it groups establishments into industries, based on the activity in which they are primarily engaged. Establishments using similar raw material inputs, similar capital equipment and similar labor are
Introducing NAICS (cont.)

classified in the same industry. In other words, establishments that do similar things in similar ways are classified together.

The new NAICS classification system provides a new tool that ensures that economic statistics reflect our nation’s changing economy. However, improved statistics will result in time series breaks. Every sector of the economy has been restructured and redefined. A new information sector combines communications, publishing, motion pictures, sound recording and online services, in recognition of our information-based economy. Advanced manufacturing is restructured to recognize new high-tech industries.

A new sub-sector is devoted to computers and electronics, including reproduction of software.

The NAICS system uses six-digit codes to classify all economic activity into twenty industry sectors. Five sectors are mainly goods-producing sectors and 15 are entirely services-producing sectors. This six-digit hierarchical structure allows greater coding flexibility than the four-digit structure of the SIC. In addition, NAICS allows for the identification of 1,170 industries compared to the 1,004 found in the SIC system.

The advantage of using industry-level definitions, such as NAICS, is that we can use publicly collected data to support our assertions. In addition, using standard industry definitions allows valid comparison across geographic regions and across time.

By contrast, comprehensive data encompassing the universe of individual firms is extremely difficult and expensive to gather.

Still, even with NAICS, there are other drawbacks. Most notably, a situation could occur whereby an individual firm may be highly technology intensive, but it may be
grouped with an industry that is typically not. This will result in the firm being excluded from classification as technology. Likewise, not all individual firms classified within technology industries actually may employ above average technology in their processes and/or products.

Also, in a departure from previous years, this edition of the State of the Industry Report will publish only the most recent two years of statistical data, since NAICS is not directly comparable with the outmoded SIC system. In other words, comparing NAICS data for the years 2000 and 2001 with previous years’ SIC data would be largely inconsistent and irrelevant.
Key Criteria

Aside from NAICS, there are three main criteria for determining if an industry is qualified as technology:

- Research and development activity
- Scientists and engineers employed
- Specialty technology workers employed

The research and development (R&D) intensity of any industry is expressed as the percentage of sales invested in R&D. Industries with greater R&D intensity exhibit more innovation and are likely to utilize higher levels of technology.

Technology industries also feature higher levels of scientists and engineers in their employment.

The third criterion includes the number of specialty technology workers in the region who are employed in typically non-technology industries. These specialty job functions include, but are not limited to, information systems (IS) workers and computer programmers who may work at financial and other IS-intensive mainstream institutions. It also includes the likes of technical, medical and lab personnel working at facilities, such as hospitals and clinics that support the core life sciences cluster. Finally, this criterion also encompasses technical workers and scientists in heavy industrial processes, such as metallurgy, chemical engineering, process engineering, etc.
There are a few aspects of technology activity that this report does not capture which, in turn, may serve to understate the importance of technology in the regional economy in the following ways:

- It does not capture the R&D facility of a firm in an industry not classified as technology. For example, the R&D facility of a railroad company would not be captured, despite the possibility of high levels of R&D activity and high percentages of scientists and engineers in its workforce.

- This report also does not treat university researchers as a separate industry cluster, primarily because the data is not collected at a level of detail to make accurate comparisons with other industries. However, university researchers are a significant pool of technology workers, especially in our region. Therefore, later in this report we offer a brief analysis of trends in university research to further clarify technology's role in the region's economy.
Agglomeration

A key concept behind the importance of industry clusters is that of agglomeration economies. Agglomeration refers to benefits that are enjoyed by firms because they are located in a region with other similar or related firms. These benefits can take the form of horizontal clusters, where many firms in the same industry locate in the same place, as illustrated by software companies in this region. The horizontal clusters provide benefits by:

- facilitating networking and sharing of information
- promoting the development of a deep labor pool
- developing specific policy and infrastructure components that support the cluster

Often referred to as the value chain, we identify and examine groups of industries within each cluster.

Not all of the companies and industries within these clusters are technology intensive, but they are essential to the development and operation of the cluster. For instance, many telecommunications companies hire small numbers of technical workers compared to large numbers of administrative workers. Nevertheless, these firms are an important element in a successful cluster.

This year's report more sharply defines industries within each cluster that are more technology oriented. These industries typically concern themselves with the actual development, manufacturing and marketing of advanced technology-based products or services. These companies also typically derive at least 50 percent of their revenue
from the commercial application of an advanced proprietary technology product or service, and usually the companies are intellectual property-intensive.

By the same token, this report does not exclude other industries that are considered part of the supply chain. An important example would be the inclusion of general medical and surgical hospitals within the life sciences cluster. Certainly hospitals employ large numbers of non-technical workers, and their inclusion increases the size and impact of this industry cluster. But we argue, and there are many who agree, that hospitals are an important element of a healthy and competitive life sciences cluster and that the non-technical workers are, likewise, critical to hospital operations.

The resulting industry clusters reflect a greater representation of industries that are heavy in research and development, along with companies whose employees have a high concentration of scientists and engineers.

With these distinctions in mind, the next section will examine the region’s five main technology clusters by defining the industries within each. The lists of industries that comprise each group will further be identified with NAICS codes.
THE 13-COUNTY PICTURE

The geographic boundaries served by the Pittsburgh Technology Council encompass 13 counties within the southwestern Pennsylvania region. These counties include Allegheny, Armstrong, Beaver, Bedford, Butler, Cambria, Fayette, Greene, Indiana, Lawrence, Somerset, Washington and Westmoreland.

The chart below examines the aggregate of the region’s five main technology clusters for 2002, the latest year for which data is available. These industries are defined by the NAICS tables that accompany each cluster section, and all businesses are situated within the Pittsburgh Technology Council operational 13-county area. Because of this expanded geographic frame, the overall statistical picture is greater than indicated in the six-county Metropolitan Statistical Area (MSA), which is examined later.

<table>
<thead>
<tr>
<th>Cluster(s)</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAICS Definitions (13 Counties)</td>
<td>6,613</td>
<td>221,948</td>
<td>$10,393,599,174</td>
<td>$46,829</td>
</tr>
<tr>
<td>% change 2001–2002</td>
<td>-5.9</td>
<td>-2.6</td>
<td>+1.3</td>
<td>+3.9</td>
</tr>
</tbody>
</table>

The 6,613 technology firms tallied in the year 2002 represent more than 11.5 percent of all companies in the region. These firms employ more than 222,000 individuals and account for nearly 17.5 percent of the area’s overall workforce. In addition, the $10.4 billion earned last year by the technology workforce represents 24 percent of the region’s total annual payroll.
THE SIX-COUNTY MSA

Although the 13 contiguous counties broadly define the region that is southwestern Pennsylvania, the federal government recognizes only a core configuration of six counties as the metropolitan statistical area (MSA): Allegheny, Beaver, Butler, Fayette, Washington and Westmoreland.

Major urban areas throughout the U.S. are grouped into their own MSAs, usually encompassing multiple counties, which enables more accurate comparisons among other MSAs and results in a better tool when formulating public policy and federal funding initiatives.

It is important to mention that early last year, Armstrong County was added to the MSA, thereby increasing the number of core metropolitan counties to seven. However, most federal sources will not be prepared to track data on the expanded MSA until next year. So this year’s report continues to use six counties in defining the MSA.

This subset of southwestern Pennsylvania, the MSA, therefore is the most consistent unit of measure when comparing regions throughout the U.S. Logically, the Pittsburgh MSA reports NAICS-defined cluster results that are slightly less than the wider 13-county territory for 2002.
Lastly, the Pennsylvania Bureau of Labor and Industry, from which most of the following employment and wage data is derived, maintains a strict policy of guarding the confidentiality of data from reporting companies. For this reason, certain industry clusters are unable to be reported in six-county formats, and statistics are available only for 13 counties.
INDUSTRY CLUSTER DATA: THE TECHNOLOGY SCORECARD

The region’s technology industries grew throughout the latter part of the 1990s, establishing themselves as major components of southwestern Pennsylvania’s economy. With a few exceptions, most clusters continued to add to their employment ranks.

Likewise, throughout the previous decade, there have been general positive trends in the number of companies and total annual payroll. Certain technology clusters have been creating new firms at a rapid pace, and their businesses in general pay better wages than other parts of the economy.

The following pages in this section serve to identify industries by NAICS code within each cluster and report detailed histories over the course of the last two years.
INFORMATION TECHNOLOGY

Information technology in the Pittsburgh region covers businesses that design and make computer hardware and software and that provide telecommunications services and technologies. The performance of these three subcluster industries serve to mirror the overall pattern of the aggregated core IT cluster, including the gains made across the board in average wages. As an example, the average wage for the software subcluster in the six-county MSA (metropolitan statistical area) is the highest in this report at $71,300 a year.

**Highlights:**

- **100 hardware firms** employ more than **8,564 people** with a total annual payroll of **$392 million**. This subcluster led all others within the industry in terms of gains in average wages, which grew more than 11 percent within the MSA.

- **772 software firms** employ **9,630 people** with a total annual payroll of **$681 million**, which positions this subcluster with the highest average wage examined within this report at **$71,376 per year** for the MSA.

- **495 telecommunications firms** employ **18,889 people** with a total annual payroll of nearly **$978 million**.

These three subclusters are grouped according to their NAICS codes as follows:
## Hardware

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>334111</td>
<td>Electronic Computer Manufacturing</td>
</tr>
<tr>
<td>334112</td>
<td>Computer Storage Device Manufacturing</td>
</tr>
<tr>
<td>334113</td>
<td>Computer Terminal Manufacturing</td>
</tr>
<tr>
<td>334119</td>
<td>Other Computer Peripheral Equipment Manufacturing</td>
</tr>
<tr>
<td>334210</td>
<td>Telephone Apparatus Manufacturing</td>
</tr>
<tr>
<td>334220</td>
<td>Radio and Television Broadcasting and Wireless Communications Equipment</td>
</tr>
<tr>
<td>334290</td>
<td>Other Communications Equipment Manufacturing</td>
</tr>
<tr>
<td>334310</td>
<td>Audio and Video Equipment Manufacturing</td>
</tr>
<tr>
<td>334412</td>
<td>Bare Printed Circuit Board Manufacturing</td>
</tr>
<tr>
<td>334413</td>
<td>Semiconductor and Related Device Manufacturing</td>
</tr>
<tr>
<td>334414</td>
<td>Electronic Capacitor Manufacturing</td>
</tr>
<tr>
<td>334415</td>
<td>Electronic Resistor Manufacturing</td>
</tr>
<tr>
<td>334417</td>
<td>Electronic Connector Manufacturing</td>
</tr>
<tr>
<td>334418</td>
<td>Printed Circuit Assembly (Electronic Assembly) Manufacturing</td>
</tr>
<tr>
<td>334419</td>
<td>Other Electronic Component Manufacturing</td>
</tr>
<tr>
<td>334515</td>
<td>Instrument Manufacturing for Measuring and Testing Electricity and Electrical</td>
</tr>
<tr>
<td>334613</td>
<td>Magnetic and Optical Recording Media Manufacturing</td>
</tr>
</tbody>
</table>
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The Pittsburgh Supercomputing Center is one of only eight such centers throughout the U.S., and it houses a full-scale Terascale Computing System, the most powerful in the world available for public research. Researchers nationwide are allocated time for a range of projects that include AIDS research, astrophysics, fluid dynamics, materials science, earthquake modeling and the structure and function of proteins and DNA. Plans ultimately call for storing and managing a petabyte of data, which is equivalent to 100 times the contents of the Library of Congress, the largest library in the world.

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## Telecommunications

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>515111</td>
<td>Radio Networks</td>
</tr>
<tr>
<td>515112</td>
<td>Radio Stations</td>
</tr>
<tr>
<td>515120</td>
<td>Television Broadcasting</td>
</tr>
<tr>
<td>515210</td>
<td>Cable and Other Subscription Programming</td>
</tr>
<tr>
<td>516110</td>
<td>Internet Publishing and Broadcasting</td>
</tr>
<tr>
<td>517110</td>
<td>Wired Telecommunications Carriers</td>
</tr>
<tr>
<td>517211</td>
<td>Paging</td>
</tr>
<tr>
<td>517212</td>
<td>Cellular and Other Wireless Telecommunications</td>
</tr>
<tr>
<td>517310</td>
<td>Telecommunications Resellers</td>
</tr>
<tr>
<td>517410</td>
<td>Satellite Telecommunications</td>
</tr>
<tr>
<td>517510</td>
<td>Cable and Other Program Distribution</td>
</tr>
<tr>
<td>517910</td>
<td>Other Telecommunications</td>
</tr>
<tr>
<td>518111</td>
<td>Internet Service Providers</td>
</tr>
<tr>
<td>518112</td>
<td>Web Search Portals</td>
</tr>
<tr>
<td>518210</td>
<td>Data Processing, Hosting and Related Services</td>
</tr>
<tr>
<td>541513</td>
<td>Computer Facilities Management Services</td>
</tr>
<tr>
<td>541519</td>
<td>Other Computer-related Services</td>
</tr>
</tbody>
</table>
The following charts illustrate the aggregate of all the previously defined IT subclusters and they report the cluster’s growth in employment, number of establishments, total annual payroll and average wage.

**Aggregated Information Technology Cluster**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,487</td>
<td>40,444</td>
<td>2,151,727,950</td>
<td>$53,202</td>
</tr>
<tr>
<td>2002</td>
<td>1,367</td>
<td>37,083</td>
<td>2,052,053,165</td>
<td>$55,336</td>
</tr>
</tbody>
</table>

% change 2001–2002: -8.0 -8.3 -4.6 +4.0

**Aggregated Information Technology Cluster**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,372</td>
<td>37,518</td>
<td>$2,051,857,630</td>
<td>$54,689</td>
</tr>
<tr>
<td>2002</td>
<td>1,261</td>
<td>34,150</td>
<td>$1,946,766,191</td>
<td>$57,006</td>
</tr>
</tbody>
</table>

% change 2001–2002: -8.0 -8.9 -5.1 +4.2
According to NAICS data, the number of establishments, the number of employees and total annual payroll decreased considerably between 2001 and 2002 within the entire IT cluster. The average wage, however, increased by more than four percent, largely due to the increase in the hardware subcluster.

In November 2003, the Pittsburgh Digital Greenhouse was awarded $4.5 million from the Commonwealth of Pennsylvania’s Department of Community and Economic Development. Of the awarded funds, $2 million will be used to foster applied research and faculty startup packages for the emerging System-on-a-Chip (SoC) industry cluster; $1.5 million will be invested in commercial research and the foundation of SoC companies.
The Pittsburgh Technology Council recognizes a variety of software that is included within the general NAICS classifications (334611 and 511210) in this report. These types of software include:

**Prepackaged Software (shrink-wrapped and standardized)**
Shrink-wrapped software is developed for a mass market; standardized software targets a more specific, yet still large, market niche. Windows XP Professional predominantly serves the office market and is considered standardized.

**Customized Software**
Customized software is tailor-made for a specific application user. In many cases, a software developer will start with a shrink-wrapped or standardized package.

**Embedded Software**
In order to allow a computer to perform dedicated functions, embedded software is that which is integrated within the hardware.

**Enterprise Software**
This distributed systems and networking software is specifically intended to enhance corporate capabilities and typically involve a client/server model, such as databases and file systems.

**Internet Software**
This type of software allows Internet companies to create home pages, provide electronic forms and offer search engines or browsers that assist Internet users.
Between 2001 and 2002, software as a subset of the IT industry lost ground in the number of companies, the number of employees and total annual payroll, however it still managed to post the highest average wage examined within this report.

### IT: Software Subcluster - 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>813</td>
<td>11,175</td>
<td>$766,400,399</td>
<td>$68,580</td>
</tr>
<tr>
<td>2002</td>
<td>772</td>
<td>9,630</td>
<td>$681,735,952</td>
<td>$70,794</td>
</tr>
</tbody>
</table>

| % change 2001–2002 | -5.0 | -13.8 | -11.0 | +3.2 |

### IT: Software Subcluster - Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>778</td>
<td>11,039</td>
<td>$760,909,961</td>
<td>$68,927</td>
</tr>
<tr>
<td>2002</td>
<td>735</td>
<td>9,429</td>
<td>$672,982,978</td>
<td>$71,376</td>
</tr>
</tbody>
</table>

| % change 2001–2002 | -5.5 | -14.5 | -11.5 | +3.5 |
The telecommunications subcluster still continued to suffer the results of an industry shakeout due to overcapacity, as the number of companies declined in excess of 12 percent. Declines in total employment were not as drastic; growth in the total annual payroll could be considered flat, while average wages improved.

### IT: Telecommunications Subcluster

#### 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>566</td>
<td>19,572</td>
<td>$983,857,091</td>
<td>$50,269</td>
</tr>
<tr>
<td>2002</td>
<td>495</td>
<td>18,889</td>
<td>$977,963,865</td>
<td>$51,775</td>
</tr>
</tbody>
</table>

% change 2001–2002: -12.5, -3.4, -0.6, +2.9

#### Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>502</td>
<td>17,542</td>
<td>$910,806,836</td>
<td>$51,921</td>
</tr>
<tr>
<td>2002</td>
<td>440</td>
<td>16,827</td>
<td>$900,535,807</td>
<td>$53,519</td>
</tr>
</tbody>
</table>

% change 2001–2002: -12.3, -4.0, -1.1, +3.0

---

Cybersecurity in the Pittsburgh Region

[READ RELATED ARTICLE]
LIFE SCIENCES

Since Pittsburgh earned its reputation for being a world-renowned organ transplantation center, there has been significant growth of newer, thriving commercial ventures that are engaged in a wide spectrum of the newly renamed life sciences cluster.

In this year’s report, the life sciences cluster is divided into five subclusters:

- Medical Equipment and Supplies
- Health Services
- Bio Research
- Instruments and Devices
- Pharmaceuticals

Medical instruments and devices, cell research, tissue engineering and biomedical informatics comprise a widening list of life sciences disciplines in which the Pittsburgh region has a significant stake.

The formidable research programs at southwestern Pennsylvania universities provide the genesis of most of the commercial ventures in the region’s life sciences. This is especially true at the University of Pittsburgh, which ranked eighth among universities funded through the National Institutes of Health.

Other firms have focused on medical instruments and devices. Respironics, for example, is the leading manufacturer of devices for use in clinical or in-home care of respiratory disorders. Medrad, a recent Malcom Baldrige Award winner, also exemplifies this
Technology in Southwestern Pennsylvania

Subcluster. With 1,200 employees worldwide (900 of which are local), Medrad is a global leader in devices that enable and enhance imaging of the human body. Other newer medical device companies in southwestern Pennsylvania include ALung Technologies, AntakaMatics, Ardiem, Dymax, Lifecor, Oberg and many more.

Cell research has spawned a cadre of newer, thriving commercial ventures, and among them are Automated Cell, Bioptechs, Cellomics, Sequel Genetics and others. Precision Therapeutics, as an example, is commercializing a process to assist physicians in determining the effectiveness of anti-cancer drug therapies on individual patients whose tumor-derived cells are grown outside of the body.

*(See related article, “Tissue Engineering in the Pittsburgh Region.”)*

And for more than a decade, McKessonHBOC Automated Healthcare Group has been manufacturing and marketing several lines of automation systems for healthcare institutions. ROBOT-Rx, AcuDose-Rx, Admin-Rx and SupplyScan all reduce medication errors, increase cost savings and improve the quality of care.

The artificial heart program at the University of Pittsburgh Medical Center is among the most active in the world in implanting mechanical circulation support devices.
Highlights:

- Including the Health Services subcluster, there are 2,619 life sciences firms in the region employing more than 116,000 people with a total annual payroll in excess of $5 billion.

- The Health Services subcluster encompasses 2,238 companies employing more than 101,500 people with a total annual payroll of $4.3 billion.

- Instruments & Devices employment increased nearly three percent; total annual payroll increased more than 10 percent, and average wages increased nearly eight percent, making this subcluster one of the few that grew consistently over the course of a year.

- The 254 companies in the Bio Research subcluster employing 8,045 people are responsible for a $464 million total annual payroll.

- Though employment was down by only five people in the Pharmaceuticals subcluster, the total annual payroll increased more than seven percent to $25.8 million, and the average wage increased nearly nine percent to more than $49,000 a year.
The subclusters’ NAICS definitions are as follows:

### Medical Equipment and Supplies

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>339113</td>
<td>Surgical Appliance and Supplies Manufacturing</td>
</tr>
<tr>
<td>339114</td>
<td>Dental Equipment and Supplies Manufacturing</td>
</tr>
<tr>
<td>339115</td>
<td>Ophthalmic Goods Manufacturing</td>
</tr>
<tr>
<td>339116</td>
<td>Dental Laboratories</td>
</tr>
</tbody>
</table>

### Health Services

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>621111</td>
<td>Offices of Physicians (except Mental Health Specialists)</td>
</tr>
<tr>
<td>621112</td>
<td>Offices of Physicians, Mental Health Specialists</td>
</tr>
<tr>
<td>621320</td>
<td>Offices of Optometrists</td>
</tr>
<tr>
<td>621391</td>
<td>Offices of Podiatrists</td>
</tr>
<tr>
<td>621492</td>
<td>Kidney Dialysis Centers</td>
</tr>
<tr>
<td>621493</td>
<td>Freestanding Ambulatory Surgical and Emergency Centers</td>
</tr>
<tr>
<td>621498</td>
<td>All Other Outpatient Care Centers</td>
</tr>
<tr>
<td>621511</td>
<td>Medical Laboratories</td>
</tr>
<tr>
<td>621512</td>
<td>Diagnostic Imaging Centers</td>
</tr>
<tr>
<td>621991</td>
<td>Blood and Organ Banks</td>
</tr>
<tr>
<td>622110</td>
<td>General Medical and Surgical Hospitals</td>
</tr>
<tr>
<td>622210</td>
<td>Psychiatric and Substance Abuse Hospitals</td>
</tr>
<tr>
<td>622310</td>
<td>Specialty (except Psychiatric and Substance Abuse) Hospitals</td>
</tr>
</tbody>
</table>
### Biotechnology

**NAICS** | **Description**
--- | ---
325413 | In-Vitro Diagnostic Substance Manufacturing
339111 | Laboratory Apparatus and Furniture Manufacturing
541380 | Testing Laboratories
541710 | Research and Development in the Physical, Engineering and Life Sciences
541720 | Research and Development in the Social Sciences and Humanities

### Instruments and Devices

**NAICS** | **Description**
--- | ---
334510 | Electromedical and Electrotherapeutic Apparatus Manufacturing
334516 | Analytical Laboratory Instrument Manufacturing
334517 | Irradiation Apparatus Manufacturing
339112 | Surgical and Medical Instrument Manufacturing

### Pharmaceuticals

**NAICS** | **Description**
--- | ---
325199 | All Other Basic Organic Chemical Manufacturing
325411 | Medicinal and Botanical Manufacturing
325412 | Pharmaceutical Preparation Manufacturing
325414 | Biological Product (except Diagnostic) Manufacturing

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The aggregated life sciences cluster represents a positive note in this report in that employment, payroll and average wages are up.

### Aggregated Life Sciences Cluster

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2,777</td>
<td>113,320</td>
<td>$4,755,458,478</td>
<td>$41,964</td>
</tr>
<tr>
<td>2002</td>
<td>2,619</td>
<td>116,014</td>
<td>$5,111,147,188</td>
<td>$44,056</td>
</tr>
</tbody>
</table>

% change 2001–2002  
-5.6  +2.3  +7.4  +4.9

* Six-county data is unable to be disclosed for this industry cluster.
According to the Center for Workforce Information and Analysis of the Pennsylvania Department of Labor and Industry, this cluster is expected to grow in employment by nearly 15,000 by the year 2008. Growth industries identified by the Center include drugs, agricultural chemicals, measurement and control devices, medical instruments and supplies, ophthalmic goods, research and testing services.

Medical equipment mirrors the overall cluster’s performance, including a significant jump (9.2 percent) in total annual payroll to nearly $80 million.

### LIFE: Medical Equipment and Supplies Subcluster
#### 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>86</td>
<td>1,841</td>
<td>$72,646,692</td>
<td>$39,459</td>
</tr>
<tr>
<td>2002</td>
<td>83</td>
<td>1,972</td>
<td>$79,330,526</td>
<td>$40,220</td>
</tr>
</tbody>
</table>

% change 2001–2002: -3.4 +7.1 +9.2 +1.9

### LIFE: Medical Equipment and Supplies Subcluster
#### Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>77</td>
<td>1,819</td>
<td>$71,884,632</td>
<td>$39,519</td>
</tr>
<tr>
<td>2002</td>
<td>71</td>
<td>1,930</td>
<td>$78,012,945</td>
<td>$40,423</td>
</tr>
</tbody>
</table>

% change 2001–2002: -7.8 +6.1 +8.5 +2.2
The Health Services subcluster is an important element of the life sciences industry cluster. Hospitals, in particular, are essential sources for the generation of new ideas and talent, and they are a crucial resource for clinical trials and non-laboratory experience. There are no successful life sciences clusters in markets without high-quality hospitals.

The number of facilities has decreased over the measured period, most likely as a result of consolidation. While employment and average wages have increased slightly, the total annual payroll for this subcluster grew by nearly eight percent between 2001 and 2002.

In 2002, the University of Pittsburgh ranked eighth among all U.S. universities receiving funding from the National Institutes of Health. The average amount awarded for all institutions was $6.8 million; the University of Pittsburgh received $308 million.
Less robust during the stagnant economy was the biological research subcluster. Although the total annual payroll and average wage increased modestly, the number of companies doing business in this arena and the people they employed decreased.

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>269</td>
<td>8,049</td>
<td>$457,185,073</td>
<td>$56,801</td>
</tr>
<tr>
<td>2002</td>
<td>254</td>
<td>8,045</td>
<td>$464,213,375</td>
<td>$57,700</td>
</tr>
</tbody>
</table>

% change 2001–2002: -5.5 -0.04 +1.5 +1.5%

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>240</td>
<td>6,942</td>
<td>$406,443,092</td>
<td>$58,551</td>
</tr>
<tr>
<td>2002</td>
<td>225</td>
<td>6,989</td>
<td>$413,567,827</td>
<td>$59,171</td>
</tr>
</tbody>
</table>

% change 2001–2002: -6.2 +0.6 +1.7 +1.0%

The University of Pittsburgh Cancer Centers has more oncologists than any other U.S. cancer center. The $130 million, 350,000-square-foot Hillman Cancer Center is the cornerstone of the Center's goal of becoming one of the top five cancer centers in the country.
While the number of companies within the instruments and devices subcluster decreased by only a few firms, employment increased modestly and total annual payroll increased significantly (13 percent in the MSA). Average wages also increased at a rate well above the rate of inflation.

### LIFE: Instruments and Devices Subcluster

**13 Counties**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>36</td>
<td>3,813</td>
<td>$176,074,077</td>
<td>$46,177</td>
</tr>
<tr>
<td>2002</td>
<td>33</td>
<td>3,920</td>
<td>$194,965,827</td>
<td>$49,743</td>
</tr>
</tbody>
</table>

% change 2001–2002: -8.3 +2.8 +10.7 +7.7

**Six-County MSA**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>30</td>
<td>2,983</td>
<td>$145,657,491</td>
<td>$48,836</td>
</tr>
<tr>
<td>2002</td>
<td>28</td>
<td>3,119</td>
<td>$164,682,811</td>
<td>$52,801</td>
</tr>
</tbody>
</table>

% change 2001–2002: -6.6 +4.5 +13.0 +8.1

University of Pittsburgh surgeons were the first in the U.S. to use the Zeus robot during cardiac bypass surgery. UPMC’s “Intelligent OR” is a $2.5 million operating suite that features Zeus.
The pharmaceuticals subcluster held steady ground over the measured period, as the number of companies increased by only two, and the total decline in employment was negligible. Yet, the total annual payroll and average wages increased markedly.

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>9</td>
<td>531</td>
<td>$23,971,954</td>
<td>$45,131</td>
</tr>
<tr>
<td>2002</td>
<td>11</td>
<td>526</td>
<td>$25,802,286</td>
<td>$49,093</td>
</tr>
</tbody>
</table>

% change 2001–2002: +22.2 % -0.9 % +7.6 % +8.7 %

* Six-county data is unable to be disclosed for this industry cluster.

Several of the world’s top 10 pharmaceutical companies employ Pittsburgh-based Cellomics’ high-content screening tools to hasten the drug discovery process.
ADVANCED MANUFACTURING

Manufacturing meets information technology. This cluster encompasses industries that typically are largely automated and that have a high degree of process controls, such as computer numerical control systems and robotics. (See “Robotics in the Pittsburgh Region” and “Electro-Optics in the Pittsburgh Region” related articles.) This cluster also encompasses those businesses that develop and install these systems for other manufacturers. (See “Manufacturing in the Pittsburgh Region” related article.)

Four of Pittsburgh’s seven Fortune 500 companies are manufacturers. They include Alcoa, H.J. Heinz, PPG Industries and U.S. Steel. Mellon Financial Corporation, PNC Financial Services Group and WESCO International round out the crop.
## Advanced Manufacturing

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>332111</td>
<td>Iron and Steel Forging</td>
</tr>
<tr>
<td>332112</td>
<td>Nonferrous Forging</td>
</tr>
<tr>
<td>332114</td>
<td>Custom Roll Forming</td>
</tr>
<tr>
<td>332115</td>
<td>Crown and Closure Manufacturing</td>
</tr>
<tr>
<td>332116</td>
<td>Metal Stamping</td>
</tr>
<tr>
<td>332117</td>
<td>Powder Metallurgy Part Manufacturing</td>
</tr>
<tr>
<td>332710</td>
<td>Machine Shops</td>
</tr>
<tr>
<td>332721</td>
<td>Precision Turned Product Manufacturing</td>
</tr>
<tr>
<td>332811</td>
<td>Metal Heat Treating</td>
</tr>
<tr>
<td>332812</td>
<td>Metal Coating, Engraving (except Jewelry and Silverware) and Allied Services to Manufacturers</td>
</tr>
<tr>
<td>332813</td>
<td>Electroplating, Plating, Polishing, Anodizing and Coloring</td>
</tr>
<tr>
<td>333210</td>
<td>Sawmill and Woodworking Machinery Manufacturing</td>
</tr>
<tr>
<td>333220</td>
<td>Plastics and Rubber Industry Machinery Manufacturing</td>
</tr>
<tr>
<td>333291</td>
<td>Paper Industry Machinery Manufacturing</td>
</tr>
<tr>
<td>333292</td>
<td>Textile Machinery Manufacturing</td>
</tr>
<tr>
<td>333293</td>
<td>Printing Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333294</td>
<td>Food Product Machinery Manufacturing</td>
</tr>
<tr>
<td>333295</td>
<td>Semiconductor Machinery Manufacturing</td>
</tr>
<tr>
<td>333298</td>
<td>All Other Industrial Machinery Manufacturing</td>
</tr>
</tbody>
</table>
### Advanced Manufacturing (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>333311</td>
<td>Automatic Vending Machine Manufacturing</td>
</tr>
<tr>
<td>333312</td>
<td>Commercial Laundry, Dry-cleaning and Pressing Machine Manufacturing</td>
</tr>
<tr>
<td>333313</td>
<td>Office Machinery Manufacturing</td>
</tr>
<tr>
<td>333314</td>
<td>Optical Instrument and Lens Manufacturing</td>
</tr>
<tr>
<td>333315</td>
<td>Photographic and Photocopying Equipment Manufacturing</td>
</tr>
<tr>
<td>333319</td>
<td>Other Commercial and Service Industry Machinery Manufacturing</td>
</tr>
<tr>
<td>333511</td>
<td>Industrial Mold Manufacturing</td>
</tr>
<tr>
<td>333512</td>
<td>Machine Tool (Metal Cutting Types) Manufacturing</td>
</tr>
<tr>
<td>333513</td>
<td>Machine Tool (Metal Forming Types) Manufacturing</td>
</tr>
<tr>
<td>333514</td>
<td>Special Die and Tool, Die Set, Jig and Fixture Manufacturing</td>
</tr>
<tr>
<td>333516</td>
<td>Rolling Mill Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333518</td>
<td>Other Metalworking Machinery Manufacturing</td>
</tr>
<tr>
<td>333992</td>
<td>Welding and Soldering Equipment Manufacturing</td>
</tr>
<tr>
<td>333994</td>
<td>Industrial Process Furnace and Oven Manufacturing</td>
</tr>
<tr>
<td>333999</td>
<td>All Other Miscellaneous General Purpose Machinery Manufacturing</td>
</tr>
<tr>
<td>334411</td>
<td>Electron Tube Manufacturing</td>
</tr>
<tr>
<td>334416</td>
<td>Electronic Coil, Transformer and Other Inductor Manufacturing</td>
</tr>
<tr>
<td>334511</td>
<td>Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing</td>
</tr>
<tr>
<td>334514</td>
<td>Totalizing Fluid Meter and Counting Device Manufacturing</td>
</tr>
</tbody>
</table>

**MSA** is the largest company in the world dedicated solely to producing a complete range of equipment and systems for worker and plant protection. With corporate headquarters in Pittsburgh, the company’s operations extend around the world, and they include 28 international affiliates that help protect lives in more than 120 countries, on all continents around the globe.

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Advanced Manufacturing (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>334518</td>
<td>Watch, Clock and Part Manufacturing</td>
</tr>
<tr>
<td>334519</td>
<td>Other Measuring and Controlling Device Manufacturing</td>
</tr>
<tr>
<td>334612</td>
<td>Prerecorded Compact Disc (except Software), Tape and Record Reproducing</td>
</tr>
<tr>
<td>335311</td>
<td>Power, Distribution and Specialty Transformer Manufacturing</td>
</tr>
<tr>
<td>335312</td>
<td>Motor and Generator Manufacturing</td>
</tr>
<tr>
<td>335313</td>
<td>Switchgear and Switchboard Apparatus Manufacturing</td>
</tr>
<tr>
<td>335314</td>
<td>Relay and Industrial Control Manufacturing</td>
</tr>
<tr>
<td>335921</td>
<td>Fiber Optic Cable Manufacturing</td>
</tr>
<tr>
<td>541420</td>
<td>Industrial Design Services</td>
</tr>
<tr>
<td>541614</td>
<td>Process, Physical Distribution and Logistics Consulting Services</td>
</tr>
</tbody>
</table>

By way of examples of companies represented in the NAICS chart above, Extrude Hone Corporation employs technology in every aspect of its operations, which involve new manufacturing processes for abrasive, ultrasonic and electrochemical machining, finishing and measurement. Extrude Hone was named Manufacturer of the Year by the *Pittsburgh Business Times* in 2003.

Located in Blairsville, Pa., Clark Metal Products has a 50-year history as a precision sheet metal fabricator serving some of the most technologically demanding industries, including electronics, electrical, medical and environmental control. Clark’s 68,000-square-foot facility incorporates a wide range of state-of-the-art metal fabrication and finishing equipment.

In addition, Allegheny Technologies got its start serving the region’s steel industry. It anchors the region as a large, diversified manufacturing company serving global markets with specialty metals, aerospace, electronic, industrial and consumer products.
Although increased inventories and new orders already have begun to buoy the advanced manufacturing cluster, between 2001 and 2002, the number of companies, the employment ranks and the total annual payroll decreased. The average wage, however, increased 4.3 percent to more than $44,000 a year in the MSA.

### Advanced Manufacturing Cluster  
**13 Counties**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>886</td>
<td>24,928</td>
<td>$1,027,841,791</td>
<td>$41,232</td>
</tr>
<tr>
<td>2002</td>
<td>850</td>
<td>22,516</td>
<td>$968,384,567</td>
<td>$43,008</td>
</tr>
</tbody>
</table>

% change 2001–2002: -4.0% -9.6% -5.7% +4.3%

### Advanced Manufacturing Cluster  
**Six-County MSA**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>759</td>
<td>22,224</td>
<td>$936,083,967</td>
<td>$42,121</td>
</tr>
<tr>
<td>2002</td>
<td>724</td>
<td>20,024</td>
<td>$882,261,307</td>
<td>$44,061</td>
</tr>
</tbody>
</table>

% change 2001–2002: -4.6% -9.9% -5.7% +4.6%
ADVANCED MATERIALS

The advanced materials cluster consists of:

- Rubber and Plastics
- Chemicals

Bayer Corporation, with its U.S. headquarters in Pittsburgh, is the largest supplier of polyurethane raw materials, with more than 25 percent of the world market.
<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>316211</td>
<td>Rubber and Plastics Footwear Manufacturing</td>
</tr>
<tr>
<td>325211</td>
<td>Plastics Material and Resin Manufacturing</td>
</tr>
<tr>
<td>325212</td>
<td>Synthetic Rubber Manufacturing</td>
</tr>
<tr>
<td>325991</td>
<td>Custom Compounding of Purchased Resins</td>
</tr>
<tr>
<td>326111</td>
<td>Plastics Bag Manufacturing</td>
</tr>
<tr>
<td>326112</td>
<td>Plastics Packaging Film and Sheet (including Laminated) Manufacturing</td>
</tr>
<tr>
<td>326113</td>
<td>Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing</td>
</tr>
<tr>
<td>326121</td>
<td>Unlaminated Plastics Profile Shape Manufacturing</td>
</tr>
<tr>
<td>326122</td>
<td>Plastics Pipe and Pipe Fitting Manufacturing</td>
</tr>
<tr>
<td>326130</td>
<td>Laminated Plastics Plate, Sheet (except Packaging) and Shape Manufacturing</td>
</tr>
<tr>
<td>326140</td>
<td>Polystyrene Foam Product Manufacturing</td>
</tr>
<tr>
<td>326150</td>
<td>Urethane and Other Foam Product (except Polystyrene) Manufacturing</td>
</tr>
<tr>
<td>326160</td>
<td>Plastics Bottle Manufacturing</td>
</tr>
<tr>
<td>326191</td>
<td>Plastics Plumbing Fixture Manufacturing</td>
</tr>
<tr>
<td>326192</td>
<td>Resilient Floor Covering Manufacturing</td>
</tr>
<tr>
<td>326199</td>
<td>All Other Plastics Product Manufacturing</td>
</tr>
<tr>
<td>326211</td>
<td>Tire Manufacturing (except Retreading)</td>
</tr>
<tr>
<td>326220</td>
<td>Rubber and Plastics Hoses and Belting Manufacturing</td>
</tr>
<tr>
<td>326291</td>
<td>Rubber Product Manufacturing for Mechanical Use</td>
</tr>
</tbody>
</table>

Nanotechnology and MEMS in the Pittsburgh Region

READ RELATED ARTICLE
Rubber and Plastics
Chemicals

### Rubber and Plastics (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>326299</td>
<td>All Other Rubber Product Manufacturing</td>
</tr>
<tr>
<td>339931</td>
<td>Doll and Stuffed Toy Manufacturing</td>
</tr>
<tr>
<td>339932</td>
<td>Game, Toy and Children's Vehicle Manufacturing</td>
</tr>
<tr>
<td>339991</td>
<td>Gasket, Packing and Sealing Device Manufacturing</td>
</tr>
</tbody>
</table>

### Chemicals

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>325110</td>
<td>Petrochemical Manufacturing</td>
</tr>
<tr>
<td>325120</td>
<td>Industrial Gas Manufacturing</td>
</tr>
<tr>
<td>325131</td>
<td>Inorganic Dye and Pigment Manufacturing</td>
</tr>
<tr>
<td>325132</td>
<td>Synthetic Organic Dye and Pigment Manufacturing</td>
</tr>
<tr>
<td>325181</td>
<td>Alkalies and Chlorine Manufacturing</td>
</tr>
<tr>
<td>325182</td>
<td>Carbon Black Manufacturing</td>
</tr>
<tr>
<td>325188</td>
<td>All Other Basic Inorganic Chemical Manufacturing</td>
</tr>
<tr>
<td>325191</td>
<td>Gum and Wood Chemical Manufacturing</td>
</tr>
<tr>
<td>325192</td>
<td>Cyclic Crude and Intermediate Manufacturing</td>
</tr>
<tr>
<td>325193</td>
<td>Ethyl Alcohol Manufacturing</td>
</tr>
<tr>
<td>325221</td>
<td>Cellulosic Organic Fiber Manufacturing</td>
</tr>
<tr>
<td>325222</td>
<td>Noncellulosic Organic Fiber Manufacturing</td>
</tr>
<tr>
<td>325311</td>
<td>Nitrogenous Fertilizer Manufacturing</td>
</tr>
</tbody>
</table>
## Chemicals (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>325312</td>
<td>Phosphatic Fertilizer Manufacturing</td>
</tr>
<tr>
<td>325314</td>
<td>Fertilizer (Mixing Only) Manufacturing</td>
</tr>
<tr>
<td>325320</td>
<td>Pesticide and Other Agricultural Chemical Manufacturing</td>
</tr>
<tr>
<td>325510</td>
<td>Paint and Coating Manufacturing</td>
</tr>
<tr>
<td>325520</td>
<td>Adhesive Manufacturing</td>
</tr>
<tr>
<td>325611</td>
<td>Soap and Other Detergent Manufacturing</td>
</tr>
<tr>
<td>325613</td>
<td>Surface Active Agent Manufacturing</td>
</tr>
<tr>
<td>325620</td>
<td>Toilet Preparation Manufacturing</td>
</tr>
<tr>
<td>325910</td>
<td>Printing Ink Manufacturing</td>
</tr>
<tr>
<td>325920</td>
<td>Explosives Manufacturing</td>
</tr>
<tr>
<td>325992</td>
<td>Photographic Film, Paper, Plate and Chemical Manufacturing</td>
</tr>
<tr>
<td>325998</td>
<td>All Other Miscellaneous Chemical Product and Preparation Manufacturing</td>
</tr>
</tbody>
</table>
When examining the aggregated advanced materials cluster between 2001 and 2002, we can see that it experienced mixed results in all categories, across both its subclusters.

**Highlights:**

- The aggregated cluster’s **total annual payroll remained very stable at $753 million.** The **average wage, however, grew five percent** over the previous year to **$48,777 a year.**

- Although the number of **chemicals companies declined by 11 percent,** the **wages increased an average of seven percent** to **$55,456 a year.**

- The average wage for the Rubber and Plastics subcluster **increased four percent to $46,572 a year.**
Rubber and Plastics experienced the brunt of the aggregated cluster’s downturn during the measured period. Even the total annual payroll declined, albeit marginally. The only bright spot was an increase in the average wages.

The disappointing results in this subcluster mirror the advanced manufacturing cluster, and this can be attributed directly to the decline of factory orders for raw feedstock or finished goods during the sluggish economy.

### Rubber and Plastics

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>175</td>
<td>12,275</td>
<td>$549,203,203</td>
<td>$44,741</td>
</tr>
<tr>
<td>2002</td>
<td>161</td>
<td>11,606</td>
<td>$540,511,325</td>
<td>$46,572</td>
</tr>
</tbody>
</table>

% change 2001–2002: -8.0, -5.4, -1.5, +4.1

### Rubber and Plastics Subcluster (13 Counties)

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>135</td>
<td>9,997</td>
<td>$487,793,733</td>
<td>$48,793</td>
</tr>
<tr>
<td>2002</td>
<td>124</td>
<td>9,431</td>
<td>$479,194,869</td>
<td>$50,808</td>
</tr>
</tbody>
</table>

% change 2001–2002: -8.1, -5.6, -1.7, +4.1

### Rubber and Plastics Subcluster (Six-County MSA)

© 2004 Pittsburgh Technology Council
Southwestern Pennsylvania is rooted with a mix of large, international chemical companies, in addition to small- to mid-sized firms supplying an array of products and services. The region's largest players include Bayer Corporation, with its U.S. headquarters in Pittsburgh, and NOVA Chemical's Beaver Valley production plant.

Locally, Bayer supplies solutions, custom manufacturing services and basic fine, functional and performance chemicals to customers in the adhesive, agricultural, coatings colorant, food/beverage and a host of other industries.

NOVA Chemical's Beaver Valley plant has the capacity to manufacture more than 400 million pounds of plastic resins each year. NOVA's resins are turned into a number of products, ranging from food packaging to automotive interior parts. Its Styrenics Technology Center includes an applications lab and two pilot plants for advanced R&D and testing.

Even smaller companies significantly contribute to the region's reputation as a top chemicals center. Spun from the University of Pittsburgh, Fluorous Technologies supplies a suite of innovative tools that chemists involved in drug development require to do their jobs more effectively. The company received $3 million in venture capital in 2003.

Westmoreland County-based Ranbar Technology falls more on the traditional side of the chemical industry, experiencing growth as a manufacturer of coating resins for architectural and industrial coatings. Its product line includes more than 100 different resins and finishes.

Even though the number of chemicals companies decreased over the measured period, the total annual payroll and average wages rose.
### MTRL: Chemicals Subcluster - 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>117</td>
<td>3,985</td>
<td>$206,527,788</td>
<td>$51,832</td>
</tr>
<tr>
<td>2002</td>
<td>104</td>
<td>3,836</td>
<td>$212,711,994</td>
<td>$55,455</td>
</tr>
</tbody>
</table>

% change 2001–2002:
- Companies: -11.1
- Employment: -3.7
- Total Annual Payroll: +3.0
- Average Wages: +6.9

### MTRL: Chemicals Subcluster - Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>109</td>
<td>3,829</td>
<td>$200,584,083</td>
<td>$52,390</td>
</tr>
<tr>
<td>2002</td>
<td>97</td>
<td>3,715</td>
<td>$208,748,200</td>
<td>$56,188</td>
</tr>
</tbody>
</table>

% change 2001–2002:
- Companies: -11.0
- Employment: -2.9
- Total Annual Payroll: +4.0
- Average Wages: +7.2

---

**Fuel Cells in the Pittsburgh Region**

**READ RELATED ARTICLE**
ENVIRONMENTAL TECHNOLOGY

With the change to NAICS-based industry definitions, the environmental technology cluster now includes firms in a narrower cross section of industries than previously examined. The cluster is now composed of three subclusters:

- Environmental Equipment
- Professional Services and Research
- Remediation and Waste Management

The David L. Lawrence Convention Center in Pittsburgh is the world’s largest green building of its type.
### Environmental Equipment

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>333411</td>
<td>Air Purification Equipment Manufacturing</td>
</tr>
<tr>
<td>333412</td>
<td>Industrial and Commercial Fan and Blower Manufacturing</td>
</tr>
<tr>
<td>334512</td>
<td>Automatic Environmental Control Manufacturing for Residential, Commercial and Appliance Use</td>
</tr>
<tr>
<td>334513</td>
<td>Instruments and Related Products Manufacturing for Measuring, Displaying and Controlling Industrial Process Variables</td>
</tr>
<tr>
<td>334514</td>
<td>Totalizing Fluid Meter and Counting Device Manufacturing</td>
</tr>
</tbody>
</table>

### Professional Services and Research

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>541310</td>
<td>Architectural Services</td>
</tr>
<tr>
<td>541320</td>
<td>Landscape Architectural Services</td>
</tr>
<tr>
<td>541330</td>
<td>Engineering Services</td>
</tr>
<tr>
<td>541360</td>
<td>Geophysical Surveying and Mapping Services</td>
</tr>
<tr>
<td>541370</td>
<td>Surveying and Mapping (except Geophysical) Services</td>
</tr>
<tr>
<td>541380</td>
<td>Testing Laboratories</td>
</tr>
<tr>
<td>541620</td>
<td>Environmental Consulting Services</td>
</tr>
<tr>
<td>541710</td>
<td>Research and Development in the Physical, Engineering and Life Sciences</td>
</tr>
<tr>
<td>924110</td>
<td>Administration of Air and Water Resource and Solid Waste Management Programs</td>
</tr>
<tr>
<td>924120</td>
<td>Administration of Conservation Programs</td>
</tr>
</tbody>
</table>
### Remediation and Waste Management

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>221320</td>
<td>Sewage Treatment Facilities</td>
</tr>
<tr>
<td>325311</td>
<td>Nitrogenous Fertilizer Manufacturing</td>
</tr>
<tr>
<td>325612</td>
<td>Polish and Other Sanitation Good Manufacturing</td>
</tr>
<tr>
<td>562211</td>
<td>Hazardous Waste Treatment and Disposal</td>
</tr>
<tr>
<td>562212</td>
<td>Solid Waste Landfill</td>
</tr>
<tr>
<td>562213</td>
<td>Solid Waste Combustors and Incinerators</td>
</tr>
<tr>
<td>562219</td>
<td>Other Nonhazardous Waste Treatment and Disposal</td>
</tr>
<tr>
<td>562910</td>
<td>Remediation Services</td>
</tr>
<tr>
<td>562920</td>
<td>Materials Recovery Facilities</td>
</tr>
<tr>
<td>562991</td>
<td>Septic Tank and Related Services</td>
</tr>
<tr>
<td>562998</td>
<td>All Other Miscellaneous Waste Management Services</td>
</tr>
</tbody>
</table>
During the period following World War II, it became apparent that the prosperity of Pittsburgh’s industrial heritage also claimed a fairly heavy environmental toll. The environmental problems that were a holdover from this era needed to be tackled, and the lessons learned became the basis of the region’s environmental technology capabilities. Other countries, most notably Russia, China and Brazil, recently have looked to Pittsburgh for help in addressing some of these same challenges.

**Highlights:**

- Although the subgroups that aggregate the Environmental Technology cluster have experienced a general downturn across most categories, the *average wage has increased slightly to $51,679 a year.*

- The *number of companies* in the Environmental Equipment subcluster has *remained steady at 57* over a year’s period.

- Over the same one-year period, the *average wage* in the Professional Services and Research subcluster *grew one percent to $54,776 a year.*

- The *average wage* of the Remediation and Waste Management subcluster *gained three percent* over the prior year and stands at *$40,408 a year.*
### Aggregated Environmental Technology Cluster

#### 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,587</td>
<td>32,433</td>
<td>$1,655,880,706</td>
<td>$51,055</td>
</tr>
<tr>
<td>2002</td>
<td>1,520</td>
<td>30,888</td>
<td>$1,596,331,750</td>
<td>$51,681</td>
</tr>
</tbody>
</table>

% change 2001–2002: -4.2% -4.8% -3.6% +1.2%

#### Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,388</td>
<td>28,819</td>
<td>$1,520,518,073</td>
<td>$52,760</td>
</tr>
<tr>
<td>2002</td>
<td>1,322</td>
<td>27,293</td>
<td>$1,463,003,040</td>
<td>$53,603</td>
</tr>
</tbody>
</table>

% change 2001–2002: -4.7% -5.3% -3.7% +1.6%

The industry’s stagnation is national in scope. Broadly, the weakness in this cluster is characteristic of its very mature product cycle, combined with saturation in the U.S. environmental remediation market.

However, leading environmental firms continue to meet the challenge by reinventing the industry model. They are embracing strategies of consolidation, diversification, globalization and reconfiguration of products and services.

---

**Carnegie Mellon University's New House** is the nation’s first “green” dormitory, as designated by the U.S. Green Building Council.
Although the number of environmental equipment companies in the 13-county region remained the same, each operated with an average of two fewer employees per firm in 2002 than the previous year. This, in turn, caused a net decline of almost six percent in the total annual payroll.
The picture does not change much, even when looking at the head of the pack. Both the professional services and remediation and waste management subclusters each experienced declines, with the exception of marginal growth in average wages.

**ENV: Professional Services and Research Subcluster**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,246</td>
<td>25,003</td>
<td>$1,354,468,369</td>
<td>$54,171</td>
</tr>
<tr>
<td>2002</td>
<td>1,181</td>
<td>23,796</td>
<td>$1,303,428,004</td>
<td>$54,776</td>
</tr>
</tbody>
</table>

% change 2001–2002: -5.2 -4.8 -3.7 +1.1

**ENV: Professional Services and Research Subcluster**

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,120</td>
<td>22,347</td>
<td>$1,248,185,144</td>
<td>$55,855</td>
</tr>
<tr>
<td>2002</td>
<td>1,057</td>
<td>21,177</td>
<td>$1,200,922,553</td>
<td>$56,708</td>
</tr>
</tbody>
</table>

% change 2001–2002: -5.6 -5.2 -3.7 +1.5

Wage Increases in the Pittsburgh Region
Today, the Pittsburgh region has 36 green projects, leading Pennsylvania in its ranking of second among all 50 states in the number of LEED-certified buildings.
OTHER TECHNOLOGY-INTENSIVE INDUSTRIES

Beyond the technology industry clusters previously listed, Carnegie Mellon University's Center for Economic Development further identifies industries in which there is a high degree of scientists, engineers and other technical personnel. Included in the data on page 16, these industries also require a significant capacity of technological processes and automation as discussed earlier under Key Criteria.

The following are NAICS-based technology-intensive industries that expand upon the clusters examined previously in this report; they are important, because they add to the region’s broad base of technological capabilities and resources.
### CED Technology Definition Industries

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>211111</td>
<td>Crude Petroleum and Natural Gas Extraction</td>
</tr>
<tr>
<td>325110</td>
<td>Petrochemical Manufacturing</td>
</tr>
<tr>
<td>325120</td>
<td>Industrial Gas Manufacturing</td>
</tr>
<tr>
<td>325131</td>
<td>Inorganic Dye and Pigment Manufacturing</td>
</tr>
<tr>
<td>325182</td>
<td>Carbon Black Manufacturing</td>
</tr>
<tr>
<td>325188</td>
<td>All Other Basic Inorganic Chemical Manufacturing</td>
</tr>
<tr>
<td>325192</td>
<td>Cyclic Crude and Intermediate Manufacturing</td>
</tr>
<tr>
<td>325199</td>
<td>All Other Basic Organic Chemical Manufacturing</td>
</tr>
<tr>
<td>325211</td>
<td>Plastics Material and Resin Manufacturing</td>
</tr>
<tr>
<td>325212</td>
<td>Synthetic Rubber Manufacturing</td>
</tr>
<tr>
<td>325411</td>
<td>Medicinal and Botanical Manufacturing</td>
</tr>
<tr>
<td>325412</td>
<td>Pharmaceutical Preparation Manufacturing</td>
</tr>
<tr>
<td>325413</td>
<td>In-Vitro Diagnostic Substance Manufacturing</td>
</tr>
<tr>
<td>325414</td>
<td>Biological Product (except Diagnostic) Manufacturing</td>
</tr>
<tr>
<td>325510</td>
<td>Paint and Coating Manufacturing</td>
</tr>
<tr>
<td>325520</td>
<td>Adhesive Manufacturing</td>
</tr>
<tr>
<td>325611</td>
<td>Soap and Other Detergent Manufacturing</td>
</tr>
<tr>
<td>325612</td>
<td>Polish and Other Sanitation Good Manufacturing</td>
</tr>
<tr>
<td>325613</td>
<td>Surface Active Agent Manufacturing</td>
</tr>
<tr>
<td>325620</td>
<td>Toilet Preparation Manufacturing</td>
</tr>
<tr>
<td>325910</td>
<td>Printing Ink Manufacturing</td>
</tr>
</tbody>
</table>
### CED Technology Definition Industries (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>325920</td>
<td>Explosives Manufacturing</td>
</tr>
<tr>
<td>325991</td>
<td>Custom Compounding of Purchased Resins</td>
</tr>
<tr>
<td>325992</td>
<td>Photographic Film, Paper, Plate and Chemical Manufacturing</td>
</tr>
<tr>
<td>325998</td>
<td>All Other Miscellaneous Chemical Product and Preparation Manufacturing</td>
</tr>
<tr>
<td>333120</td>
<td>Construction Machinery Manufacturing</td>
</tr>
<tr>
<td>333131</td>
<td>Mining Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333132</td>
<td>Oil and Gas Field Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333210</td>
<td>Sawmill and Woodworking Machinery Manufacturing</td>
</tr>
<tr>
<td>333220</td>
<td>Plastics and Rubber Industry Machinery Manufacturing</td>
</tr>
<tr>
<td>333292</td>
<td>Textile Machinery Manufacturing</td>
</tr>
<tr>
<td>333293</td>
<td>Printing Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333294</td>
<td>Food Product Machinery Manufacturing</td>
</tr>
<tr>
<td>333295</td>
<td>Semiconductor Machinery Manufacturing</td>
</tr>
<tr>
<td>333298</td>
<td>All Other Industrial Machinery Manufacturing</td>
</tr>
<tr>
<td>333313</td>
<td>Office Machinery Manufacturing</td>
</tr>
<tr>
<td>333314</td>
<td>Optical Instrument and Lens Manufacturing</td>
</tr>
<tr>
<td>333315</td>
<td>Photographic and Photocopying Equipment Manufacturing</td>
</tr>
<tr>
<td>333319</td>
<td>Other Commercial and Service Industry Machinery Manufacturing</td>
</tr>
<tr>
<td>333411</td>
<td>Air Purification Equipment Manufacturing</td>
</tr>
<tr>
<td>333412</td>
<td>Industrial and Commercial Fan and Blower Manufacturing</td>
</tr>
<tr>
<td>333414</td>
<td>Heating Equipment (except Warm Air Furnaces) Manufacturing</td>
</tr>
</tbody>
</table>
### CED Technology Definition Industries (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>333511</td>
<td>Industrial Mold Manufacturing</td>
</tr>
<tr>
<td>333512</td>
<td>Machine Tool (Metal Cutting Types) Manufacturing</td>
</tr>
<tr>
<td>333513</td>
<td>Machine Tool (Metal Forming Types) Manufacturing</td>
</tr>
<tr>
<td>333514</td>
<td>Special Die and Tool, Die Set, Jig and Fixture Manufacturing</td>
</tr>
<tr>
<td>333515</td>
<td>Cutting Tool and Machine Tool Accessory Manufacturing</td>
</tr>
<tr>
<td>333516</td>
<td>Rolling Mill Machinery and Equipment Manufacturing</td>
</tr>
<tr>
<td>333518</td>
<td>Other Metalworking Machinery Manufacturing</td>
</tr>
<tr>
<td>333611</td>
<td>Turbine and Turbine Generator Set Units Manufacturing</td>
</tr>
<tr>
<td>333612</td>
<td>Speed Changer, Industrial High-Speed Drive and Gear Manufacturing</td>
</tr>
<tr>
<td>333613</td>
<td>Mechanical Power Transmission Equipment Manufacturing</td>
</tr>
<tr>
<td>333911</td>
<td>Pump and Pumping Equipment Manufacturing</td>
</tr>
<tr>
<td>333912</td>
<td>Air and Gas Compressor Manufacturing</td>
</tr>
<tr>
<td>333921</td>
<td>Elevator and Moving Stairway Manufacturing</td>
</tr>
<tr>
<td>333922</td>
<td>Conveyor and Conveying Equipment Manufacturing</td>
</tr>
<tr>
<td>333923</td>
<td>Overhead Traveling Crane, Hoist and Monorail System Manufacturing</td>
</tr>
<tr>
<td>333924</td>
<td>Industrial Truck, Tractor, Trailer and Stacker Machinery Manufacturing</td>
</tr>
<tr>
<td>333991</td>
<td>Power-Driven Hand Tool Manufacturing</td>
</tr>
<tr>
<td>333992</td>
<td>Welding and Soldering Equipment Manufacturing</td>
</tr>
<tr>
<td>333993</td>
<td>Packaging Machinery Manufacturing</td>
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<td>333994</td>
<td>Industrial Process Furnace and Oven Manufacturing</td>
</tr>
<tr>
<td>333995</td>
<td>Fluid Power Cylinder and Actuator Manufacturing</td>
</tr>
</tbody>
</table>
## CED Technology Definition Industries (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>333996</td>
<td>Fluid Power Pump and Motor Manufacturing</td>
</tr>
<tr>
<td>333997</td>
<td>Scale and Balance (except Laboratory) Manufacturing</td>
</tr>
<tr>
<td>333999</td>
<td>All Other Miscellaneous General Purpose Machinery Manufacturing</td>
</tr>
<tr>
<td>334111</td>
<td>Electronic Computer Manufacturing</td>
</tr>
<tr>
<td>334113</td>
<td>Computer Terminal Manufacturing</td>
</tr>
<tr>
<td>334119</td>
<td>Other Computer Peripheral Equipment Manufacturing</td>
</tr>
<tr>
<td>334210</td>
<td>Telephone Apparatus Manufacturing</td>
</tr>
<tr>
<td>334220</td>
<td>Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing</td>
</tr>
<tr>
<td>334290</td>
<td>Other Communications Equipment Manufacturing</td>
</tr>
<tr>
<td>334310</td>
<td>Audio and Video Equipment Manufacturing</td>
</tr>
<tr>
<td>334412</td>
<td>Bare Printed Circuit Board Manufacturing</td>
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<td>334413</td>
<td>Semiconductor and Related Device Manufacturing</td>
</tr>
<tr>
<td>334414</td>
<td>Electronic Capacitor Manufacturing</td>
</tr>
<tr>
<td>334415</td>
<td>Electronic Resistor Manufacturing</td>
</tr>
<tr>
<td>334417</td>
<td>Electronic Connector Manufacturing</td>
</tr>
<tr>
<td>334418</td>
<td>Printed Circuit Assembly (Electronic Assembly) Manufacturing</td>
</tr>
<tr>
<td>334419</td>
<td>Other Electronic Component Manufacturing</td>
</tr>
<tr>
<td>334510</td>
<td>Electromedical and Electrotherapeutic Apparatus Manufacturing</td>
</tr>
<tr>
<td>334511</td>
<td>Search, Detection, Navigation, Guidance, Aeronautical and Nautical System and Instrument Manufacturing</td>
</tr>
<tr>
<td>NAICS</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>334512</td>
<td>Automatic Environmental Control Manufacturing for Residential, Commercial</td>
</tr>
<tr>
<td></td>
<td>and Appliance Use</td>
</tr>
<tr>
<td>334513</td>
<td>Instruments and Related Products Manufacturing for Measuring, Displaying</td>
</tr>
<tr>
<td></td>
<td>and Controlling Industrial Process Variables</td>
</tr>
<tr>
<td>334514</td>
<td>Totalizing Fluid Meter and Counting Device Manufacturing</td>
</tr>
<tr>
<td>334515</td>
<td>Instrument Manufacturing for Measuring and Testing Electricity and</td>
</tr>
<tr>
<td></td>
<td>Electrical Signals</td>
</tr>
<tr>
<td>334516</td>
<td>Analytical Laboratory Instrument Manufacturing</td>
</tr>
<tr>
<td>334517</td>
<td>Irradiation Apparatus Manufacturing</td>
</tr>
<tr>
<td>334519</td>
<td>Other Measuring and Controlling Device Manufacturing</td>
</tr>
<tr>
<td>334611</td>
<td>Software Reproducing</td>
</tr>
<tr>
<td>334612</td>
<td>Prerecorded Compact Disc (except Software), Tape and Record Reproducing</td>
</tr>
<tr>
<td>334613</td>
<td>Magnetic and Optical Recording Media Manufacturing</td>
</tr>
<tr>
<td>336111</td>
<td>Automobile Manufacturing</td>
</tr>
<tr>
<td>336112</td>
<td>Light Truck and Utility Vehicle Manufacturing</td>
</tr>
<tr>
<td>336120</td>
<td>Heavy Duty Truck Manufacturing</td>
</tr>
<tr>
<td>336211</td>
<td>Motor Vehicle Body Manufacturing</td>
</tr>
<tr>
<td>336212</td>
<td>Truck Trailer Manufacturing</td>
</tr>
<tr>
<td>336214</td>
<td>Travel Trailer and Camper Manufacturing</td>
</tr>
<tr>
<td>336312</td>
<td>Gasoline Engine and Engine Parts Manufacturing</td>
</tr>
<tr>
<td>336322</td>
<td>Other Motor Vehicle Electrical and Electronic Equipment Manufacturing</td>
</tr>
<tr>
<td>336340</td>
<td>Motor Vehicle Brake System Manufacturing</td>
</tr>
</tbody>
</table>
### CED Technology Definition Industries (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>336350</td>
<td>Motor Vehicle Transmission and Power Train Parts Manufacturing</td>
</tr>
<tr>
<td>336399</td>
<td>All Other Motor Vehicle Parts Manufacturing</td>
</tr>
<tr>
<td>336411</td>
<td>Aircraft Manufacturing</td>
</tr>
<tr>
<td>336412</td>
<td>Aircraft Engine and Engine Parts Manufacturing</td>
</tr>
<tr>
<td>336413</td>
<td>Other Aircraft Part and Auxiliary Equipment Manufacturing</td>
</tr>
<tr>
<td>336419</td>
<td>Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing</td>
</tr>
<tr>
<td>336992</td>
<td>Military Armored Vehicle, Tank and Tank Component Manufacturing</td>
</tr>
<tr>
<td>336999</td>
<td>All Other Transportation Equipment Manufacturing</td>
</tr>
<tr>
<td>339111</td>
<td>Laboratory Apparatus and Furniture Manufacturing</td>
</tr>
<tr>
<td>339112</td>
<td>Surgical and Medical Instrument Manufacturing</td>
</tr>
<tr>
<td>339113</td>
<td>Surgical Appliance and Supplies Manufacturing</td>
</tr>
<tr>
<td>339114</td>
<td>Dental Equipment and Supplies Manufacturing</td>
</tr>
<tr>
<td>339932</td>
<td>Game, Toy and Children's Vehicle Manufacturing</td>
</tr>
<tr>
<td>339991</td>
<td>Gasket, Packing and Sealing Device Manufacturing</td>
</tr>
<tr>
<td>339999</td>
<td>All Other Miscellaneous Manufacturing</td>
</tr>
<tr>
<td>511210</td>
<td>Software Publishers</td>
</tr>
<tr>
<td>518111</td>
<td>Internet Service Providers</td>
</tr>
<tr>
<td>541310</td>
<td>Architectural Services</td>
</tr>
<tr>
<td>541330</td>
<td>Engineering Services</td>
</tr>
</tbody>
</table>
## CED Technology Definition Industries (cont.)

<table>
<thead>
<tr>
<th>NAICS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>541370</td>
<td>Surveying and Mapping (except Geophysical) Services</td>
</tr>
<tr>
<td>541380</td>
<td>Testing Laboratories</td>
</tr>
<tr>
<td>541511</td>
<td>Custom Computer Programming Services</td>
</tr>
<tr>
<td>541512</td>
<td>Computer Systems Design Services</td>
</tr>
<tr>
<td>541710</td>
<td>Research and Development in the Physical, Engineering and Life Sciences</td>
</tr>
<tr>
<td>541720</td>
<td>Research and Development in the Social Sciences and Humanities</td>
</tr>
</tbody>
</table>
A region’s technology economy is described by a variety of other indicators beyond the number of companies, jobs and wages. This section illustrates some of the most important measures, many of which directly influence the pace of technology growth.

UNIVERSITY-BASED RESEARCH AND DEVELOPMENT

The level of research and development spending at local universities and research centers can have a great impact on the development and success of technology firms. Throughout the United States, there are strong examples of positive links between research universities and high technology industries. While it is possible for one to exist without the other, regions where universities and high technology industries strongly complement each other continue to receive worldwide recognition for their ability to generate new technologies and businesses. They also draw large amounts of investment capital and human talent.

Within this context, it is significant that Pittsburgh is home to two of the largest research universities in the region, Carnegie Mellon University and the University of Pittsburgh. Other institutions that have contributed to research, but on a lesser scale, include Duquesne University and Indiana University of Pennsylvania.
Other Key Growth Indicators

Highlights:

- By the year 2001, the total R&D spending at the region’s universities and the Software Engineering Institute (SEI)* was $534 million. This total represents an increase of 44 percent over the total from five years previous and an 8.5 percent increase over the previous year.

- Two institutions accounted for 99 percent of the region’s university-based R&D expenditures in 2001. Research and development at the University of Pittsburgh accounted for 70 percent of total spending, with Carnegie Mellon accounting for nearly all of the remainder (29 percent of total expenditures).

- In 2001, compared to 589 universities across the U.S., the University of Pittsburgh’s R&D spending ranked 27th with $348.7 million (an 18 percent increase over the previous year), thereby advancing three places.

- Carnegie Mellon University’s R&D (exclusive of the SEI) ranked 84th with $144.8 million, an increase of five percent over the previous year.

*The SEI is the region’s only federally funded research and development center.
Expenditures at Carnegie Mellon’s Software Engineering Institute, the region’s lone FFRDC, remained relatively stable. Excluding a year 2000 peak of $56 million, spending at the FFRDC has ranged from $30 million to $37 million between 1997 and 2001.

The region’s growth in R&D spending seems to be fueled by research and development activity in the life sciences, which is dominated by the activity at the University of Pittsburgh and the University of Pittsburgh Medical Center and its affiliates. Important biomedical research work also occurs, however, at the West Penn Allegheny Health System and at Carnegie Mellon University.

The share of total R&D spending in the life sciences at regional colleges and universities climbed from 55 percent in 1997 to 63 percent in 2001.
Math and Computer Science is the second largest discipline, accounting for 14 percent of 2001 expenditures. Carnegie Mellon generally is acknowledged to be among the top three computer science schools in the nation, along with Stanford and M.I.T. Computer engineering at Carnegie Mellon University was ranked second by *U.S. News & World Report* in 2003. Carnegie Mellon has been successful for decades in attracting significant research funding from government and industry.

Engineering’s 11 percent share of total spending places the discipline third.
SCIENCE AND ENGINEERING GRADUATE STUDENTS

The number of science and engineering students that any region’s colleges and universities graduate each year continues to be an important trump card in attracting and expanding technology development. Companies wishing to establish a presence in any given locale will examine the number of graduate students produced by nearby science and engineering departments as a ready source of technology talent.

Highlights:

- Altogether, six southwestern Pennsylvania universities accounted for 6,972 science and engineering graduate students in 2001, the last year for which complete data is available.

- Of 33 Pennsylvania colleges and universities offering science and engineering degrees, the University of Pittsburgh was ranked second in total graduate students with 3,400, accounting for nearly half of the 13-county totals.

- Carnegie Mellon University is the region’s second highest in science and engineering graduate students with 2,329 in the year 2001—a 32 percent increase over five years, which places it third in the state. Carnegie Mellon’s share has grown to 33 percent of the regional total in 2001.

Science and Engineering Graduate Students

Source: National Science Foundation
The following chart shows the percentage distribution of graduate students among southwestern Pennsylvania institutions.

2001 Pittsburgh Region—13 Counties

Science & Engineering Graduate Students
(by institution)

Source: National Science Foundation

University of Pittsburgh* 48%
Duquesne University 7%
California University of PA 3%
Slippery Rock University of PA 2%
Indiana University of PA* 7%
Carnegie Mellon University 33%

* Includes all campuses
UNIVERSITY-BASED TECHNOLOGY TRANSFER

University technology transfer activity represents the vehicle by which science and technology developed at the universities is translated into commercial activity. As such, technology transfer is a vital component of regional economic development. There are four measures of technology transfer that are examined here:

- Patents, which represent the discoveries that have sufficient commercial value
- Licenses and Options, which are one means by which established companies access these discoveries
- License Income, because it measures the importance or value of the discoveries that are licensed
- Start-up Companies, because they are an increasingly important vehicle for taking university research to market

Taken together, these measures are an indication of the value that is perceived from university research. In order for a region to capture the benefits of university research, there must be the capacity to adapt and apply the knowledge from basic and applied research to commercial products and processes. This absorption requires strong linkages between the universities and corporations that have product development capacity and which offer employment and advancement opportunities for the technically skilled workforce produced by the universities.
Highlights:

- The number of patents issued to the University of Pittsburgh and Carnegie Mellon University **increased in 2001 by 13 percent**, from 67 to 76, an all-time combined high.

- In comparison to other universities throughout the U.S., Carnegie Mellon is **tied for 29th place**, an advancement of 11 spots since the previous year; the University of Pittsburgh is **ranked 13th**, an advancement of 12 spots.

- With respect to the ranking in the number of startups, both Carnegie Mellon University and the University of Pittsburgh are **tied at 26th nationwide**.

### Technology Transfer in Southwestern Pennsylvania

<table>
<thead>
<tr>
<th>Year</th>
<th>Licenses &amp; Options Executed</th>
<th>Gross License Income</th>
<th>Patents Filed</th>
<th>Patents Issued</th>
<th>Start-up Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>29</td>
<td>$14,597,500</td>
<td>78</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>1998</td>
<td>31</td>
<td>$32,625,000</td>
<td>89</td>
<td>28</td>
<td>8</td>
</tr>
<tr>
<td>1999</td>
<td>39</td>
<td>$6,501,135</td>
<td>106</td>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>2000</td>
<td>45</td>
<td>$5,549,291</td>
<td>149</td>
<td>67</td>
<td>9</td>
</tr>
<tr>
<td>2001</td>
<td>38</td>
<td>$3,270,777</td>
<td>133</td>
<td>76</td>
<td>8</td>
</tr>
</tbody>
</table>

### Technology Transfer of Regional Academic Institutions (FY2001)

<table>
<thead>
<tr>
<th>Institution</th>
<th>Patent Applications</th>
<th>Patents Issued</th>
<th>License Income Received</th>
<th>Startups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnegie Mellon University</td>
<td>38</td>
<td>27</td>
<td>$1,982,562</td>
<td>4</td>
</tr>
<tr>
<td>University of Pittsburgh</td>
<td>95</td>
<td>49</td>
<td>$1,288,215</td>
<td>4</td>
</tr>
<tr>
<td>Maximum in each category of all U.S. Universities</td>
<td>348</td>
<td>152</td>
<td>$148,938,057</td>
<td>31</td>
</tr>
<tr>
<td>National Average</td>
<td>47</td>
<td>18</td>
<td>$5,327,863</td>
<td>2</td>
</tr>
</tbody>
</table>
The growth and above average performance in patent application, patents issued and startups are very important trends for the region’s economic development. In addition to maintaining and growing a strong research base, the key challenge moving forward is to ensure that local companies and industries are capable of benefiting from this research, and that the process serves the needs of the institutions and the region.

Although the number of patents filed by the region’s universities has shown a growth trend over the last five years, 76 percent of the region’s total patents still came from the private sector in 2002.
PRIVATE SECTOR PATENTS

The total number of patents filed in any given year, both by the universities and the private sector, is one measure of the robustness of its innovation culture.

**Highlights:**

- Total patents with assignees in the Pittsburgh region remained relatively steady in 2002, only *declining by five percent* from 2001 totals.

- Throughout the beginning and middle parts of the last decade, the region averaged *629 patent issues per year*, but after the trough year of 1997 (581 patents issued) the annual *average increased to 697* through 2001, including the peak year of 1999 (841 patents issued).

- In the year 2002, *675 patents were issued* to inventors located in southwestern Pennsylvania, 44 of which came from the university community.

- Just over *three-quarters of all patents* issued in 2002 to regional inventors were *assigned to corporations*; *17 percent were assigned to individuals* and *seven percent were assigned to universities*.

- Although still a small proportion, the share of patents issued to universities has *doubled since 1997*, reflecting increased research and development and increased focus on formalized technology transfer activity.

Source: U.S. Patent and Trade Office, Calculations by the Carnegie Mellon Center for Economic Development
SBIR AWARDS

The Small Business Innovation Research (SBIR) program is a large source of early stage technology financing in the country, and it encourages the development and commercialization of new technology products and services by funding cutting-edge research.

Federal agencies with more than $100 million in their R&D budgets must set aside 2.5 percent for partnerships with private industry. Small businesses are eligible to win up to $850,000 for a single two-phased project. More than 30 percent of the projects that enter the second phase of the SBIR program lead to commercialized products or services.

The federal agencies that participate in the SBIR program include:

- Department of Health and Human Services
- Department of Energy
- Department of the Air Force
- Defense Advanced Research Projects Agency
- Ballistic Missile Defense Organization
- Environmental Protection Agency
- Secretary of Defense
- NASA
- National Science Foundation
- Department of the Navy
- Department of Transportation
- Department of Education
- Department of Agriculture
- Department of the Army
- Department of Defense (unspecific)
Other Key Growth Indicators

1. Introduction
2. Technology in Southwestern Pennsylvania
3. Other Key Growth Indicators
4. Challenges and Opportunities

- SBIR Awards

**Highlights:**

- The total value of Phase I awards made to companies in the 13-county region in 2001 **eclipsed all other years**, including the previous high year, 1998. The average award for 2001 was the **highest** of any previous.

- The total amount of SBIR Phase I funding to regional firms **increased by more than 67 percent**, when comparing 2001 with five years previous.

- In comparing 1997 and 2001, Phase II funding **increased 230 percent**.

- The Department of Health and Human Services continued its decade-long tradition of awarding the most funding **($16.2 million)** to the region’s companies.

SBIR Phase I Awards (All Agencies)

Sources: Small Business Administration and the National Institutes of Health
In 2003, 60 percent of the companies nationwide that applied won an SBIR Phase II award for the first time.
VENTURE CAPITAL

Seed, start-up and early stage venture capital typically are sought by new or small firms when they have innovative products with high earnings potential. Monitoring the flow of venture capital can provide valuable insights into high technology industries or technology-oriented economies, because more than half of all venture capital investments are made within high technology-related businesses.

Highlights:

- The Pittsburgh region’s performance in securing seed, start-up and early stage venture capital financing historically has kept pace with the nation, in general.
- The 49 percent drop in southwestern Pennsylvania venture capital between 2001 and 2002 is in line with a 47 percent decline nationally.
- Although venture capital funding has fallen sharply, the decline in the number of companies receiving venture capital investment has been less severe than the pace of the nation. The 28 regional companies receiving investment represented a 24 percent drop from 2001 and a 55 percent decline from the year 2000 peak. The national decrease in the number of firms was greater than the regional decline, at 33 percent since 2001 and 58 percent since 2002.
- While the percentage of venture capital invested in early stage companies fell significantly throughout the U.S. and remained unchanged in the state, it grew to 24 percent in the region in 2002.
More than **three-quarters** of the Pittsburgh region’s venture capital investments in 2002 were made **within technology-related industries**, such as computer software and hardware, semiconductors and biotechnology. This **compares favorably with the national average** for investments, of which only about 50 percent is directed toward technology ventures.

Of the region’s venture capital in 2002, **60 percent** of the recipients were **internet-specific and computer-related ventures**.

The share of investments in the **medical/health and biotechnology** industries maintained their share of **25 percent in 2002**. Nationally, the share of venture capital invested in biotechnology companies was 8.5 percent.
13 Counties of Southwestern Pennsylvania

Venture Capital Disbursements, 1998–2002

Source: Venture Economics
Of the venture capital invested in the region in 2002, 60 percent went to internet-specific and computer-related ventures. The share of investments grew in the related medical/health and biotechnology industries 25 percent in 2002, up three percentage points over the previous year.

Eighty percent of Innovation Works-funded companies have participated in the Pittsburgh Technology Council’s EnterPrize Business Plan Competition.

Source: Venture Economics
Since 1997, early-stage investment in the region as a proportion of total investment generally kept pace with or exceeded either state or national levels, or both. The exception was in 2001 when the region’s investment exceeded neither the state nor the national levels. And although the share of companies receiving early-stage investment in the region fell during this period, the decline still mirrored state and national trends.
INCORPORATIONS

The rate of incorporation is an important indicator of the current and future health of a region’s economy. A relationship exists between the creation of new businesses and future job growth. Furthermore, new incorporations signify a favorable business climate and conditions that favor risk taking.

Highlights:

- **New business incorporations** in the year 2002 for the 13-county southwestern Pennsylvania region **totaled 3,675**.
- Allegheny County led the region with 1,976 or **53 percent of the region’s incorporations**.
However, when examining the total number of incorporations per 10,000 in population, Allegheny County, although a clear leader, is not the only player in the field. The following chart indicates that there is at least a constant level of business activity throughout the region.
The rate of business incorporations per 10,000 residents for the region compares weakly within the state. The incorporation rate of southwestern Pennsylvania's 13 counties (12.5 per 10,000) continued to trail the entire state's (17.7 per 10,000) in 2002. Allegheny County's 14.5 rate was the only county approaching the state's incorporation rate. The region has trailed the state in the rate of incorporations since at least 1990.
INITIAL PUBLIC OFFERINGS

When a business has successfully grown itself to a point where it has a solid product line and a competent management organization, a large infusion of new capital often is needed for the firm to expand further and secure a significant market share. Conducting an initial public offering (IPO) is one option that many firms consider at this stage.

This heightened business activity benefits the region as well, but not only from a financial standpoint. Any metropolitan area that can sustain a significant share of IPOs tends also to be identified as a region that is economically vibrant.

**Highlights:**
- There were two IPOs in southwestern Pennsylvania in 2002, Dick’s Sporting Goods and Printcafe, generating total proceeds of nearly $120 million.
- Compared to Pennsylvania, the Pittsburgh region had more companies and IPO proceeds per capita in 2002.
- While the region compared favorably to the U.S. in companies per million, it trailed the nation in proceeds per capita.
Southwestern Pennsylvania—13 Counties

Initial Public Offerings, 1998–2002

As indicated in the chart above, there is no clear trend in the number of IPOs during the five years ending in 2002.

Further, the total proceeds when measured as a function of the total population, reveals a brighter picture. Three out of the last five years, the per capita proceeds of the region’s IPOs approached or exceeded the levels posted by the state. In addition, during the peak year of 1999, the per capita proceeds came very close to that of all the U.S.
Per Capita Proceeds from IPOs, 1998–2002

Source: Securities Data Company

No Regional IPOs in 2001
The region’s technology industries have become significant parts of the southwestern Pennsylvania regional economy, and those that surmount the challenges posed by the economy will have the opportunity to grow in ever-increasing importance during the remainder of this decade.

At the same time, technology industries face certain challenges that, while they affect all industries, they particularly impact technology firms. These challenges include:

- continuing workforce education and development
- ensuring entrepreneurial vitality
- improving the regional and state business climate

These challenges help define the mission of the Pittsburgh Technology Council, and the initiatives described on the following pages highlight how the Council has answered the call.
WORKFORCE EDUCATION AND DEVELOPMENT

With respect to workforce education and development, the Council along with Catalyst Connection, an affiliate organization of the Council, has designed and implemented a number of vital and successful initiatives to develop, attract and retain highly qualified talent.

The Manufacturing Pathway Initiative is a business, education and community partnership that combines summer classroom instruction and paid workplace experiences for high school students, in order to increase their awareness of and preparation for careers in the manufacturing industry. During the last fiscal year, 85 secondary schools (including eight vocational schools), six post-secondary schools and more than 100 businesses participated in the initiative.

The Technology Literacy Initiative is an information technology workforce strategy that provides students in kindergarten through 12th grade with the necessary skills to compete in today’s economy. The initiative is designed to help educators bridge the gap between skills being taught and the level of technology literacy required for careers, both inside and outside of the IT industry. Twenty-four secondary schools and four post-secondary schools throughout the region participated last year.

Adventures in Technology is a business, education and community partnership that engages high school students in an eight-week hands-on project to design and build a product or to re-engineer an existing product, process or system for a local company. During the last session, 12 secondary schools (including vocational schools) and 12 businesses participated.
**Internship services** provided by the Council and Catalyst Connection include a comprehensive package of offerings for companies that engage in internships for undergraduates in southwestern Pennsylvania. Services include job posting, resume screening, targeted recruiting, mentoring and outcome evaluation. Nearly 180 students from 40 post-secondary schools, as well as 63 businesses throughout southwestern Pennsylvania took advantage of these services during the last fiscal year.

A **new student membership program** in the Council promotes early interest in career opportunities within the technology clusters in southwestern Pennsylvania. Benefits of the new membership category promise post-secondary students one-on-one interaction with business professionals, company tours, professional development seminars, a bi-monthly career newsletter, discounted admission rates at Council events, opportunities to build a professional network and access to industry contacts that they cannot get anywhere else.

Companies like Blattner Brunner, Cellomics, Fed Ex, FreeMarkets, GlaxoSmithKline, PNC Bank and Union Switch and Signal have conducted highly successful and highly attended tours. The student membership maintains advisory boards at universities and colleges throughout the region, including Robert Morris University, Carnegie Mellon University, the University of Pittsburgh, St. Vincent College and Duquesne University. For more information, visit http://www.pgtech.org/membership/students.asp

**Career Literacy** is an initiative that will provide a Web site to students, ages 12 to 18, that helps them learn about career options. The site will guide them through the process of evaluating their interests, learning about career opportunities and making decisions about their future. Separately, the Council’s on-line Career Center also provides regional career opportunities to a variety of audiences from students to job seekers with
the objective of retaining valuable talent. As of December 2003, there were 850 active, open positions listed on the site, and last year 600,000 visitors logged on.

**Information Technology Cluster Workforce Development** is an initiative that creates a more effective relationship between the demand and supply sides of the information technology labor market. This effort establishes regional employer leadership around IT workforce issues and endorses a cohesive action agenda related to the development, attraction, recruitment and retention of the region’s technology-related workforce. More than 40 businesses currently are involved in this initiative.

**The Life Sciences Pipeline Initiative** is a coalition of educational and economic development organizations in southwestern Pennsylvania that is developing and implementing an integrated life sciences curriculum to meet the emerging needs of the region’s biotechnology and biomedical industry cluster. A new initiative currently in its pilot phase, the Life Sciences Pipeline has the involvement of one secondary school, four post-secondary schools and 15 businesses. Both the Council and Catalyst Connection are leaders of the coalition.

Advocacy initiatives carried out by the Council and Catalyst Connection have demonstrated successes in mobilizing employers to advocate effectively for specific workforce education issues, and to represent manufacturing and technology clusters in the education community. By assisting in the articulation of public policy issues, business leaders can ensure that the next generation of workers in the region will have the skills necessary not only to succeed, but also to propel the industry forward.
ENTREPRENEURIAL ACTIVITY

Fully 57 percent of the Pittsburgh Technology Council’s member companies employ 10 employees or fewer. It is essential, therefore, that as a region we should concentrate our efforts in developing these firms and positioning them for continued growth.

With regard to entrepreneurial activity, the Council has assisted the startup of hundreds of businesses with the EnterPrize Business Plan Competition and its associated curriculum of business planning fundamentals. Since the first EnterPrize in 1999, participants have attracted total funding in excess of $46 million, regardless of whether they won in the competition or not. This was a result that was expected when the EnterPrize competition was first being devised in its early years, because venture capital firms and Innovation Works, which are involved in the judging, have direct access to all participants. In fact, 80 percent of Innovation Works-funded companies have participated in the EnterPrize Business Plan Competition.

The Council also manages an Entrepreneurs Network, where members share experiences, business leads and advice. In addition, the Council’s Venture Out program helps entrepreneurs help themselves to build better enterprises through the examination of ongoing case studies. Last year more than 470 would-be entrepreneurs attended these programs.

The Council also worked collaboratively with the Pittsburgh Venture Capital Association and Innovation Works to implement the 3 Rivers Venture Fair, which provided a forum for the region’s technology companies to interface with investors and financiers from throughout the northeastern U.S. Approximately 425 attended the Venture Fair in 2003, including venture capitalists, investment bankers and angel investors. In
addition, as a direct result of their participation in the previous year’s Venture Fair, presenting companies collectively raised more than $54 million in investment capital.

Catalyst Connection, an affiliate of the Council, executes an SBIR grant program that also assists the region’s entrepreneurs in identifying and applying for federal R&D awards. Most recently, Catalyst Connection became affiliated with the Small Business Development Centers, the Ben Franklin Partnership and other organizations in an initiative called the Innovation Partnership. The partnership was able to secure additional funding from the commonwealth for grant writing and related activities. The state increased its annual commitment from $50,000 to $500,000. Other members of the partnership include PABioTech, Innovation Philadelphia, the Small Business Development Centers and the Life Sciences Greenhouses of Pittsburgh, central and southeastern Pennsylvania.
BUSINESS CLIMATE

In 2003, the Pittsburgh Technology Council continued an aggressive initiative to improve Pennsylvania's business climate, as it relates to the region’s technology industries. The effort, which is part of a multi-year plan to improve the structure and level of business taxes, sought to reduce the commonwealth’s business taxes to a point where it would, at the very least, stand in the “middle of the pack” among other states. As a primary goal, taxes that would preclude businesses from locating or expanding continue to be key targets for reductions or elimination.

According to a study conducted by the Pennsylvania Economy League in 2001, some of Pennsylvania’s more onerous provisions include:

- a corporate net income tax rate that is the third highest in the nation
- a capital stock and franchise tax that is the eighth highest in the nation
- local business and property taxes that are substantially higher than those of competitor cities

In addition to having high rates of taxation, Pennsylvania’s various taxes often are the wrong type of taxes to help stimulate and grow the commonwealth’s technology community. More specifically, taxes that are assessed against a business's worth or its gross receipts, as opposed to its net profits, are generally more harmful to companies that are in their start-up or growth phases.

Moreover, in November of 2002 and through the early months of 2003, the City of Pittsburgh sought legislative approval to enact a payroll preparation tax that would have been charged against a corporation’s expenditures on payroll. Initially proposed
at a half percent, this tax would have been imposed in addition to the City's existing six-mill gross receipts tax.

During this debate, the Council worked aggressively to educate our elected officials about the potential impact of this new tax on the region’s technology community.

For his part, Governor Ed Rendell championed legislation that would increase Pennsylvania’s R&D tax credit from $15 million to $30 million. Equally important, the governor also endorsed a bill introduced by Representative Tom Stevenson (R-Mt. Lebanon) that would permit technology businesses to sell their unused R&D tax credits.

In 2004, a statewide task force appointed by the governor will release a report that makes broad recommendations about improving the Pennsylvania tax system to better represent our 21st century economy and to improve the commonwealth’s ability to compete for, attract and retain businesses.

The challenges discussed in this section provide a framework around which to build strategies and implement tactics that will result in growth among the existing and emerging technology clusters. The continued success in solidifying technology’s foundation and seating the region’s reputation as a center of excellence will hinge on how well we address these challenges. The region’s success also will depend upon how well it continues and expands upon the vital initiatives, like the ones described on the previous pages.

For more updates on the Council’s advocacy and public policy initiatives, visit the Council Web site at http://www.pghtech.org/advocacy/index.html
CONCLUSION

The southwestern Pennsylvania region is building the foundation of a world-class technology center organized around five existing industry clusters and several emerging ones. The existing clusters are:

- information technology (including software, hardware and telecommunications)
- life sciences (including medical equipment and supplies, health services, bio research, instruments and devices and pharmaceuticals
- advanced manufacturing
- advanced materials (including rubber and plastics and chemicals)
- environmental technology (including environmental equipment, professional services and research and remediation and waste management)

Emerging clusters include:

- Cybersecurity
- Data storage
- Electro-optics
- Fuel Cells
- Nanotechnology and MEMS
- Robotics
- System-on-a-Chip
- Tissue Engineering
Information Technology

Information technology in the Pittsburgh region covers businesses that design and make computer hardware and software and that provide telecommunications services and technologies. The performance of these three subcluster industries serve to mirror the overall pattern of the aggregated core IT cluster, including the gains made across the board in average wages. As an example, the average wage for the software subcluster in the six-county MSA (metropolitan statistical area) is the highest in this report at $71,300 a year.

Life Sciences

Medical instruments and devices, cell research and tissue engineering comprise a widening list of life sciences disciplines in which the Pittsburgh region has a significant stake.

Aside from the formidable research programs at southwestern Pennsylvania universities (especially at the University of Pittsburgh, which ranked once again among the top eight universities funded through the National Institutes of Health), the region also has shown a significant growth in the number of companies that are commercializing technologies discovered in the lab. The more established firms have focused on medical instruments and devices.

Advanced Manufacturing

This cluster encompasses industries that are largely automated and that employ a high degree of process controls, such as computer numerical control systems and robotics. This cluster also encompasses those businesses that develop and install these systems...
for other manufacturers. Although most aspects of this cluster suffered declines over the measured period, the average wage increased four percent.

**Advanced Materials**

Southwestern Pennsylvania is rooted with a mix of large, international chemical and plastics companies, in addition to small- to mid-sized firms supplying an array of products and services that are recognizing considerable growth, even in a downturn. The aggregated cluster’s total annual payroll remained very stable. The average wage, however, grew five percent over the previous year.

**Environmental Technology**

During the period following World War II, it became apparent that the prosperity of Pittsburgh’s industrial heritage also claimed a fairly heavy environmental toll. The environmental problems that were a holdover from this era needed to be tackled, and the lessons learned became the basis of the region’s environmental technology capabilities. Other countries, most notably Russia, China and Brazil, recently have looked to Pittsburgh for help in addressing some of these same challenges.

The total annual payroll and average wages of this cluster have remained steady, most likely due to the completion of a shakeout that began during the years when it had overcapacity.

**University-based Research and Development**

The level of research and development spending at local universities and research centers can have a great impact on the development and success of technology firms. Regions where universities and high technology industries strongly complement each
other continue to receive worldwide recognition for their abilities to generate new technologies and businesses. They also draw large amounts of investment capital and human talent.

Within this context, it is significant that Pittsburgh is home to two of the largest research universities in the region, Carnegie Mellon University and the University of Pittsburgh. Other institutions that have contributed to research include Duquesne University and Indiana University of Pennsylvania.

Science and Engineering Graduate Students

The number of science and engineering students that any region’s colleges and universities graduate each year continues to be an important trump card in attracting and expanding technology development. Companies wishing to establish a presence in any given locale will examine the number of graduate students produced by nearby science and engineering departments as a ready source of technology talent.

Of 33 Pennsylvania colleges and universities offering science and engineering degrees, the University of Pittsburgh was ranked second in total graduate students, accounting for nearly half of the 13-county totals. Carnegie Mellon University is the region’s second highest in science and engineering graduate students, which places it third in the state.

University-based Technology Transfer

University technology transfer activity represents the vehicle by which science and technology developed at the universities is translated into commercial entities. As such, technology transfer is a vital component of regional economic development. Four measures here include patents, licenses and options, license income and start-up companies.
In terms of the number of university patents issued nationally, Carnegie Mellon University is tied for 29th place, an advancement of 11 spots since the previous year; the University of Pittsburgh is ranked 13th, an advancement of 12 spots.

With respect to the ranking in the number of startups, both Carnegie Mellon University and the University of Pittsburgh are tied at 26th nationwide.

**Private Sector Patents**

The total number of patents filed in any given year, not only by the universities but by the private sector, is one measure of the robustness of a region’s innovation culture. Just over three-quarters of all 675 patents issued in 2002 to regional inventors were assigned to corporations; 17 percent were assigned to individuals and seven percent were assigned to universities.

**SBIR Awards**

The Small Business Innovation Research (SBIR) program is a large source of early stage technology financing, and it encourages the development and commercialization of new technology products and services by funding small, technology-based companies that are performing cutting-edge research.

The total value of Phase I awards made to companies in the 13-county region in 2001 eclipsed all other years, and the average award for that year was the highest of any previous. Phase II awards in 2001 also surpassed the previous high year.

**Venture Capital**

Seed, start-up or early stage venture capital typically is sought by new or small firms when it has an innovative product with high earnings potential. Monitoring the flow of venture capital can provide valuable insights into high technology industries and
technology-oriented economies, because more than half of all venture capital investments are made within high technology-related industries.

The Pittsburgh region’s performance in securing seed, start-up or early stage venture capital financing historically has kept pace with the nation, in general. While the percentage of venture capital invested in early stage companies fell significantly throughout the U.S. and remained unchanged in the state, it grew to 24 percent in the region in 2002.

**Up Periscope. All Ahead Full.**

The region’s technology industries, when taken in aggregate, have felt the brunt of a difficult economy, however some of the more dynamic technology industries have continued to increase their average wages.

Southwestern Pennsylvania has transformed itself from an economy based on large, traditional and older manufacturing-oriented employers, primarily in the steel and other metals and materials industries, to one based on a diversified mix of technology, services and advanced manufacturing businesses. The more than 200,000 jobs created within these clusters have offset those that were lost in steel and other industry downsizing a decade earlier.

Indicators show that the region’s technology clusters have weathered the most recent storm, and economists, like PNC Financial Group’s Stuart Hoffman, have reason to be optimistic about their longer term growth and success.
DATA SOURCES

The Carnegie Mellon Center for Economic Development (CED) provides the research and policy intelligence to foster an innovative region. An affiliate of Carnegie Mellon’s H. John Heinz III School of Public Policy and Management, the CED’s services include:

- Technical assistance in policy and strategy
- Economic analysis and modeling
- Mapping of economic and demographic data
- Performance benchmarking and evaluation
- Timely analysis of critical policy issues

The CED collected and analyzed much of the data for this report, including information from the following sources:


Manufacturing. Source: “Manufacturing Pennsylvania’s Future: Regional Strategies that Build from Current Strengths and Competitive Challenges,” a study commissioned by the Pennsylvania Industrial Resource Centers and Team Pennsylvania and conducted by Deloitte.

University-based Research and Development. Research and Development Expenditures at Universities and Federally Funded Research and Development Centers (FFRDCs). Source: National Science Foundation, Survey of Research and Development Expenditures. Data on the R&D expenditures for major science and technology fields was obtained from the NSF WebCASPAR Database System.
Science and Engineering Graduate Students. Source: National Science Foundation, Survey of Graduate Students and Postdoctorates in Science and Engineering. Data was obtained from the NSF WebCASPAR Database System.

Initial Public Offerings. Source: Securities Data Company, Inc. Data includes U.S. proceeds only.


Venture Capital. Source: Venture Economics. Data excludes buyouts, and includes deals reported through July, 2003. “Early stage” financing is defined as “seed,” “startup” or “other early stage” financing.

University-based Technology Transfer. Source: AUTM Licensing Survey Association of University Technology Managers, Inc. Because data for the University of California and State University of New York systems was presented in aggregate for all institutions, data was excluded from the maximum and average calculations.

SBIR Awards. Source: Office of Technology, Small Business Administration, for all SBIR-granting agencies other than the National Institutes of Health (NIH). NIH SBIR data was obtained directly from the NIH Web site. Using zip codes, firms were matched to the Pittsburgh region by the Carnegie Mellon Center for Economic Development.

Patents. Source: United States Patent Grants patent records obtained from the Office for Patent and Trademark Information, U.S. Patent and Trademark Office. The patent data includes only utility (i.e., invention) patents. Not included in this report are plant patents, design patents, statutory invention registrations and patent reissues. Data was linked to zip code location names by the Carnegie Mellon Center for Economic Development and aggregated to the regional definition.
Incorporations. Source: Pennsylvania Department of State. The incorporations data was compiled from the annual Business Incorporation Filings reports for each county. The CED totals all incorporations in the following categories: Domestic For-Profit, Domestic Professional, Domestic Non-Profit, Foreign For-Profit and Foreign Professional incorporations.

Employment, Establishments, Payroll and Average Wages. Source: Pennsylvania Department of Labor and Industry, ES-202 database. Data was provided to the CED under a contract with the Pennsylvania Department of Labor and Industry. To protect firm confidentiality, data was withheld for clusters with fewer than three companies or clusters in which one firm accounts for over 80 percent of total employment or wages. Average wages are calculated as the total payroll divided by total employment. Figures were calculated by the Carnegie Mellon University Center for Economic Development, based on the cluster definitions.

Industrial classifications of firms are reviewed periodically by the data creators and are subject to change. In addition to cluster totals being determined by firm birth, death, growth, decline and relocation, the totals also may be influenced by the reclassification of a firm's industry code.
System-on-a-Chip in the Pittsburgh Region

System-on-a-Chip (SoC) technology is designed as a programmable platform that integrates most of the functions of the end product into a single chip. System-on-a-Chip essentially packages all of the necessary electronic circuits and parts for a system onto one single integrated circuit, generally known as a microchip.

System-on-a-Chip components incorporate at least one processing element (microprocessor) that runs a system’s embedded software, and they can contain both memory and analog functions. Products manufactured within this emerging cluster include capacitors, resistors, microprocessors, bare and loaded printed circuit boards, electron tubes, electronic connectors and computer modems.

Advantages of SoC technology include the ability to pack more processing power and memory into ever smaller, faster and more portable devices. With SoC, designers can create ever more complex electronic systems for easy transport that will require little power at no cost to reliability.

Good examples of System-on-a-Chip applications encompass cell phones, digital cameras and video equipment for which the sound-detecting devices alone might include an audio receiver, an analog-to-digital converter, a microprocessor, necessary memory and the input/output logic control for a user—all on a single microchip.

The Internet also is a key driver of SoC development, because as access to the Internet grows, the need for more bandwidth also increases. System-on-a-Chip technology helps to meet this challenge. With SoC technology, handheld computers with small whip antennas might someday be capable of browsing the Internet at megabit-per-second speeds from any point on the surface of the earth.

Challenges for Development

The broad-based application of SoC demands a new and very complex design methodology. Major challenges for SoC development are linked to time and cost constraints.
Expert engineering talent also is a requirement. System-on-a-Chip development requires a highly skilled design team with extensive system-level knowledge, very high quality tools, the availability of embeddable memory elements, logic and processor cores and a stable manufacturing process.

The ability to verify the system in a virtual environment before committing to manufacturing also is essential, and the tools to accomplish this are not yet widely available on the market.

**Meeting the Challenge—The Pittsburgh Digital Greenhouse**

Founded in 1999, the Pittsburgh Digital Greenhouse is a strategic economic development initiative established to foster growth across the region’s emerging cluster and the companies that are developing and employing System-on-a-Chip and related technologies for networking and multimedia applications.

The Pittsburgh Digital Greenhouse fosters a pre-competitive environment for SoC companies, by leveraging the region’s existing technology base. Cooperative efforts combine resources and support from local universities, private foundations, regional development organizations, state and local government and industry. As of the end of fiscal year 2003, the state had spent $21.5 million to turn the region into an SoC hub.

As a member-driven initiative, the Greenhouse delivers four high value-added programs that include:

- collaborative research and development
- talent recruitment
- education and professional development training
- start-up and expansion services
System-on-a-Chip in the Pittsburgh Region (cont.)

The Greenhouse also funds $3 million to $4 million annually in precursor design and embedded-system solutions that reach beyond the current generation of available products and services. This funding has a dynamic reach into such areas as micro-electromechanical systems; mobile and low-power systems; wired, optical and wireless networking; human-computer interface technologies; piezoelectric elements and multimedia applications.

In 2003, 248 research proposals were submitted to the Greenhouse, representing a total funding request of $55.9 million. As of November 2003, $11.4 million in funding was awarded to a total of 64 projects.

On the talent front, the Greenhouse’s talent recruitment program identifies, attracts and retains the best digital, analog and mixed-signal engineering and management talent in the world. Services include:

- technical and university recruiting
- representation at job fairs and online career sites
- internship and co-op program coordination

As a result, the Greenhouse has generated 228 jobs in the 13-county southwestern Pennsylvania region.

Three distinct programs foster additional educational and professional training development efforts targeting SoC.

Three local universities, the University of Pittsburgh, Carnegie Mellon University and The Pennsylvania State University, offer graduate level SoC certificate programs. The development of a cadre of professional engineers also is enabled through practical training courses, as well as funding to companies for technical and management efforts.
System-on-a-Chip in the Pittsburgh Region (cont.)

The Digital Sandbox Program at the Greenhouse addresses infrastructure and technical support to sustain the hands-on laboratory environment of both university and professional development programs. This virtual SoC design facility provides industrial hardware, software, workflows and technical support staff to all three Greenhouse member universities, thereby enabling companies to get further in design faster.

The Pittsburgh Digital Greenhouse also is committed to making it easy and financially attractive to locate new chip design and research facilities in southwestern Pennsylvania, as well as to establish new local start-up companies developing SoC and related technologies for networking and multimedia applications. Expansion and support services include incubation facilities, access to the regional investment community, business networking events and business support services, such as business plan consultation.

Regional Companies

Southwestern Pennsylvania’s System-on-a-Chip companies span a range of industries that design, develop and/or use SoC-related technologies. These companies include integrated device manufacturers, fabless semiconductor companies, integrated circuit designers, embedded system integrators and advanced electronic component companies.

The Pittsburgh Digital Greenhouse currently boasts a membership of 33 companies. Notable among them are industry leaders, like Bridge Semiconductor, Cadence, Cisco Systems, Fairchild Semiconductor, IBM, Laurel Networks, Marconi and Sony.

By way of an example, Fairchild—a maker of analog and mixed-signal, discrete, interface and logic microcontrollers and electro-optics—is singularly focused on creatively managing, converting, minimizing and distributing power.
Laurel Networks also is indicative of the scope of this emerging industry cluster. The company provides data service delivery architectures comprised of a single packet-switched network. By bringing together the best of switching and routing technology into a single device, Laurel Networks enables more flexible, scalable architecture that translates to dramatic cost reductions.

Another example is Pittsburgh-based Akustica, who last year introduced the world's first acoustic system-on-a-chip. The microphone and speaker chips are based on patented MEMS technology that integrates the functionality of multiple microphones or speakers with microelectronics and software onto a single, standard semiconductor. The result is a new class of acoustic solutions that deliver unprecedented capabilities for capturing, processing and reproducing sound.

Other Fortune 1,000, growth-oriented and entrepreneurial companies with forceful R&D initiatives make up the bulk of southwestern Pennsylvania's SoC industry cluster. With the addition of the Pittsburgh Digital Greenhouse initiatives, prospects for growth in the region's SoC technologies are high.

Visit: http://www.digitalgreenhouse.com
Data Storage in the Pittsburgh Region

Every time someone accesses the Internet, trades a stock online, watches television, listens to a CD or uses an ATM, among a countless list of other everyday activities, he or she creates, accesses and stores information.

Data storage requires the integration of physics, tribology (the study of surfaces in relative motion), aerodynamics, fluid mechanics, information theory, magnetics and other disciplines. The fundamental goals of data storage, however, are simply to place as much information as possible (called maximizing areal density) on a hard disk or tape, using magnetic or optical methods, and to provide the means for its rapid access.

Since the mid-1950s, when initial attempts at these fundamental goals were successful, the quest has been to get more and more magnetic storage bits crammed into smaller areas. Today’s ultimate goal is to squeeze 1,000 gigabytes per square inch on a disk, up from a maximum of 60 gigabytes, thereby opening the possibility of a one-terabyte drive. One terabyte is equal to one thousand gigabytes, or a trillion bytes.

To place such large numbers in context, the entire Library of Congress is thought to hold about 20 terabytes of text.

To meet the one-terabyte goal, scientists must overcome the superparamagnetic effect, a phenomenon that is projected to limit the density of magnetically stored information to 36 gigabytes per square inch, above which heat destroys the data. Going beyond that threshold will require significant changes in how data is recorded, the widths of tracks on discs, the protective coatings on components, the ultra-thin lubricants between them and the precision of the tiny suspension systems and sliders within the disk drive.

If cramming in the magnetic bits were the only requirement, the goal would be more easily met. But the magnets must be functional, too. Writing a digital “one” or “zero” in such small areas, then subsequently reading back the values, requires extreme precision
in discerning one bit from another. The bit also must be stable for long periods of time; if some “ones” switch to “zeros,” the data will be filled with errors.

Different Products, Different Markets

There are several different types of products under the general data storage industry cluster. The high-end storage area networks (SANs), for example, are large, special-purpose networks that centralize data storage for large corporations. The market for SANs is expected to grow from about $1.2 billion in 2002 to $4.3 billion in 2006.

The market for easy-to-use data storage devices, however, has increased nearly tenfold in five years. The devices, called network-attached storage (NAS), typically are single-purpose machines that can be plugged into a network to ease departmental needs for data storage capacity. The devices span the range from single-purpose, easy-to-configure file servers to fancier machines with customized hardware and operating systems for high speeds. Sales of NAS products have jumped from $540 million in 1998 to $5.1 billion in 2003.

Yet another subcluster, the disk storage system market, has enjoyed recent growth wherein worldwide gross revenues for this type of product are expected to reach approximately $19 billion. Hewlett-Packard, IBM, Hitachi, Dell and Sun Microsystems are among the major companies competing within the disk storage systems business.

The Pittsburgh Connection

Hard disk drives are major components of the products described above, and Seagate Technology is the worldwide leading independent maker of both internal and external rigid disk drives. The company's products are used to store data in systems ranging from personal computers and workstations, including most recently 2.5-inch disk drives for laptop and other mobile computers, to high-end servers and mainframes. Seagate sells its products directly to computer manufacturers, including those mentioned above.
At its Pittsburgh-based research facility, Seagate is attempting to close in on the holy grail of one terabyte per square inch. The highest-volume disk available today is Seagate’s Cheetah; it stores 73 gigabytes on one disk (some 18 thousand megabytes per square inch), equivalent to all the text on one floor of the New York Library.

Seagate introduced the first 5.25-inch hard drives specifically for personal computers in 1979, helping to fuel the PC revolution. Suddenly, data could be stored and accessed in unprecedented quantities and at unprecedented speed, giving rise to developments such as the Internet.

Today, 24 years later, the worldwide sales for hard disk drives is $21 billion, and Seagate commands one-third of the market. Hard drives remain the most common form of mass storage for personal computers, and Seagate is pursuing new technologies that will increase both storage capacity and performance in products, such as servers, workstations, PCs, personal video recorders, gaming consoles, cell phones, personal digital assistants and cameras.

Seagate offers disk drives with capacities of 18 to 200 gigabytes, magnetic recording heads and rotating media. In addition, the company is devising new storage subsystem architectures with increased intelligence and functionality, with hundreds of patents already filed. Products are manufactured in Pittsburgh and five other locations in the U.S. and in Ireland and Singapore.

Seagate and other manufacturers have made immense strides in drive capacity, size and performance. For example, 3.5-inch gigabyte drums, capable of storing and accessing billions of bytes of data, are commonplace in workstations running with multimedia, high-end graphics, networking and communications applications. And palm-sized drives not only store hundreds of thousands of pages of information, they also retrieve or select items from this data in just a few thousandths of a second. One result is that the cost of storage and the space needed has plummeted since fewer disks are needed.
Data Storage in the Pittsburgh Region (cont.)

New Research

Research is extremely important in this fast-paced business that depends on being first with new products. The engineers and scientists at Seagate’s research facilities are developing the next generation of data storage devices, magnetoresistive random access memory. It magnetically stores a large amount of data, eliminating the need for power to retain the data, and largely because of the high density of the stored data, it is inexpensive relative to other methods. Access is more rapid as well.

Another promising process is heat-assisted magnetic recording. It uses “harder” magnetic material for its bits that make it more difficult to flip between magnetic states, adding stability.

Seagate is one of eleven member companies of Carnegie Mellon University’s Data Storage Systems Center (DSSC), which was established by the National Science Foundation. Other major company members include Hitachi Maxwell, Sharp and Sony. The connections between the Center and Seagate extend far beyond membership. Marc Kryder, for example, Seagate’s vice president of research, was the first director of the Center, and he was a professor and still teaches at Carnegie Mellon. Kryder is known worldwide as a leading expert in magnetics.

The Center’s goals, among others, are to cooperate with industry to identify future data storage systems, to develop the more promising applications and to transfer the technology to commercial businesses. A specific goal is to demonstrate the feasibility of one terabyte per square inch density in magnetic disk drives by 2005. Other projects span a wide range of disciplines, including thin film and particulate media, magnetic and optical recording, materials for magnetic and optical heads, tape dynamics and more.
Data Storage in the Pittsburgh Region (cont.)

Regional Industry Base

The DSSC’s successes include some five or six invention disclosures, patents and software licenses per year. A succession of spin-off companies also has been a by-product.

Among the spin-offs is Ansoft, which was formed in 1989 to develop software for the design of electromagnetic devices, including recording heads. The software is based on advanced computer algorithms developed at the Center. Ansoft’s HF product suite is a solution for system analysis, circuit design and electromagnetic simulation that go into developing wireless technology, broadband communication networks, antenna systems and aerospace electronics. Headquartered in Pittsburgh, Ansoft operates three other locations in the U.S. and five overseas.

Another spin-off is Advanced Materials Corporation, a premier manufacturer of permanent magnets and related materials. The company’s facilities are located in the laboratories provided through a contractual relationship with the Carnegie Mellon Research Institute. The facilities are fully equipped for the characterization of hard and soft magnetic materials and the exploitation of metal hydrides. They include equipment to fabricate alloys, ferrites and hydrides.

As these organizations continue to prosper, it will be a signal that the Pittsburgh region will be on the forefront of an emerging cluster that places the most amount of information on the least amount of real estate.

Visit: http://www.seagate.com

http://www.ece.cmu.edu/research/dssc
Cybersecurity in the Pittsburgh Region

Last year, the Internet Fraud Complaint Center reported more than 75,000 complaints classifiable as cyber crimes. The number of incidents will likely have doubled in 2003. The Computer Emergency Response Team Coordination Center (CERT/CC) at Carnegie Mellon University’s Software Engineering Institute alone reported more than 114,000 incidents of virus attacks and other computer breaches in just the first nine months of 2003. In addition to these incidents, 2,982 vulnerabilities also were documented.

In 2001, cyber attacks cost businesses roughly $13.2 billion in damage and clean-up expenses.

Cyber crimes generally entail technological attacks resulting in one of three major types of computer failure:

- very slow, unavailable or inoperable systems or networks
- corrupted systems or networks
- leaky systems or networks which extend information access to normally restricted users

A recent FBI report on cybersecurity details a wide range of known criminal cyber activities. Viruses, worms, trojans, computer intrusions, Web site attacks and defacements, denial-of-service attacks, identity theft, privacy breaches and child pornography are included as just some of the better known examples.

Attackers fall into a range of categories from disgruntled and dismissed employees, domestic and overseas competitors and even foreign governments and terrorists. Scores of Web sites are now readily vulnerable to hackers and virus writers in numerous languages and cultures.

As government, global e-commerce and mass computer use continue to grow, cybersecurity initiatives become all the more pressing. Simultaneously, progressive changes in intruder techniques increase the difficulties of predicting or detecting attacks or of limiting their potential damages. In short, such sophisticated threats demand truly sophisticated responses.
Amid such a backdrop, southwestern Pennsylvania has become a center of excellence in cybersecurity.

**CERT—Nationally Recognized Cybersecurity Hub**

The Computer Emergency Response Team Coordination Center has been leading the way in cybersecurity research, development and response for 15 years. It is located at the Software Engineering Institute (SEI), a federally funded research and development center at Carnegie Mellon University.

Following the Morris worm incident which brought 10 percent of Internet systems to a halt in November 1988, the Defense Advanced Research Projects Agency (DARPA) charged the SEI with establishing a center to coordinate communication among experts during security emergencies and to help prevent future incidents on a national basis.

Today, CMU’s CERT/CC alerts U.S. industry and computer users worldwide to potential threats to the security of their systems and provides information about how to avoid, minimize or recover from the damage. The Center has played a key role in coordinating responses to major security events, such as the Code Red worm, Melissa virus and recently, the MS Blaster worm and the Sobig.F virus.

The Center’s primary charge is to preempt or respond to any threats to the security of the Internet—and the millions of computers connected to it—and to analyze product vulnerabilities that place organizations and individuals at risk. As part of the SEI Networked Systems Survivability Program, CERT/CC also ensures that appropriate technology and systems management practices are used to resist attacks on networked systems, to limit damages and to ensure continuity of critical services in spite of successful attacks ("survivability"). Numerous alerts, vulnerability reports, educational guides and other statistics are published by CERT/CC each year.
Cybersecurity in the Pittsburgh Region (cont.)

To accomplish its mission, CERT/CC specializes in survivable enterprise management, survivable network technology, incident handling and incident and vulnerability analysis. The Center also is committed to increasing awareness of security issues and helping organizations improve systems security by disseminating information through many channels.

While there is only one CERT Coordination Center, more than 200 computer security incident response teams have adopted the organization’s incident-handling technique. The Center coordinates with these numerous independent teams, the Internet Security Alliance and the Federal Computer Incident Response Center to manage security incident responses. Many independent response teams also are members of the Forum of Incident Response and Security Teams, of which the CERT/CC is a founding member.

In September 2003, U.S. Secretary of Homeland Security Tom Ridge recognized CERT/CC as “a key element to our national strategy to combat terrorism and protect our critical infrastructure.” Accordingly, Carnegie Mellon University and the Department of Homeland Security (DHS) announced a partnership with CERT/CC to create US-CERT, a coordination point for prevention, protection and response to cyber attacks across the Internet.

The US-CERT will begin as a partnership between the National Cyber Security Division within DHS and CERT/CC. The US-CERT will grow to include other partnerships with private-sector security vendors and domestic and international organizations. These groups will work together to coordinate national and international efforts to prevent cyber attacks, protect systems and respond to the effect of cyber attacks across the Internet.

FBI/Pittsburgh—Computer Crimes Task Force

The Pittsburgh office of the FBI also has been a leading cyber crime-fighting unit since 2000, when it became the first branch to hire an official computer science agent. During the same year, FBI/Pittsburgh and CERT/CC joined forces in the formation of the Pittsburgh High Tech Computer Crimes Task Force – a first of its kind in the nation.
Cybersecurity in the Pittsburgh Region (cont.)

As a unit of consolidated federal, state and local law enforcement, the task force was created with the purpose of pooling technical and investigative resources trained in computer technology and cyber crime in order to advance the mission of all enforcement agencies. The Pittsburgh High Tech Computer Crimes Task Force provides forensic examination, intelligence and technical assistance to all agencies encountering computers during the course of their investigations.

Unlike traditional types of crimes, technology has made it more difficult to answer the who, what, where, when and how of both traditional and non-traditional criminal activity; as a result, evidence in the digital space must be handled differently. The task force meets these evolving challenges as part of its mission. A proposed Regional Forensic and Training Center would allow businesses to run test hack scenarios to measure how well security initiatives perform.

Since 2000, similar task forces have since been deployed in every FBI field office. And in 2002, the FBI reorganized to create its own Cyber Division. This division simultaneously supports FBI priorities across program lines, assisting counterterrorism, counterintelligence and other criminal investigations when aggressive technological investigative assistance is required.

University Contributions

Pittsburgh is home to a number of other cybersecurity assets. In 2001, Carnegie Mellon University and the University of Pittsburgh together received 18.6 percent of the National Science Foundation grants, a total of $5 million, eclipsing both Purdue and Stanford.

Carnegie Mellon ranks second overall in total NSF awards for cybersecurity research and development between 1975 and 2001. Its large faculty in cybersecurity-related fields and significant levels of funding at its Software Engineering Institute are important assets in the development of a larger cybersecurity market.
Cybersecurity in the Pittsburgh Region (cont.)

Since education is a necessary component of safeguarding the computer network, Carnegie Mellon also recently announced the development of CyLab – a new educational program that will be directed by the school’s Information Networking Institute.

CyLab’s mission is to create a partnership between academia, government and industry-based organizations to create technologies for improving the nation’s capabilities in the response, prediction, education and development of new technologies for addressing the threats to cyber infrastructure.

CyLab aims to ensure safety and privacy for all computer users. Its goal is to make 10 million citizens around the world aware of the issues surrounding cybersecurity within three years. Working in collaboration with industry and government and with the aim of having security technology readily accessible across the globe, CyLab will bring together more than 50 researchers and 80 students in three of Carnegie Mellon’s schools and CERT/CC.

CyLab also will act as the Executive Secretariat for the newly formed Global Council of Chief Security Officers – a newly formed group of influential senior cybersecurity leaders from academia, business and government dedicated to enhancing cybersecurity.

U.S. Representative Mike Doyle obtained funding of $2.5 million last year for Carnegie Mellon’s cybersecurity efforts. This year, an additional $6 million will be used for CyLab development.

The Community College of Allegheny County (CCAC) in cooperation with the Software Engineering Institute recently was awarded $1.3 million by the U.S. National Guard Bureau to develop courses that will help companies defend their computer systems and survive a cyber attack.

The Community College and the SEI have each received a portion of the funding to standardize a cybersecurity curriculum for community colleges across the country, making
such training affordable and accessible to professionals and employers. The Survivability and Information Assurance Certificate Program will arm network and system administrators with the necessary skills for recognizing, resisting and recovering from attacks on networked systems. Students enrolled in the hands-on program will have the opportunity to defend a network against simulated cyber attacks.

By completing the certificate program, system administrators will be better prepared for network catastrophes by learning how to integrate security policy, practices and technologies into their daily tasks. The new program will blend theory with intensive, hands-on learning.

Upon successful completion of the pilot, the program will be expanded to other CCAC locations, and by 2005, the program should be ready for other community colleges to offer.

U.S. Representative John Murtha played a critical role in obtaining funding for the initiative through the U.S. Department of Defense.

**Private Sector**

Although many large corporations and government agencies manage computer security in-house by hiring their own staff of experts, the market for cybersecurity services is expected to grow to $21 billion by 2005. Part of this anticipated growth will be fueled by the financial services industry, where spending on security-related products and services is expected to reach $2.2 billion by the same year.

More than 40 businesses in southwestern Pennsylvania claim some level of involvement and expertise in cybersecurity, and all are poised to take advantage of the growth trend.

Included in this community are hardware and software designers, cybersecurity consulting services, developers of monitoring software and tracking devices and manufacturers of technical surveillance and security counter-measures equipment.
Cybersecurity in the Pittsburgh Region (cont.)

Intelytics (a division of iVentureLab), RedSiren Technologies, Congruity Technologies, Fortrex Technologies, Internet Security Systems and InnovationsTech are just a few regional organizations driving our progressive cybersecurity efforts.

The largest dedicated security firm in the Pittsburgh region is RedSiren, which employs 120 people worldwide, with offices in the United States, the United Kingdom and Japan. The company currently has more than 800 active clients on three continents. It recently acquired the cybersecurity arm of Atomic Tangerine (the spin-off of SRI International of Menlo Park, California), Secure Network Group (Kansas) and Verticon (Virginia).

Another regional firm worth examining is VigilantMinds. The company offers consulting and managed security services to help assess, monitor and protect client company networks. It provides security services to many prominent national businesses, including a $6 billion international manufacturer and a $1 billion healthcare services company.

The Pittsburgh region continues to solidify its claim of a center of excellence in cybersecurity. The private firms that operate within this emerging cluster are only part of the picture. The presence of university-based and government agencies also attract a disproportionate share of federal funding for research, development and national cybersecurity services.

Visit: www.cert.org
www.cyber-reponse.com
http://asp1.ccac.edu/sia
www.redsiren.com
Tissue Engineering in the Pittsburgh Region

Broadly defined, tissue engineering is the development and manipulation of laboratory-grown molecules, cells, tissues or organs to replace or support the function of defective or injured body parts.

Although cells have been cultured or grown outside the body for many years, the possibility of growing complex, three-dimensional tissues—literally replicating the design and function of human tissue—is a recent development. The intricacies of this process require input from many types of scientists, including the problem-solving expertise of engineers, hence the name tissue engineering.

Tissue engineering crosses numerous medical and technical specialties. Cell biologists, molecular biologists, biomaterial engineers, computer-assisted designers, microscopic imaging specialists, robotics engineers and developers of equipment, such as bioreactors, where tissues are grown and nurtured, all are involved in the process of tissue engineering.

Tissue engineers in the United States and abroad have set out to grow virtually every type of human tissue – liver, bone, muscle, cartilage, blood vessels, heart muscles, nerves, pancreatic islets and more. Commercially produced skin is already available for use in treating patients with diabetic ulcers and burns.

Many current medical therapies may be improved upon by tissue engineering with significant financial savings. In standard organ transplantation, for example, a mismatch of tissue types necessitates lifelong immunosuppression, with its attendant problems of graft rejection, drug therapy costs and the potential for the development of certain types of cancer.

Furthermore, there is always the potential for rejection of the tissue, but as the field of tissue engineering progresses, it inevitably will provide many improvements, as the costs of tissue harvest and postoperative patient costs will be reduced significantly.
By actually designing replacements to mimic the native tissue being reconstructed, the adequacy of tissue function will be optimized, leading to improved patient care at less expense.

As a world leader in organ transplantation, it is little wonder that Pittsburgh became a world-class center of excellence in tissue engineering.

**McGowan Institute for Regenerative Medicine**

To realize the vast potential of tissue engineering and other techniques aimed at repairing damaged or diseased tissues and organs, the University of Pittsburgh School of Medicine and UPMC Health System have established the McGowan Institute for Regenerative Medicine (MIRM). As an entity, the MIRM serves as a single base of operations for the university's leading scientists and clinical faculty working to develop tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ devices.

The mission of the new institute is to devise innovative clinical protocols, as well as to pursue rapid commercial transfer of its technologies related to regenerative medicine.

The faculty and programs of the McGowan Center for Artificial Organ Development have been incorporated into the MIRM, and other university faculty will join its forces as well. These include researchers working in tissue engineering, adult-derived stem cell research, wound healing and biomaterials research, among other branches.

The MIRM is considered to be the most ambitious tissue engineering program in the nation, coupling biology, engineering, organ transplantation and biomedical research in all facets of its work. One of the attractive features of the MIRM is that it enables cutting-edge basic and clinical research to be performed across disciplines, allowing organ and tissue engineering and cellular and regenerative therapies to be developed and swiftly evaluated in the clinical setting.
Tissue Engineering in the Pittsburgh Region (cont.)

A number of projects are underway at the MIRM, including:

- an axial-flow left-ventricular assist system for patients with end-stage heart disease
- a respiratory assist device for patients with acute lung failure
- a biohybrid artificial lung intended for long-term use
- a novel blood additive that improves blood flow to oxygen-deprived tissues
- a bioengineered blood vessel and a myocardial patch of muscle cells intended to repair heart tissue damaged by heart attack

The new McGowan Institute for Regenerative Medicine and the former McGowan Center for Artificial Organ Development are named after the late William G. McGowan, who as chief executive officer at MCI Communications, underwent a successful heart transplant at the University of Pittsburgh Medical Center in 1987.

In 2003, the McGowan Institute announced a new Pre-Doctoral Tissue Engineering Program and worked on tissue-engineered solutions for heart disease. University of Pittsburgh surgeons were the first in the U.S. to use the Zeus robot during cardiac bypass surgery.

National Tissue Engineering Center

In 2002, the McGowan Institute established the National Tissue Engineering Center (NTEC) in Pittsburgh to serve the Department of Defense as a single base of operations for the leading civilian and military scientists and clinicians working to advance the science of tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ devices, and to translate these new technologies to clinical practice. The goal of
Tissue Engineering in the Pittsburgh Region (cont.)

the NTEC is to save lives and reduce soldier downtime. In order to meet this goal, its work centers on three general areas:

- wound healing
- cardiothoracic and vascular tissue engineering
- musculoskeletal tissue engineering

It is clear that optimal progress in developing new regenerative medicine methods only can be realized by multi-disciplinary teams that range across a wide spectrum of scientists, engineers and clinicians starting at the cellular level, such as cell biologists, through materials engineers, to clinical translation specialists and practicing clinicians. The National Tissue Engineering Center brings this wide expertise together.

University of Pittsburgh Department of Bioengineering

The University of Pittsburgh’s bioengineering department has an active, interdisciplinary graduate program in conjunction with faculty from the School of Medicine, the School of Health and Rehabilitation Sciences and the clinical staffs at the University of Pittsburgh Medical Center hospitals.

This program is directed toward engineering and life science education and research, with particular emphasis on the PhD. Its scope is broadly defined to incorporate the application of engineering principles, methods and technology in two broad areas:

- scientific inquiries into fundamental biological phenomena
- development of instrumentation, arterials, devices and systems relative to application in the biological sciences and medicine
Tissue Engineering in the Pittsburgh Region (cont.)

Active, externally funded areas of research include, but are not limited to:

- computer processing of biologically derived signals
- development of prostheses, artificial organs and implantable sensors
- development of medically related instrumentation
- mathematical modeling of physiological systems
- tissue engineering
- biomaterials
- orthopedic biomechanics and sports medicine
- vascular mechanics
- other related fields

Thus, the bioengineering faculty is applying various forms of engineering principles, mathematics computation, technology and methodology to a broad variety of medical and life sciences problems.

**Bone Tissue Engineering Initiative at Carnegie Mellon University**

The need for bone substitutes is particularly important. They often are required to help repair or replace damaged or diseased tissues in cases that include congenital and degenerative diseases, cancer and cosmetic surgery.

There are approximately 500,000 surgical procedures performed every year in the U.S. that require bone substitutes. Currently available bone substitutes, including autografts, allografts and synthetic materials, are the most implanted materials second only to transfused blood products. However, these substitutes are far from ideal and have many associated problems. Autografting is expensive and can have significant donor site morbidity, and synthetic materials wear and do not behave like true bone. The goal of the Bone Tissue Engineering Initiative is to provide an alternative solution by creating large-scale, tissue-engineered bone.
Tissue Engineering in the Pittsburgh Region (cont.)

A major technology for creating tissue-engineered bone is an advanced computer-aided-design/computer-aided-manufacturing (CAD/CAM) bioreactor system capable of growing large-scale, customized bone substitutes. A CAD model of the desired bone substitute first would be derived from CAT scans or MRI data of the patient. The synthetic bone then would be fabricated, in-vitro, in an advanced CAM bioreactor by depositing layers of biodegradable scaffolding material, while simultaneously embedding donor cells and growth factors within the layers.

Synthetic vasculature also would be embedded within the scaffold as it is being built up, until the new bone was mature enough to be removed from the bioreactor and implanted into the patient. Such a system would also have applicability to other tissues and whole organs.

Current research involves not only laying the foundation for several of the components required for realizing such an advanced system, but also gaining knowledge and developing components that will have clinical relevance in the nearer term. Projects include scaffold materials, solid freeform fabrication scaffolds, synthetic vessels and growth factors.

The Pittsburgh Tissue Engineering Initiative

The mission of the Pittsburgh Tissue Engineering Initiative (PTEI) is to facilitate the recognition of Pittsburgh as an international center of excellence in tissue engineering research and education. The PTEI also fosters economic development by promoting the growth of a regional biotechnology industry rooted in tissue engineering.

The PTEI accomplishes its goals through:

- funding of research with clear potential commercial impact
- playing a leadership role in defining community strategies for regional development
- sponsorship of educational programs for a spectrum of students and professionals
- facilitating access to innovative technology transfer systems
Tissue Engineering in the Pittsburgh Region (cont.)

- promoting collaboration among Pittsburgh’s leading health and academic centers and within the larger field of tissue engineering
- global dissemination of tissue engineering-related information

In 2002, PTEI debuted a new Tissue Engineering Educational Program and Planetarium Show entitled “Tissue Engineering for Life.” The unique educational program focused on tissue engineering and its applications. Curriculum materials for use in classrooms, a K–12 outreach program and Web-based tools were features of the program.

“Tissue Engineering for Life” was funded by a $1.62 million Science Education Partnership Award from the National Institutes of Health—the largest award ever given for information science education. Regional partners involved with the project included:

- Carnegie Science Center
- Carnegie Mellon University’s STUDIO for Creative Inquiry
- Carnegie Mellon’s Center for Light Microscope Imaging and Biotechnology
- UPMC Health System
- University of Pittsburgh’s Bioengineering Department
- Pittsburgh Supercomputing Center

In January 2003, Catalyst Connection assisted the PTEI in obtaining a $300,000 award for the development of a life-science curriculum using the biotechnology program at the Community College of Allegheny County; the undergraduate research programs and biology programming at Duquesne University; the Technology Studies magnet school in the Pittsburgh School District and the professional-development training for middle and high school teachers provided through the PTEI.

Strategic industry partnerships fostered by PTEI aim to position and showcase Pittsburgh as a leader in the fields of regenerative medicine and tissue engineering. Partnerships include affiliation with The Society for Biomaterials, the Wound Healing Society, the
Tissue Engineering in the Pittsburgh Region (cont.)

Society for Regenerative Medicine, the Tissue Engineering Society International and the Tissue Engineering Research Centers in Japan and North America.

Pittsburgh also is home to the Engineering Tissue Growth International Conference & Exposition (ETG), the world’s largest gathering of tissue engineering thought leaders, which attracts scientists from academia and industry, as well as representatives of government, business and economic development organizations. The PTEI organizes the conference annually. This unique tissue engineering event combines a comprehensive scientific program with an exhibition of products, services and technologies. The objectives of the conference are to stimulate the exchange of information and ideas, to foster collaborations for the advancement of the field and to accelerate the pace of scientific discovery so that tissue-engineered products can be more quickly developed to help patients worldwide.

The third annual ETG, which was held in Pittsburgh during the spring of 2003, attracted more than 650 thought leaders from North America, South America, Europe, Asia and the Pacific Rim. Attendees chose from more than 70 scientific sessions in seven focused tracks, and they attended keynote presentations by some of the world’s most preeminent scientists, in addition to several innovative panel presentations and roundtable discussions.

The Industry Cell

More than 75 life sciences firms call southwestern Pennsylvania home. Among these organizations, TissueInformatics, Inc. and Kytaron Technologies are two specializing in tissue engineering.

TissueInformatics provides pathologists and biomedical researchers with fully automated pathology software and services for the rapid, consistent and quantitative assessment of tissue. The company has revolutionized the tissue analysis process by making possible automated quantitative analysis of tissue resulting in new TissueAnalytics software and services. By integrating sophisticated tissue imaging with proprietary tissue analysis software,
Tissue Engineering in the Pittsburgh Region (cont.)

the company is able to arrive at precise mathematical comparison of tissues resulting in greater speed, consistency and accuracy where precise tissue comparison is critical.

Kytaron Technologies is a Pittsburgh-based tissue engineering startup that aims to discover, develop and commercialize proprietary methods for stimulating organ regeneration in patients with potentially life threatening disorders. Using stem-cell-based cellular therapies, Kytaron will assist in the development of new treatments for liver, metabolic, endocrine and other diseases. Its cellular products also may be used for evaluating pre-clinical drug candidates and for use in drug metabolism studies, enzyme induction experiments and toxicology testing. Kytaron is one of five young biotech companies residing in the Pittsburgh Life Sciences Greenhouse incubator space.

The PTEI underscored its commitment to the development of a vibrant tissue engineering sector in southwestern Pennsylvania with the creation of its Senior Management Fund. The goal of the fund is to advance tissue engineering technologies toward clinical utility by financing strategy and business plan development, as well as by recruiting qualified senior management. The PTEI anticipates that investments by the Senior Management Fund will attract experienced leadership and significantly advance recipient companies’ commercial strategies to secure other sources of funding and investment.

Preserving the Human Face of Tissue Engineering

In November 2003, Duquesne University joined with the PTEI to present a symposium entitled Stem Cell Research: Science, Religion & Ethics. The event offered a forum for debate spanning theoretical, scientific, medical, political and ethical considerations resulting from tissue engineering efforts and its outgrowths. The Symposium was opened by Eric Cohen, director of the Biotechnology and American Democracy, Ethics and Public Policy Center.
Efforts like the Stem Cell Research symposium illustrate southwestern Pennsylvania’s acute attention to the underlying human, cultural and philosophical issues necessarily resulting from the application of new technologies and engineering practices to the physiological space. Each of Pittsburgh’s individual institutions is considered to be a world-class center of excellence. Together they form a solid, informed and noble foundation on which to build a global reputation for the region in tissue engineering.

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Manufacturing in the Pittsburgh Region

The manufacturing sector continues to dominate as an economic driver for the 13-county region that represents southwestern Pennsylvania, according to a major study sponsored by the Pennsylvania Industrial Resource Centers (IRCs) and the TEAM PA Foundation.

Described as the most ambitious and comprehensive research ever conducted in the U.S. on any of the states’ manufacturing industries, the study is entitled “Manufacturing Pennsylvania’s Future: Regional Strategies that Build from Current Strengths and Competitive Challenges.” It was commissioned in the fall of 2003 by Pennsylvania’s IRC network, and it was conducted by Deloitte, an international consulting firm.

This analysis evaluated manufacturing sectors and regions according to comprehensive criteria that measured manufacturer output totals, output growth and employment rates over a 10-year period, in addition to a special wealth creation index that factored average output per employee, average real wages, capital expenditures and shareholder value.

The purpose of the study was to document the role of manufacturing in several regions of the state and to analyze the forces shaping the future of the sector. According to the Deloitte report, manufacturing remains the number one industry sector in southwestern Pennsylvania, accounting for more than $11 billion in annual output, which represents 12.8 percent of the region’s total output of all industries. That same $11 billion represented 17.3 percent of all the commonwealth’s manufacturing output.

Manufacturing also is the fourth largest sector for employment in the region, employing 128,545 people in 2003.
### Key Industries in Southwestern Pennsylvania

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<tbody>
<tr>
<td><strong>Manufacturing</strong></td>
<td>128,545</td>
<td>$11,444</td>
<td>-3.0%</td>
<td>-0.3%</td>
<td>2.0%</td>
<td>12.8%</td>
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<tr>
<td>Real Estate and Rental Leasing</td>
<td>16,400</td>
<td>$8,942</td>
<td>5.9%</td>
<td>2.9%</td>
<td>2.5%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Finance and Insurance</td>
<td>61,178</td>
<td>$7,745</td>
<td>4.2%</td>
<td>3.9%</td>
<td>3.5%</td>
<td>8.7%</td>
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<tr>
<td>Retail Trade</td>
<td>159,301</td>
<td>$7,709</td>
<td>2.6%</td>
<td>2.6%</td>
<td>3.5%</td>
<td>8.6%</td>
</tr>
<tr>
<td>Public Administration</td>
<td>174,368</td>
<td>$7,686</td>
<td>2.0%</td>
<td>1.0%</td>
<td>0.9%</td>
<td>8.6%</td>
</tr>
<tr>
<td>Health Care and Social Assistance</td>
<td>187,774</td>
<td>$6,957</td>
<td>1.6%</td>
<td>0.9%</td>
<td>0.0%</td>
<td>7.8%</td>
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<tr>
<td>Wholesale Trade</td>
<td>51,762</td>
<td>$5,588</td>
<td>5.3%</td>
<td>3.5%</td>
<td>4.0%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Professional, Scientific and Technical Services</td>
<td>67,666</td>
<td>$4,909</td>
<td>-1.3%</td>
<td>0.6%</td>
<td>0.6%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Construction</td>
<td>66,211</td>
<td>$4,444</td>
<td>-0.2%</td>
<td>1.3%</td>
<td>1.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Administrative and Other Support Services</td>
<td>63,114</td>
<td>$3,843</td>
<td>4.1%</td>
<td>2.6%</td>
<td>1.6%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Transportation and Warehousing</td>
<td>49,072</td>
<td>$3,505</td>
<td>5.2%</td>
<td>3.1%</td>
<td>4.5%</td>
<td>3.9%</td>
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<tr>
<td>Information</td>
<td>29,658</td>
<td>$3,147</td>
<td>1.3%</td>
<td>4.0%</td>
<td>3.6%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Other Services (except Public Administration)</td>
<td>83,544</td>
<td>$3,006</td>
<td>4.4%</td>
<td>2.2%</td>
<td>1.8%</td>
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<tr>
<td>Accomodations and Food Services</td>
<td>98,799</td>
<td>$2,818</td>
<td>5.6%</td>
<td>3.7%</td>
<td>3.7%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Utilities</td>
<td>9,263</td>
<td>$2,339</td>
<td>-4.5%</td>
<td>-0.6%</td>
<td>-1.0%</td>
<td>2.6%</td>
</tr>
<tr>
<td>Mining</td>
<td>10,174</td>
<td>$1,786</td>
<td>3.0%</td>
<td>2.3%</td>
<td>8.1%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Educational Services</td>
<td>53,255</td>
<td>$1,305</td>
<td>0.2%</td>
<td>-0.9%</td>
<td>0.7%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Management of Companies and Enterprises</td>
<td>16,260</td>
<td>$1,091</td>
<td>-10.7%</td>
<td>-5.6%</td>
<td>-3.1%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Agriculture, Forestry, Fishing and Hunting</td>
<td>4,358</td>
<td>$590</td>
<td>14.0%</td>
<td>13.8</td>
<td>5.8%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Arts, Entertainment and Recreation</td>
<td>18,453</td>
<td>$572</td>
<td>1.2%</td>
<td>0.2%</td>
<td>1.1%</td>
<td>0.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,349,155</strong></td>
<td><strong>$89,426</strong></td>
<td><strong>1.8%</strong></td>
<td><strong>1.8%</strong></td>
<td><strong>2.0%</strong></td>
<td></td>
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*CAGR = Compound Annual Growth Rate*
Manufacturing in the Pittsburgh Region (cont.)

Over the past 10 years, the region’s manufacturing sector has grown two percent, which was average for all industries within the region. However the challenges inherent in the past recession affected the sector more than other industries. Manufacturing’s output growth rate over the past three years was negative three percent, well below the region’s average of 1.8 percent.

Southwestern Pennsylvania’s Driver Industries

According to the study, which examined the state as a whole, as well as each of the seven IRC regions, the southwestern region is home to eight of the state’s 16 “driver industries” that are responsible for producing nearly 50 percent of the state’s manufacturing output.

Southwestern Pennsylvania’s eight driver industries and two emerging drivers are illustrated in the following chart.

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<tbody>
<tr>
<td>Electrical Equipment</td>
<td>$757</td>
<td>5.9%</td>
<td>6.9%</td>
<td>9.1%</td>
<td>2.76</td>
<td>62</td>
</tr>
<tr>
<td>Metalworking Machinery</td>
<td>$616</td>
<td>1.2%</td>
<td>-0.2%</td>
<td>8.4%</td>
<td>1.99</td>
<td>140</td>
</tr>
<tr>
<td>Resins, Rubber and Synthetic Fibers</td>
<td>$500</td>
<td>-5.1%</td>
<td>-0.5%</td>
<td>2.2%</td>
<td>3.24</td>
<td>17</td>
</tr>
<tr>
<td>Plastics</td>
<td>$477</td>
<td>2.6%</td>
<td>2.6%</td>
<td>4.2%</td>
<td>1.66</td>
<td>130</td>
</tr>
<tr>
<td>Architectural and Structural Metals</td>
<td>$437</td>
<td>0.2%</td>
<td>1.6%</td>
<td>3.4%</td>
<td>2.29</td>
<td>276</td>
</tr>
<tr>
<td>Glass</td>
<td>$386</td>
<td>-6.6%</td>
<td>-4.7%</td>
<td>-0.4%</td>
<td>6.34</td>
<td>54</td>
</tr>
<tr>
<td>Other Electrical Equipment and Components</td>
<td>$324</td>
<td>16.3%</td>
<td>14.5%</td>
<td>13.0%</td>
<td>1.13</td>
<td>48</td>
</tr>
<tr>
<td>Electric Lighting Equipment</td>
<td>$211</td>
<td>11.4%</td>
<td>10.9%</td>
<td>13.2%</td>
<td>1.20</td>
<td>17</td>
</tr>
</tbody>
</table>

Emerging Driver Industries

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Equipment</td>
<td>$229</td>
<td>12.1%</td>
<td>9.0%</td>
<td>3.5%</td>
<td>2.32</td>
<td>66</td>
</tr>
<tr>
<td>Soap and Cleaning Compounds</td>
<td>$213</td>
<td>4.0%</td>
<td>7.0%</td>
<td>8.3%</td>
<td>1.14</td>
<td>30</td>
</tr>
</tbody>
</table>

*CAGR = Compound Annual Growth Rate
Manufacturing in the Pittsburgh Region (cont.)

Industry sectors identified in the report as emerging economic drivers for southwestern Pennsylvania were medical equipment, with an output of $229 million in 2003, and soap and cleaning compounds, with an output of $213 million in 2003.

Since 2000, the region’s fastest growing sectors were: other electrical equipment and components (16.3 percent annually); medical equipment (12.1 percent annually) and electrical lighting equipment (11.4 percent annually).

According to the report, sectors that suffered declines or near-zero growth during the same period were: glass (-6.6 percent annually); resin, rubber and synthetic fibers (-5.1 percent annually) and architectural and structural metals (0.2 percent annually).

Taken in aggregate, wages for the region’s manufacturing industry are above average in comparison with other industries.

### Average Wages by Industry in Southwestern Pennsylvania

<table>
<thead>
<tr>
<th>Industry</th>
<th>Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accomodation and Food Services</td>
<td>$14,144</td>
</tr>
<tr>
<td>Other Services (except Public Administration)</td>
<td>$19,123</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>$23,776</td>
</tr>
<tr>
<td>Arts, Entertainment and Recreation</td>
<td>$26,000</td>
</tr>
<tr>
<td>Educational Services</td>
<td>$27,023</td>
</tr>
<tr>
<td>Agriculture, Forestry, Fishing and Hunting</td>
<td>$28,708</td>
</tr>
<tr>
<td>Health Care and Social Assistance</td>
<td>$32,162</td>
</tr>
<tr>
<td>Real Estate and Rental and Leasing</td>
<td>$32,951</td>
</tr>
<tr>
<td>Transportation and Warehousing</td>
<td>$33,957</td>
</tr>
<tr>
<td>Public Administration</td>
<td>$36,301</td>
</tr>
<tr>
<td>Administrative and Other Support Services</td>
<td>$39,504</td>
</tr>
<tr>
<td>Construction</td>
<td>$42,451</td>
</tr>
<tr>
<td>Management of Companies and Enterprises</td>
<td>$42,680</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td><strong>$46,551</strong></td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>$47,442</td>
</tr>
<tr>
<td>Information</td>
<td>$48,091</td>
</tr>
<tr>
<td>Mining</td>
<td>$51,976</td>
</tr>
<tr>
<td>Professional, Scientific and Technical Services</td>
<td>$52,219</td>
</tr>
<tr>
<td>Finance and Insurance</td>
<td>$56,108</td>
</tr>
<tr>
<td>Utilities</td>
<td>$67,365</td>
</tr>
</tbody>
</table>
Manufacturing in the Pittsburgh Region (cont.)

Highlights:

- Southwestern Pennsylvania’s manufacturing wages are above average relative to other industries. The average manufacturing wage in 2003 in the region was $46,551 per year, which is slightly higher than the average for all manufacturing in Pennsylvania ($44,994).

- The region is strong in several moderately technology-intensive industries, most notably resins and other synthetic materials, electrical equipment and medical equipment.

- Average productivity per employee in manufacturing throughout the region is $89,028, slightly higher than the Pennsylvania average of $86,814, but lower than the U.S. average of $96,549.

- The overall average annual productivity growth rate for the region is 3.1 percent; leading industries in terms of productivity are electrical equipment, electrical lighting equipment and resin.


The increases in productivity in the region’s manufacturing sector may be partially explained by the decreases in employment (-7.5 percent). Manufacturers are being forced to adopt practices and techniques that provide the same volume and quality of products with fewer people.

The Deloitte study also attributes the decrease in employment over several years to the recent recession, the trend toward off-shore outsourcing and foreign competition, particularly with respect to low-cost commodity products.
Manufacturing in the Pittsburgh Region (cont.)

The following charts show trends within the region’s manufacturing sector and compare the two most recent years for which complete data was available.

### Total Manufacturing Cluster

#### 13 Counties

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>4,065</td>
<td>147,794</td>
<td>$6,011,282,798</td>
<td>$40,673</td>
</tr>
<tr>
<td>2002</td>
<td>3,792</td>
<td>136,634</td>
<td>$5,691,149,782</td>
<td>$41,653</td>
</tr>
</tbody>
</table>

% change 2001–2002: -6.7  -7.5  -5.3  +2.4

#### Six-County MSA

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Employment</th>
<th>Total Annual Payroll</th>
<th>Average Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>3,284</td>
<td>121,073</td>
<td>$5,219,560,656</td>
<td>$43,111</td>
</tr>
<tr>
<td>2002</td>
<td>3,057</td>
<td>111,899</td>
<td>$4,924,052,721</td>
<td>$44,005</td>
</tr>
</tbody>
</table>

% change 2001–2002: -6.9  -7.5  -5.6  +2.0
Electro-Optics in the Pittsburgh Region

A technical definition of electro-optics describes a technology associated with components, devices and systems designed to interact between the electromagnetic and visible light spectrum and the electronic state. It states that electro-optics uses applied electrical fields to generate and control optical radiation.

In the simplest sense, electro-optics is a technology based around the conversion of electricity into light and light into electricity. Human sight is perhaps the closest model for the conceptual processes involved in electro-optics.

Two primary categories of electro-optics exist: outside-in mechanisms, which include imaging and sighting devices, and inside-out mechanisms, which typically involve lasers and laser applications. As a broader term, electro-optics also is used to encompass laser, optics, fiber-optics and photonics technologies.

Typical electro-optic devices include concave and convex mirrors, convergent and divergent lenses, prisms, beam-splitters, optical filters, resonators and lasers. Components include semiconductor diodes, light-emitting diodes (LEDs), photodetectors, liquid crystal optics and multiplexers. Emerging fields within this cluster include fiber optic communications, which make up 40 percent of the total market, imaging acquisition products and optical disk storage.

The worldwide market for this industry cluster was estimated at $73 billion in 2000. The core of this cluster, with the exception of photonics and optics firms, contains 425 businesses nationwide with sales of more than $3 billion. The U.S. military historically has invested in and benefited the most from electro-optic research and development, and although the technology steadily has become more commercial, the federal government remains at the forefront of the industry.

The Army has used electro-optics for air defense systems, ground-based deep space surveillance equipment, night vision devices and a host of other optical tools. Powerful,
small weapons-grade electro-optic lasers are applied in military missile defense. For example, war fighter use of electro-optic uncooled sensors and flash ladar will improve weapons systems size, weight, power, costs and sensitivity. Flash ladar creates high-resolution three-dimensional images that enable robust target detection and identification with minimum collateral damage. Increasingly, our nation’s defense depends on electro-optical components because of the distinct advantages they afford.

But the larger field of electro-optics has been growing over the past 20 years. Light-emitting diodes used in video display screens are a recognizable application of electro-optics in the general public space. Other devices incorporating electro-optics include metalworking tools, surgery and medical devices, telecommunications equipment, night vision surveillance, art restoration and traffic lights. With LED technology, traffic bulbs will last 30 years and cost only 85 cents a month to operate, compared with five years and $6.00 a month for conventional bulbs.

According to a National Research Council report, large companies do not dominate the industry. Certainly Kodak, AT&T, IBM and other large corporations are very involved in the electro-optics industry, but it is small entrepreneurial companies that comprise the bulk of the cluster.

**The Electro-Optics Center**

Armstrong County in southwestern Pennsylvania is home to the Electro-Optics Center (EOC), the focal point for many of the nation’s cutting-edge research initiatives, including products for the Department of Defense (DoD) and U.S. industry. As such, it has the potential to become a formidable national and international resource.

Formally established in 1999 as the U.S. Navy’s Center of Excellence in Electro-Optics Manufacturing, the Kittanning-based Center is charged with ensuring excellence and world leadership in the emerging industry of electro-optics. The Electro-Optics Center
Electro-Optics in the Pittsburgh Region (cont.)

originally was established and managed by The Pennsylvania State University’s Applied Research Laboratory (Penn State ARL) under an Office of Naval Research Manufacturing Technology (ManTech) initiative.

The Center’s vision is to become a manufacturing technology enabler. To realize this vision, EOC serves the needs of the Navy, the DoD and private industry through the development and execution of technical programs, workforce development activities and technology transfer efforts.

The four key services of the Electro-Optics Center include:

Technical Project Development and Management, which includes assistance in the development of technical solutions for industry electro-optics manufacturing issues and requirements.

Manufacturing Technology Transfer and Deployment, which develops resources and expertise that enable the transition from prototype demonstrations to production capability, resulting in the creation of new businesses or enhanced product lines.

Workforce Development and Education, which encompasses programs that provide skill-based training and academic courses in basic and advanced electro-optics manufacturing technologies. This service also operates a teaching and demonstration facility, and it conducts various outreach activities to heighten electro-optics awareness and opportunities.

Electro-Optics Technical Resources, which involve technical oversight and consulting, proposal evaluation, program management, prototype production demonstrations and acceptance tests.

Electro-Optics Center research projects generally have targeted laser technology and fiber optics. But each year, EOC expands the number of research and development projects it coordinates and in which it directly participates.
Electro-Optics in the Pittsburgh Region (cont.)

In 2002, $64.7 million was appropriated by the defense industry for EOC-coordinated efforts. Funding was used for R&D projects that included, but were not limited to:

- advanced multiband optical surveillance system ($4 million)
- advanced silicon carbide crystal device technology ($6 million)
- Avenger upgrade of the first generation of FLIR Systems’ infrared detection components ($3.4 million)
- dual band detector imaging technology for Army ($2.6 million) and for the U.S. Special Operations Command computer system ($4.3 million)
- high-energy laser/missile for ship self-defense ($6 million)
- imaging system upgrade development ($6 million)
- infrared space sensors ($3 million)
- aircraft missile warning sensors ($2.1 million)

Funding for general EOC operations in 2002 was $1.8 million, while $200,000 was provided for electro-optics workforce development initiatives.

Electro-Optics Alliance

The Electro-Optics Center is home to the Electro-Optics Alliance (EOA), with a roster of more than 240 member organizations spanning industry, university and government organizations. Some significant names include Honeywell, ITT Industries, Lockheed Martin, Northrop Grumman, Raytheon, Rockwell, Tyco and others.

The Alliance creates essential electro-optics infrastructure by promoting strategic partnerships among its members and by disseminating R&D findings to expand the electro-optics knowledge base and the commercialization of electro-optics technology. The Alliance also assists companies in obtaining ManTech funding and implementing technology developed under such programs.
Electro-Optics in the Pittsburgh Region (cont.)

Educational Outreach

Penn State ARL has demonstrated innovation and practicality in technology-based research through its involvement with the EOC. Penn State ARL is one of just four other U.S. Navy academic research centers in the country. While the lab itself has served as a center of excellence in undersea technology, it also has facilitated Penn State in becoming second among U.S. universities in industrial R&D funding.

Penn State also ranks 26th nationwide in National Science Foundation R&D awards for electro-optics research. Penn State offers a graduate degree in electro-optics with specializations in non-destructive inspection, high-precision surface metrology and vibration and ultrasonic-guided wave monitoring.

<table>
<thead>
<tr>
<th>University</th>
<th>Awards</th>
<th>Amount</th>
<th>National Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penn State University</td>
<td>12</td>
<td>$2,656,895</td>
<td>26</td>
</tr>
<tr>
<td>University of Pittsburgh</td>
<td>4</td>
<td>$1,153,086</td>
<td>49</td>
</tr>
<tr>
<td>Carnegie Mellon University</td>
<td>3</td>
<td>$415,294</td>
<td>92</td>
</tr>
</tbody>
</table>

Carnegie Mellon offers optics specialization in its electrical and computer engineering disciplines that focus on military target identification, Raman imaging and spectroscopy for environmental monitoring and polymer materials characterization for recycling.
Electro-Optics in the Pittsburgh Region (cont.)

The University of Pittsburgh's department of electrical engineering is the focal point for many electro-optics efforts within Pittsburgh. The department’s areas of research and development include:

- optically based computing using reconfigurable processors and optical cache memory system-level modeling for free-space interconnects and optical micro-electro-mechanical systems (MEMS)
- erbium-doped waveguide optical amplifiers
- zero insertion-loss beam splitters
- optoelectronic packaging technologies for high-speed optical communication
- integrated-optic ultraviolet detectors, based on wide band gap semiconductors

Indiana University of Pennsylvania (IUP) also forged a recent partnership with the EOC to further a new career-training program in electro-optics. To maximize its educational opportunities, IUP’s educational facilities for electro-optics will be housed in close proximity to the EOC at the Northpointe Technology Center in Armstrong County. Synergy with the EOC is expected to create unique student opportunities for advanced education and workforce training focused on emerging electro-optics technology.

Additional EOC partnerships exist with Lenape Vocational-Technical School and area secondary and post-secondary schools.

Private Sector

Numerous electro-optics companies are located in Armstrong County making it a prime location for future technology-cluster build-out. A short sampling of efforts at some of the prominent businesses illustrates the range of electro-optics activities already underway in southwestern Pennsylvania.

**II-VI** (pronounced Two-Six) is a public company that manufactures optics equipment for military and medical use. In June 2001, II-VI acquired a competitor, San
Diego-based Laser Power Corp., which boosted II-VI's revenue by 66 percent. The acquisition also pushed the company's military sales from 10 percent to 25 percent of its total revenues.

**Armstrong Laser Technology** develops laser equipment for defense contractors.

**Brashear, LP** provides optical systems and instrumentation to defense and scientific customers, domestically and internationally. Brashear was awarded a five-year, $8.1 million contract from Raytheon to manufacture 35 electro-optic systems for the Navy's Phalanx Weapon System, a computerized laser and gun. The contract could extend to another 300 similar systems.

**Raytheon** is another regional producer of electro-optical systems. Raytheon produces focal plane detector arrays, which enable both high-performance military sensors and low-cost sensors for commercial applications.

**Optical Systems Technology** designs, manufactures and integrates high-performance, image-intensified, night vision products, stabilized gimbaled optical platforms, large optical assemblies and fiber-optic illumination engines. Its products are marketed under the STAR*TRON brand name associated with the largest and fastest night vision catadioptric lenses in continuous production for over 30 years.

The region also has key companies that either use electro-optic technology in their products or have compatible products. They include Draeger Safety, Mine Safety Appliances, ChemImage, Bridge Semiconductor and Westinghouse Electro-Mechanical Division, among others.
Regional Growth Efforts

The Electro-Optics Initiative is a program developed to combine the efforts of industry, education, community and government to make opportunities available for electro-optics companies to locate within Armstrong County.

In 2003, four new companies announced plans to locate in Armstrong County: Sabeus Sensor Systems, DRS Technologies, RAPT Industries, Inc. and ANALUX. Such development plans are positive indicators of electro-optic clustering in the region and help to further establish and expand wider incentives for future growth.

Sabeus Sensor Systems, a division of California-based Sabeus Photonics, manufactures fiber optic sensors. In 2003, Sabeus began development work on a new sensor in its Freeport facility.

The company expects to create up to 100 new jobs over the next two years.

DRS Technologies Inc. chose to open space in Armstrong County to focus on upgrading infrared technology used by the United States Armed Forces. The company has been awarded a contract to manufacture pre-production hardware for the Avenger and the AN/TAS-4 systems that will provide low-cost imaging technology upgrades. The company’s electro-optical systems group provides electro-optical sensors technology, components and systems for both the domestic and international military markets.

RAPT Industries specializes in a patented process called reactive atom plasma used for polishing and shaping optical, ceramic and semiconductor components. The RAPT system provides for non-contact work and can remove subsurface damage due to traditional polishing and grinding.

Finally, ANALUX, a Pittsburgh enterprise, expanded its facilities to foster new cooperative work in electro-optics. ANALUX makes hyper spectral cameras capable of seeing through
such inclement conditions as smoke, dense fog and heavily wooded areas. ANALUX, too, anticipates filling 50 to 100 jobs in its new facility.

As an industry, electro-optics requires access to precision machinists, casting makers, computer engineers and other specialized talent to help develop it further.

Armstrong County is equipped to serve these needs as home to more than 30 precision manufacturers. Some companies, such as Spark Technologies, specialize in the manufacture of custom components for electro-optics. Workforce development programs at the EOC also aggressively have striven to fill the talent pool.

Northpointe

The presence of the Electro-Optics Center has generated business growth throughout Armstrong County. To better serve and foster this growth, Armstrong County developed a state-of-the-art business and technology park at Northpointe. The park serves as a site for expanded partnerships between academic, industrial and government organizations in electro-optics and other areas.

Due to its own technical growth and workforce development advances, the Electro-Optics Center itself announced plans to relocate to Northpointe. The expanded facilities of the EOC are slated to open in August 2004.

ARMTech

Each year, the EOC joins forces with the Armstrong County Regional Manufacturing Initiative to host the ARMTech Showcase, a national trade show that draws national defense and aerospace contractors, medical researchers, regional electro-optics companies and advanced manufacturers.

In 2003, more than 60 exhibitors featuring nearly 80 interactive exhibits participated in ARMTech. Local, regional and national industry representation in advanced manufacturing,
Electro-Optics in the Pittsburgh Region (cont.)

medical research and defense-related industries participated. The Public Showcase displayed thermal imaging video cameras, combat helmets with night vision capabilities and body armor protection systems.

The Department of Defense has played and will continue to play an important role in the development and funding of the region’s electro-optics industry cluster. Many items the DoD uses are fairly easy to purchase commercially, however with optical equipment, there usually are sophisticated modifications required for military use.

Most recently, U.S. Representative John Murtha secured a $25 million contract for the Center to perform pioneering research on ways to improve Navy aircraft.

With military applications as a source of contracts and funding, the region’s electro-optics industry represents a promising emerging cluster. The penetration of electro-optics devices into the medical and industrial markets also will continue to add to the cluster’s growth.


The Applied Research Laboratory at The Pennsylvania State University at http://www.arl.psu.edu/capabilities.html
Robots are everywhere. The industrial, medical, and service sectors are all seeing a surge in the use of robotics. Robotics in the Pittsburgh Region

Japan is the world leader in industrial robotics, with approximately 50 percent of the world market. By 2004, the U.S. market share is projected to decrease to nine percent.

In a study conducted for the Defense Advanced Research Projects Agency (DARPA), a group of robotics experts predicted that 2006 will be the first year for successful commercialization of mobile robots, and that by 2005, revenues in this industry will reach $5.4 billion. The DARPA survey also predicted that by 2036, mobile robots will comprise a significant portion of the United States’ economy.

By the same token, the sales volume for medical robots is expected to reach $2.08 billion by 2010, and it could capture 10 percent of the minimally invasive surgery market by 2007. The International Federation of Robotics estimates that there currently are 1,600 medical robots in use around the globe and that an additional 4,800 units will be installed by 2004.

In the meantime, other robotics applications continue to span the gamut with a higher concentration of uses in industrial, commercial and defense applications. A significant number of applications address the “three Ds”—work that is dirty, dangerous or dull for humans.

While Pittsburgh has been somewhat slow to develop a large industry base in any single robotics field, the region has had and continues to foster a defining presence in the larger North American robotics community.

But Pittsburgh’s robotics development situation is not uncommon. Most North American activity in non-industrial and service robotics takes place around universities with substantial research programs, such as the University of California at Berkeley, MIT and Carnegie Mellon University. One reason for this trend is that research universities are simply better equipped than young start-ups to fund research and development programs.
As the demand for non-industrial robots increases, Pittsburgh will be in a bright position to develop its industry base, due to unparalleled research resources.

Research Assets

Now entering its 25th year, the Robotics Institute at Carnegie Mellon University has made Pittsburgh a worldwide leader in robotics research.

Established in 1979 to conduct basic and applied research in robotics technologies relevant to industrial and human service tasks, Carnegie Mellon’s Robotics Institute aims to realize the potential of the robotics field. Seeking to combine the practical and the theoretical, the Robotics Institute undertakes diversified efforts and approaches to robotics science to achieve its mission.

The Robotics Institute also is the largest research facility of its kind in the United States. The umbrella organization features five distinct robotics-related sub-centers:

The Medical Robotics and Information Technology Center, also known as the MERIT Center, is a program aimed at fostering collaborations between Carnegie Mellon researchers and clinicians in the region’s health care community.

The Field Robotics Center focuses on the use of mobile robots in field environments, such as work sites and natural terrain, where the robots must safeguard themselves while performing non-repetitive tasks and objective sensing, as well as self-navigation in random or dynamic environments.

The Vision & Autonomous Systems Center is a large research group working in the areas of computer vision, autonomous navigation, virtual reality, intelligent manipulation, space robotics and related fields.
Robotics in the Pittsburgh Region (cont.)

The Center for Integrated Manufacturing Decision Systems is a loosely related group of eight laboratories performing research in manufacturing, scheduling, stereo displays, inspection robotics, sensor-based process control and information visualization.

The National Robotics Engineering Consortium (NREC) is an entity dedicated to the development of products incorporating advanced mobile robotics technologies. The NREC currently is developing robotic vehicles for the mining, earth moving, agricultural and industrial materials handling industries. The National Aeronautics and Space Administration (NASA) also is a partner in NREC research.

A part of Carnegie Mellon’s School of Computer Science, CMU’s Robotics Institute is the only institution in the country offering M.S. and Ph.D. programs, as well as an undergraduate minor in robotics. Stanford, MIT and Berkeley offer competitive robotics education programs, but they do not offer formal degrees.

Technology transfer is enabled through industry-research partnerships at the Robotics Institute. Affiliate companies participate by sponsoring specific research projects. In return, they receive research results prior to public release; access to highly trained research personnel; information on promising robotics talent and graduate students and access to the Institute’s vast library, archives, global affiliations and other additional resources and activities.

Pennsylvania was ranked third in the country in both number of awards and total National Science Foundation (NSF) funding for robotics research between 1989 and 2001.

Since 1989, the Pittsburgh region has received more than 40 grants, 35 of which were sponsored by Carnegie Mellon, accounting for nine percent of all robotics research funding awarded by the NSF between 1989 and 2001. This funding was more than any other institution.
During the 2002 fiscal year, total research volume for Carnegie Mellon’s Robotics Institute alone was $33.5 million. Funds were obtained from a variety of sources including DARPA, NASA, the NSF, private industry and other federal and non-federal sources.

**Robotics Talent**

The Robotics Institute currently employs more than 350 faculty, staff, visitors and students; almost half of these positions (123) are research staff positions.

### 2002 Employment at the Robotics Institute and Its Affiliated Centers

<table>
<thead>
<tr>
<th>Institution</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Robotics Institute</td>
<td>300</td>
</tr>
<tr>
<td>Medical Robotics and Information Technology Center</td>
<td>34</td>
</tr>
<tr>
<td>Field Robotics Center</td>
<td>31</td>
</tr>
<tr>
<td>The Vision and Autonomous Systems Center</td>
<td>100</td>
</tr>
<tr>
<td>The Center for Integrated Manufacturing Decision Systems</td>
<td>26</td>
</tr>
<tr>
<td>The National Robotics Engineering Consortium</td>
<td>27</td>
</tr>
</tbody>
</table>

A considerable robotics talent base could be built on the established reputation of regional robotics researchers. The U.S. Patent and Trademark Office awarded 1,917 patents for robotics-related technologies between January 1, 1996 and June 4, 2002. Of these patents, 26 were attributed to residents of Pittsburgh. Of Pittsburgh’s 26 patents, employees of Carnegie Mellon received 13. Nine patents were assigned to universities and companies in Pittsburgh, four of which were assigned to Carnegie Mellon.
Regional Industry Base

Research, talent and technology resources alone do not create a successful industry cluster. In the year 2003, Pittsburgh made significant efforts to translate its historic robotics research expertise into a working and thriving industry base.

The Robotics Foundry is a Pittsburgh-based, independent, non-profit economic development organization that directs programs and initiatives intended to accelerate the growth of agile robotics technologies and to establish a $1 billion industry cluster in the newly designated “RoboCorridor,” encompassing southwestern Pennsylvania.

The RoboCorridor, anchored by CMU’s Robotics Institute, encompasses a wide range of robotics-related organizations and initiatives, including the University of Pittsburgh School of Engineering and Swanson Center, the Software Engineering Institute and TIDE center in Pittsburgh, The Electro-Optics Center in Kittanning, the newly formed National Center for Defense Manufacturing and Machining in Latrobe, various defense-related engineering and manufacturing organizations based in Johnstown, and the Applied Research Laboratory at The Pennsylvania State University in State College.

The Robotics Foundry is the result of a merger between two previously independent economic development organizations focused on robotics, the Pittsburgh Robotics Initiative and the National Center for Defense Robotics (NCDR).

The Foundry’s mission is being implemented through three sets of activities: business development, technology transition and industry partnerships.

To date, funding for the Robotics Foundry includes $500,000 from regional foundations, a $1.6 million commitment from the Commonwealth of Pennsylvania and $1.5 million from the 2003 defense budget to fund initial NCDR-directed projects. The Foundry also has submitted $24 million in 2004 federal appropriation requests.
Currently the organization has a membership of 35 companies, the majority of them based in southwestern Pennsylvania. The Pittsburgh Technology Council has a current membership of about 14 businesses with a primary focus in robotics; however more than 60 companies extend the field into the wider arena of enabling technologies and automation, such as electro-optics. (See “Electro-Optics in the Pittsburgh Region” related article.)

At least two world leaders of robotic engineering are based in southwestern Pennsylvania—RedZone Robotics and McKessonHBOC Automated Healthcare.

RedZone Robotics is the world leader in robots and mobile equipment that work where people cannot. The company focus is on the construction and field service automation industry by developing innovative products that reduce costs, simplify operations, increase work quality and provide a safe work environment for customers. RedZone’s robots are especially designed to clean, inspect and rehabilitate pipes, tanks, nuclear facilities and other hazardous or hard-to-reach environments.

McKesson designs and manufactures hospital drug distribution systems that automate the storage, retrieval, dispensing, restocking and crediting of unit dose, bar-coded inpatient medications. The company’s products reduce medication errors, increase cost savings and improve the quality of care.

Other successful robotics and automation companies headquartered in the region include Aethon, a developer of personal robots for both home and office; AssistWare, a designer of robotic devices with consumer applications, such as one that prevents drowsy drivers from leaving the road; CASurgica, which develops computer-assisted technologies to enable more accurate and less invasive surgery; and Pittsburgh Roboscope, a developer of surgical robotics for abdominal, neuro- and orthopedic surgery.

National robotics companies with a presence in southwestern Pennsylvania include Fanuc, a global company with 175 different models of manufacturing robots; Cegelec
Corporation, a $2 billion contracting and industrial automation company that employs more than 26,000; and American Robot Corporation, a manufacturer of industrial robots and motion controllers serving the automotive, aerospace, defense and general manufacturing industries.

**Front Lines of Defense**

Recent regional robotics efforts support the development of a core expertise in robotics for the defense industry.

The Defense Department’s Future Combat Systems (FCS) program was formed to develop network-centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat. The FCS aims to develop an ensemble of manned and unmanned ground and air platforms by 2010. This “robotic army” would be enhanced with artificial intelligence, affording the U.S. military more lethal and tactical capabilities, while removing human troops from the line of fire.

The FCS project is divided into three phases, the first of which, concept and technology development, received $154 million in funding and was led by Boeing’s defense unit.

The program currently is in its $14.9 billion system development and demonstration phase.

Carnegie Mellon has had representation on FCS projects, and estimated spending on future phases in which local enterprises are well positioned to take part, is projected at $34 billion.

In 2002, the Pittsburgh Regional Alliance and Carnegie Mellon formed the NCDR to support entry into FCS and other defense-related projects. Located in Lawrenceville, the NCDR obtained start-up funding from state, local and federal governments, as well as from foundations, private sources and FCS funds.
Robotics in the Pittsburgh Region (cont.)

As a facilitator bringing together the manufacturing expertise of local companies and the research experience of Carnegie Mellon, the NCDR (now merged with the Robotics Foundry) began the task of establishing the region as a center for research, development and production of mobile robotics and related artificial intelligence technologies. Its efforts were focused on encouraging major defense contractors to build development and engineering centers in the region.

The Regional Industrial Development Corporation of southwestern Pennsylvania also recently has acquired a 25-building industrial site in Lawrenceville and plans to develop a $13 million facility where small, start-up robotic companies can develop and manufacture their products. These proposed facilities are located in very close proximity to the NCDR.

Evolution

Collaborative efforts are already beginning to pay off. In August, Wexford-based Applied Perception landed a $750,000 federal grant to continue work on a robot that can retrieve injured soldiers from the battlefield. Applied Perception is creating the hardware and software and sensors for navigation and patient detection.

Likewise, Carnegie Mellon’s Intelligent Software Agents Group has been working with DARPA on a $5 million, five-year project to develop different aspects of multi-agent systems, such as scalability, robustness, service discovery and semantic interoperation. In the process they have devised a mock evacuation plan of the U.S. embassy in Kuwait in which software agents monitor intelligence reports related to the crisis and design a route map to the airport, thereby avoiding rebel roadblocks.

Public educational efforts for robotics have not been overlooked by the region, either. The Carnegie Science Center has developed a traveling robotics exhibit that brings Pittsburgh’s rich robotics tradition to others across the county. A state-of-the-art Robotics
Robotics in the Pittsburgh Region (cont.)

Hall of Fame also has been proposed for development in the City of Pittsburgh to further general robotics awareness.

In November 2003, an inaugural online prototype of the Robot Hall of Fame went live.

The successful evolution of an industry from emerging to thriving requires a considerable amount of collaboration between the public and private sectors. The organizations and centers previously discussed aim to lead the way in these type of collaborations, by uniting the regional robotics community for the realization of this emerging cluster’s potential.

Visit: Carnegie Mellon University’s Robotics Institute at http://www.ri.cmu.edu

www.robothalloffame.org

www.roboticsfoundry.org
Nanotechnology and MEMS in the Pittsburgh Region

The emerging fields of nanoscale science, engineering and technology afford the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions – essentially providing unforeseen powers to understand and control the basic building blocks and properties of all natural and man-made things.

Nanotechnology, sometimes called molecular manufacturing, is a branch of engineering that deals with the design and manufacture of extremely small electronic circuits and mechanical devices built at the molecular level of matter.

Dimensions and tolerances in the range of one-tenth nanometer to 100 nanometers play a critical role. To illustrate this scale, one nanometer is one billionth of a meter and several atoms across.

The number of components that can be fabricated on a semiconductor wafer or chip has traditionally been limited. Nanotechnology provides the theory to build chips up, one atom at a time, to obtain devices much smaller than those that can be manufactured using traditional etching methods.

The results of nanotechnology offer a maximized use of space; every particle would have a purpose.

Essentially every atom can be designed to fit into the right place in nanotechnology, which means engineers can design almost any structure consistent with the laws of physics specifiable in molecular detail. Manufacturing costs are greatly reduced in nanotechnological devices, because fabrication does not exceed the cost of the required raw materials and energy.

The greatest applications of nanotechnology are expected to drive ever-more-powerful computers and communications devices. This will be essential if we are to continue the revolution in computer hardware beyond the next decade. Nanotech devices enable an entire new generation of products that are cleaner, stronger, lighter and more precise.
Additional applications address medical science. So-called nanorobots might serve as programmable antibodies. As disease-causing bacteria and viruses mutate in their endless attempts to get around medical treatments, nanorobots could be reprogrammed to selectively seek and destroy them. Other nanorobots might be programmed to single out and kill cancer cells without doing damage to surrounding healthy tissue.

Recent progress in the measurement, modeling and manipulation of matter and phenomena on a scale of one to 100 nanometers has us on the verge of revolutionizing information processing, data storage, sensors, power generation, materials, environment, robotics and medicine.

Micro-electromechanical systems (MEMS) is a technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors and actuators embedded in semiconductor chips. Sometimes called “smart matter,” MEMS is expected to be the foundational technology of the next decade.

Products that contain MEMS also usually include nanotechnology but may also include technologies higher than the molecular level.

Microelectromechanical systems were first developed in the mid-1980s as a way to introduce new functionality to semiconductors, which represent integrated electronic circuitry on a silicon chip. With MEMS technology, chips are etched and layered with some microscopic structure that adds mechanical capabilities. But MEMS is distinguishable from micro-machines that contain gears, valves and other parts. As such, MEMS is much more than the miniaturization of components. It is the marriage of microscopic electronics and microscopic mechanics.

A popular application of MEMS today is in automobile air bags, but the technology also is set to revolutionize biomedicine, consumer electronics and telecommunications, such as cell phones and other wireless mobile communications devices.
Nanotechnology and MEMS in the Pittsburgh Region (cont.)

Cell phones will feature improved performance of speakers and microphones, and MEMS-enabled projection devices boast one million microscopic mirrors. There already are 120 in use in public theaters, and the home video market may benefit next. Medical diagnostics would apply MEMS devices to enable onsite diagnostic testing, greatly reducing the need for lab analysis.

In short, there are as many applications for MEMS as there are for semiconductors.

MEMS Industry Group

The southwestern Pennsylvania region is fortunate to call the MEMS Industry Group (MIG) home, ensuring we will be at the forefront of new MEMS and nanotechnology developments.

Launched in January 2001 with the help of Carnegie Mellon University professor Ken Gabriel who was named “architect” of the MEMS industry by Forbes magazine, the MIG is the premier trade association of the U.S. MEMS Industry. It has about 27 member companies nationwide.

The industry group’s mission is to:

- enable the exchange of information among its database of members and industry suppliers
- provide reliable industry data that furthers the development of MEMS technology
- work toward the greater commercial development and use of MEMS and MEMS-enabled devices

The industry group provides its members with benefits and information previously unavailable to the industry. In addition to an annual Industry Report published by MIG, members are given access to the latest MIG-generated research as well as statistics on employment, revenue and markets.
While at DARPA, Gabriel created a funding program to foster MEMS entry into industry. Much MEMS-related research is still funded by DARPA today.

**Regional Companies**

Using specific industry classifications, there is an innovative core of 18 small firms in the region within the MEMS cluster; that is, related firms that may share labor pools, technology and markets.

They include Aig Inc., Mesta Electronics Inc., Added Value Technology Inc., Sentinel Power Management, Warek Manufacturing Company, Powerex Inc., Filmtronics Inc., Depotronics and others. These firms also are anchored in key market segments by divisions of larger companies, such as Sony, Intel and OKI.

With MIG as its spearhead, southwestern Pennsylvania's cluster of MEMS start-ups may well be key players in new MEMS growth in the United States. Three startups are located in the same facility on Pittsburgh's south side, furnishing the sector with an attractive hub and exceptional opportunities for resource sharing.

Among recent MEMS startups is XACTIX, a provider of specialized equipment to etch semiconductors with a broad range of microscopic structures. XACTIX's Xetch product is particularly adept with optical MEMS devices that telecommunications companies have not yet embraced. The company has been working to develop a production machine that can handle tons of wafers at a time.

Verimetra, spin-off of XACTIX, makes MEMS sensors for medical applications. By placing MEMS sensors directly on medical tools and surgical instruments, the company has created the tools necessary for “smart” surgery. Examples include:

- Data Knife, an H-Probe designed to palpate vessels to determine the position of internal plaque
In April 2003, Gabriel’s own start-up company, Akustica, Inc., successfully produced the world’s first acoustic system-on-a-chip to revolutionize the performance of next-generation hearing aids, cell phones and other next-generation acoustic devices. The company uses a MEMS technology, licensed exclusively from Carnegie Mellon University, that can be mass-produced at relatively low cost, even by traditional suppliers.

Similarly, IC Mechanics aims to bring price points down in the manufacturing process for all MEMS technologies. The company has pioneered low-temperature processing for its wafers, an improvement over the traditional process, and it has been working to develop MEMS sensors for desktop and laptop computer disk drives, in order to increase and improve sensitivities to vibrations and shock.

And Benchmark Photonics is developing the next generation of high performance components for fiber optic communication networks, using a combination of systems-on-a-chip and MEMS technologies.

**Development Challenges**

Much of nanoscience remains at both the theoretical and experimental levels, making research a priority in the evolution of both MEMS and nanotechnology as fields ready for application and use in industry. A handful of universities are leading the charge in producing students entering the MEMS field, and among them are the University of California at Berkeley, UCLA, Stanford, Michigan, MIT and Carnegie Mellon.

New areas of focus in nanotechnology research are planned in all federal departments and agencies, and it is within this setting that Carnegie Mellon University’s Center for Interdisciplinary Nanotechnology Research (CINR) has become a hub for collaboration and research.
Nanotechnology and MEMS in the Pittsburgh Region (cont.)

Founded in 2001 to bring together the significant research being conducted in the realm of nanotechnology in various corners of the university, CINR represents a single axis around which nanotechnology research can revolve. The Center operates as both a focal point and catalyst for new research, as well as a clearinghouse for nanotechnology information.

In 2001, Carnegie Mellon researchers found that MEMS memory now in development could eventually put an entire computer system on a chip. The discovery was a result of a research grant by NASA to pursue the design of integrated MEMS storage devices for satellites. Ultimately MEMS-based storage offers faster access times at lower costs than existing disk-drive technology. MEMS-based storage devices will go into use where portability, high data density, low power consumption and ruggedness are priorities.

On the nanotechnology front, Carnegie Mellon already has work underway on Magnetoresistive Random Access Memory (MRAM). This technology stores data magnetically, so a hard drive does not require power to retain information. Advantages of MRAM are that it is cheap, dense, fast and static.

CMU’s Reconfigurable Nanotechnology Project, also known as the Phoenix Project, explores new potentials for the Field Programmable Gate Array, a fully programmable alternative to the customized computer chip, the world market for which is currently $2.6 billion. By removing the high cost of precision manufacturing, the Phoenix Project would allow for chip computing after manufacture with the added ability to reconfigure around defects.

Other CMU research applies nanotechnology to the medical arena. Hyperthermal cancer treatment involves attaching specially coated nanoparticles to cancer cells and heating them. The process would allow magnetic nanoparticles to fight cancer cells while evading damage to related cells, thereby improving cancer treatment.
Nanorobotics, a likely spawn of Carnegie Mellon research, also could allow the construction of single-function robots so small that they function in ways unimaginable for their counterparts—clinging to polished glass for spacecraft component inspection; interacting with single soil grains to search otherwise impossible terrains for life; forming colonies of thousands of individual robots for scouting and the collection of resources. Nanorobotic technology ultimately would transform the future of space by infusing ubiquitous devices that are self-contained, self-powered, autonomous, adaptable and significantly lighter, smaller and more reliable than their predecessors.

A nanobiologic institute would first be required which would work to fuse nanodevices, biometrics and informatics into wholly integrated agents. In 2002, efforts began to establish such a place with Carnegie Mellon spearheading partnerships with NASA and The Pennsylvania State University.

Penn State recently opened a Regional Center for Advanced Manufacturing Education in Nanofabrication with money from a $2 million award from the National Science Foundation. Meanwhile, the University of Pittsburgh’s Center of Molecular and Materials Simulations uses computers to understand the properties of carbon nanotubes. Potential applications of the carbon nanotubes range from the construction of nanoscale transistors to the storage of hydrogen for use in transportation.

In a separate University of Pittsburgh project, physicists funded by the National Science Foundation and the Department of Energy found a new way to create and move small bits of optical energy called “excitons” over relatively long distances. By applying laser light to separate an electron from an atom, an exciton is composed of an “excited” electron plus the hole remaining on the atom, which moves like an energy particle and could potentially carry information. The development could be an important step in creating semiconductors in which excitons are shuttled and controlled to form excitonic circuits.
Positioned for Growth

Recent forecasts predict MEMS will become an $8 to $16 billion industry by 2007, and it will represent a growth of between 60 and 130 percent, led by applications in medicine and telecommunications. The industry is estimated to spend approximately $100 million in research and development each year.

Likewise, the global nanotechnology market is expected to grow to $18 billion by 2005, with nano-enabled flat-panel displays and fuel cells expected to launch within three years. Federal nanotechnology investments exceeded $400 million in 2001.

The National Nanotechnology Initiative, a program spanning 10 federal departments and independent agencies, aims to further long-term, fundamental research aimed at discovering novel phenomena, processes and tools for nanotechnology. The organization’s 2003 budget was about $710 million, which was invested in nanoscale science, engineering and technology. This figure represented a 17 percent increase over the 2002 fiscal year.

In Pittsburgh, no one is better positioned to take advantage of this federal investment than the University of Pittsburgh and Carnegie Mellon University, both of which feature MEMS labs. With their Center for Silicon System Implementation and their Institute for Complex Engineered Systems, the facilities at Carnegie Mellon are regarded as some of the best for MEMS development in the U.S. The University of Pittsburgh, likewise, has several centers of research and academic excellence within its Institute of Nanoscience Engineering.

Additional capabilities to support MEMS research, development and growth are provided by both the Pittsburgh Digital Greenhouse and the Electro-Optics Center.

Through DARPA, local entrepreneurs also can participate in resource sharing at Carnegie Mellon, which can cut the costs of prototyping dramatically. This is because Carnegie Mellon’s MEMS facilities support an approach to prototyping that utilizes standard semiconductor technology and post-processing to reduce costs of MEMS production.
As a result of these initiatives, nanoscience talent appears to be moving steadily to the Pittsburgh region. These resources and talent provide good reasons to predict that the regional MEMS and nanotechnology cluster may rapidly be gaining in size.

Visit: www.memsindustrygroup.org

www.nano.gov

http://www.memsindustrygroup.org
Fuel Cells in the Pittsburgh Region

“Yes, my friends, I believe that water will someday be employed as fuel, that the hydrogen and oxygen...will furnish an inexhaustible source of heat and light...water will be the coal of the future.”

It seems Jules Verne, the first writer of science fiction and master of imaginary futures, was technologically prophetic when he wrote those words more than a century ago.

Some 130 years later, and after a great deal of discussion and research by such companies as Westinghouse Electric Corporation, George W. Bush kept the molecules moving. In his State of the Union message of January 2003, he praised the hydrogen car as a means for making the country “much less dependent on foreign sources of energy.” He then established a $1.2 billion research effort “so that America can lead the world in developing clean, hydrogen-powered automobiles,” and dubbed the effort “FreedomCar.”

General Motors then jumped on the bandwagon with well-publicized zeal about its “Ride and Drive” program. Under it, congressional representatives and other high government officials were invited to drive a mini van powered by a fuel cell. (GM is committed to commercializing fuel cell vehicles by 2010, one of the most optimistic targets in the fledgling industry.) And Shell Hydrogen, a division of Royal Dutch Shell, created somewhat of an international hullabaloo when it opened the first hydrogen refueling station outside of Reykjavik, Iceland. During the event, the company handed out bottles of water labeled “The Ultimate Fuel.”

A Simple Principle

Simply stated, batteries and fuel cells are alike in that both generate electricity. Unlike a battery, however, fuel cells never need to be recharged; they emit water, power and heat
Fuel Cells in the Pittsburgh Region (cont.)

continuously, as long as they are fed fuel (hydrogen, most of which is made by reforming natural gas).

Fuel cell technology has been called “leapfrog technology” simply because it vaults over what exists to reach a plateau that is totally new for meeting existing and projected needs for energy. Yet the technology itself isn’t new; William Grove, a friend of Michael Faraday’s, demonstrated it in his London laboratory during the 1830s. Grove reasoned that if it is possible to separate water into its components using electricity, then it is possible to recombine those same elements and create electricity.

Today’s fuel cells consist of two electrodes sandwiched around an electrolyte, a substance that conducts electricity easily. Hydrogen is fed into the anode; oxygen is fed into the cathode. The hydrogen atom, encouraged by a catalyst, splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte, while the electrons create a separate current that can be used before they return to the cathode, where they are reunited with hydrogen and oxygen to form water vapor, the only emission from the chemical process.

Today, there are several basic types of fuel cells that are classified by their electrolytes. Among them are:

**Proton Exchange Membrane Cells** are promising smaller units that operate at lower temperatures, making them suitable for transportation and portable power.

**Phosphoric Acid** types operate at higher temperatures, increasing warm-up time. As a result, these designs are less suitable for transportation, more suitable for small stationary power plants.

**Solid Oxide** designs operate at very high temperatures—around 1,830 degrees Fahrenheit, and are best suited for large-scale power plants. The high temperatures improve the
Fuel Cells in the Pittsburgh Region (cont.)

overall efficiency of the power plant; steam produced by the fuel cells can be channeled into turbines to generate additional electricity.

Other promising designs, each with its pros and cons for various applications, include molten carbonate, alkaline, direct methanol, regenerative, zinc-air and protonic ceramic.

The benefits of fuel cells are derived from their cleanliness and efficiency. Their extensive use could reduce air pollution caused by power plants and vehicles, decrease oil imports, reduce the trade deficit and create jobs for Americans. And hydrogen is prevalent from a wide variety of sources.

The Hydrogen Economy

The development of fuel cells has centered so far on transportation, a category that includes cars, trucks, buses and railroad engines, simply because it is the most visible and familiar application, and because the internal combustion engine is so inefficient. However, other applications are equally, if not more, important and promising. They include:

Portable power, needed for such everyday devices as laptop computers, cellular phones and hearing aids. The benefits are far longer life than a battery and rapid recharge with liquid or gaseous fuel.

Home power (also known as distributed power) using a small fuel cell installed at each residence. The benefit is the elimination of electrical transmission and distribution networks and lines.

Stationary (large) power generation, replacing conventional power plants. The benefits include the efficiencies in generating electricity directly from hydrogen in the fuel cell, in addition to using excess heat in operating steam turbines and generating more electricity.
Fuel Cells in the Pittsburgh Region (cont.)

Landfill/wastewater treatment, two industries that are concerned with managing the environment. The benefits are clean, efficient electric power with no toxic by-products.

Back-up power for any commercial applications or structures that require uninterruptible power supplies. The benefits are that fuel cells would replace bulky and more expensive emergency generators driven by diesel or gasoline engines, and the electricity would be of higher quality.

Early adopting markets for fuel cells as uninterruptible power supplies include:
- data centers
- hospitals
- military facilities
- air traffic control operations
- financial institutions (Credit card processing centers can lose $6 million per hour from power disruptions.)

Although the U.S. Department of Energy, the Department of Defense and NASA have invested in fuel cell research, private investment eclipses the total federal R&D funding with $1 to $3 billion spent by private firms on research and development since 1995.

Projections of growth for fuel cell technology and hardware have been unwaveringly rosy, yet less than uniform. Various industry consultants have predicted a wide range of market trends for this emerging cluster. Global gross revenues for fuel cell developers and suppliers have been forecast to grow to anywhere from $2.4 billion in 2004 (two-thirds of which is earmarked for power generation and motor vehicles) to $24 billion by 2012. By 2011, 108,000 direct and indirect jobs in North America could be tied to the stationary fuel cell industry.
Fuel Cells in the Pittsburgh Region (cont.)

The Pittsburgh Connection

With a fuel cell legacy at Westinghouse Electric Corporation that dates back to the 1950s, Siemens Westinghouse Power Corporation now is developing solid oxide cells at its research and development complex in Churchill, the former Westinghouse Research and Development Center. Siemens Westinghouse has generated three percent of all fuel cell patents and 18 to 23 percent of solid oxide fuel cell patents.

The company, recognized as a leader in the technology, announced plans to produce the cells commercially at a 215,000 square-foot plant on 22 acres a few miles outside of Pittsburgh’s city limits. Plans also call for an eventual expansion to 430,000 square feet and a workforce of 500.

The Siemens Westinghouse cells, each rated 125 kilowatts, are stackable in modules rated from two to five megawatts. They are intended for use as back-up power by hospitals, factories and other facilities that need continuous, uninterruptible power, and by manufacturers that need power of higher quality than is normally available from the power grid. Another application for the Siemens Westinghouse cells might be for subdivisions, especially in states with stricter environmental regulations or where the residents want “green” power.

The company expects to mass-produce fuel cells at a cost of $1,000 to $1,500 per kilowatt, and based on global market capacity estimates, Siemens Westinghouse’s initial plans could account for between 2.5 percent and six percent of the global fuel cell market by the end of this decade.

Siemens Westinghouse is poised to take advantage of several potential suppliers in the region, including firms involved in ceramics, metals, fabrication, turbines and electrical equipment. Also, notable firms in the electric power industry with headquarters or a major
Fuel Cells in the Pittsburgh Region (cont.)

presence in the region include Cutler-Hammer, ABB, Mitsubishi Electric Power Products, Elliott Turbomachinery (a division of Ebara), Alstom and Westinghouse Nuclear Fuel.

Public/Private Collaboration

In 2001, the Department of Energy awarded Siemens Westinghouse with $47.8 million, as one of four industry teams charged with developing cost-competitive fuel cells for commercial applications. The company also invested $32.8 million of its own funds.

The Pittsburgh office of the U.S. Department of Energy operates the National Energy Technology Laboratory, which has been awarded patents related to fuel cells. Scientists at the laboratory are working with the Solid State Energy Conversion Alliance, a group of corporations, universities, government agencies and national laboratories to develop commercially viable technology.

One example of this technology is being developed at Pittsburgh Electric Engines, which is set to open a fuel cell research, development and manufacturing facility in Derry, Westmoreland County, creating 150 jobs. The company has benefited from Army funding for the development of hybrid solid oxide fuel cells/turbine engines for military vehicles.

In addition, Concurrent Technologies operates the Fuel Cell Test and Evaluation Center for the Department of Defense from its Environmental Technology Facility in Johnstown, Pennsylvania. The Center provides independent, unbiased testing and validation of fuel cell power plants for military and commercial applications. The primary goal of the Center is to accelerate the development and commercialization of fuel cell power plants.

The area’s universities are involved in this emerging cluster as well. More than 500 graduate students in engineering fields relevant to fuel cells are produced annually by the region’s universities. In addition, Carnegie Mellon’s Engineering and Public Policy Program, a part of the College of Engineering, is home to the Electricity Industry Center
and the Center for Energy and Environmental Studies. A recent project involves the use
of steam turbines with fuel cells.

In addition, Fraunhofer USA Center for Energy and Environment, a subsidiary of Europe's
largest contract research organization, has begun operations in Pittsburgh. The Center
seeks partnerships with local universities and companies (including Siemens Westinghouse)
to conduct research in environmental technologies, fuels and energy generation.

As a result of the cooperation and collaboration of public, private and academic
resources, the prophesy of Jules Verne may have its genesis in the Pittsburgh region.

Visit: http://www.siemenswestinghouse.com/

The Online Fuel Cell Information Center at www.fuelcells.org

Carnegie Mellon University’s Electricity Industry Center at
http://wpweb2k.gsia.cmu.edu/ceic

Carnegie Mellon University’s Center for Energy and Environmental
Studies at http://www.iecm-online.com/cees_contact.htm

The National Energy Technology Laboratory at
http://www.netl.doe.gov/main.html

 Concurrent Technologies Corporation at http://www.ctc.com
Wage Increases in the Pittsburgh Region

Despite a stagnant economy impacting southwestern Pennsylvania’s technology industry and related subclusters, wages still continued to increase. To compensate a workforce that is expected to do more with fewer resources, many companies are adjusting their salary structures for workers at all levels.

The Pittsburgh office of Towers Perrin conducted a 2004 Merit Increase and Pay Practices Pulse Survey, gathering information from 44 regional companies employing some 158,000 workers. The survey detailed:

- 2004 merit increase budgets compared to 2003 actual merit increases
- 2004 salary structure adjustments in comparison to 2003 actual salary structure adjustments
- degree of reward differentiation for high-performing employees
- actions being considered in light of recent developments surrounding equity plans

According to the survey, the median 2004 proposed merit increases varied between employee groups:

- 3.2 percent for executive and middle management
- 3.5 percent for exempt professionals
- 3.0 percent for nonexempt salaried and hourly personnel

The survey also reported that the median 2004 projected salary structure adjustments are constant at two percent for all employee groups. Some 66 percent of respondents indicated that they intend to further differentiate reward opportunities for high-performing employees. Of the survey participants who use stock as a form of compensation, 45 percent are considering changes to their stock-based programs.
U.S. Government-Funded Research in the Pittsburgh Region

Non-commercial research and development centers in Pittsburgh that receive funding from the federal government include the:

- Department of Defense’s Software Engineering Institute
- Department of Health and Human Service’s (HHS) Pittsburgh Research Laboratory
- Department of Energy’s (DOE) National Energy Technology Laboratory–Pittsburgh
- Department of the Interior’s (DOI) Pennsylvania Cooperative Fish and Wildlife Research Unit
- Department of Veteran’s Administration’s (VA) R&D unit

The Software Engineering Institute is a federally funded research and development center sponsored by the Office of the Under Secretary of Defense for Acquisition and Technology, and it is operated by Carnegie Mellon University. It focuses exclusively on advancing the practice of software engineering, because software is such a critical part of U.S. defense systems. It seeks to ensure that operational software in software-intensive systems, be they defense or non-defense systems, is of the highest quality possible. Specific R&D activities of the institute focus on management practices of software producers, especially as they affect quality and productivity. It also is concerned with the technical practices of the industry as they affect the ability of software engineers to understand and control the functional and nonfunctional aspects of software systems.

The federally owned and contractor-operated Software Engineering Institute spent $51 million of federal R&D funds in their fiscal year ending in September of 2003; the SEI employs 450 people.

The Computer Emergency Response Team (CERT®) Coordination Center is a center of Internet security expertise, located at the Software Engineering Institute and operated by Carnegie Mellon University. CERT concerns itself with computer security incidents and vulnerabilities, publishing security alerts, researching long-term changes in networked
systems and developing information and training to help improve site security on a national basis. During the last calendar year, CERT received 137,529 computer security reports, a 40 percent increase over the previous year. *(See “Cybersecurity in the Pittsburgh Region” sidebar.)*

The Pittsburgh Research Laboratory is a unit of the National Institute of Occupational Safety and Health inside HHS’s Centers for Disease Control and Prevention. It conducts research to promote the health and safety of miners by investigating ways to reduce dust and noise in the mine environment and improving the safety of explosives and blasting practices. Specific research activities of this unit include developing a coal combustion-sensitive test for smoke detectors, studying ways to detect and control spontaneous heating in coal mine pillars and studying the performance of automatic sprinklers for extinguishing belt fires under ventilated conditions. This federal R&D unit, which includes the National Personal Protection Technology Laboratory, received $32.1 million in federal R&D funds in 2003, and it employs 308 people.

The National Energy Technology Laboratory is affiliated with the DOE and maintains offices in Pittsburgh, Morgantown, West Virginia, Tulsa, Oklahoma and Fairbanks, Alaska. This federal laboratory has a total fiscal year 2004 estimated budget of $745 million. The Pittsburgh site has more than 500 federal and non-federal employees, and it has budgeted about $18 million for in-house R&D this year. The facility develops technologies related to coal, oil and natural gas (i.e., fossil energy) and environmental cleanup. Specifically, the laboratory focuses on advancing the commercialization of pollution-reduction technologies, the more efficient use of fossil fuels and developing technologies to clean up DOE-managed and generated waste. While the laboratory maintains a modest in-house R&D capability, most of its staff oversees extramural R&D projects conducted with federal R&D funds. *(See “Fuel Cells in the Pittsburgh Region” sidebar.)*
U.S. Government-Funded Research and Development in the Pittsburgh Region (cont.)

The Pennsylvania Cooperative Fish and Wildlife Research Unit is part of the DOI. It is on the campus of The Pennsylvania State University, and it conducts research on fish and wildlife populations. Specific research activities of this unit include studies of deer populations and the effects of agricultural activities on trout streams. This federal R&D unit annually receives approximately $200,000 of federal R&D funds and has about three employees.

While the principal focus of the VA Medical Centers in Pittsburgh is providing medical care to veterans, they also are the location of a number of research activities. During the latest completed fiscal year, federally owned and operated facilities were the sites of 272 active projects with total funding of approximately $24.9 million. These R&D activities focused mainly on human studies conducted by 120 active investigators on a wide range of topics, including but not limited to schizophrenia, sleep and cognitive disorders, aging, alcoholism, nephrology, oncology, urology and vascular surgery.
Tissue Engineering in the Pittsburgh Region

Broadly defined, tissue engineering is the development and manipulation of laboratory-grown molecules, cells, tissues or organs to replace or support the function of defective or injured body parts.

Although cells have been cultured or grown outside the body for many years, the possibility of growing complex, three-dimensional tissues—literally replicating the design and function of human tissue—is a recent development. The intricacies of this process require input from many types of scientists, including the problem-solving expertise of engineers, hence the name tissue engineering.

Tissue engineering crosses numerous medical and technical specialties. Cell biologists, molecular biologists, biomaterial engineers, computer-assisted designers, microscopic imaging specialists, robotics engineers and developers of equipment, such as bioreactors, where tissues are grown and nurtured, all are involved in the process of tissue engineering.

Tissue engineers in the United States and abroad have set out to grow virtually every type of human tissue – liver, bone, muscle, cartilage, blood vessels, heart muscles, nerves, pancreatic islets and more. Commercially produced skin is already available for use in treating patients with diabetic ulcers and burns.

Many current medical therapies may be improved upon by tissue engineering with significant financial savings. In standard organ transplantation, for example, a mismatch of tissue types necessitates lifelong immunosuppression, with its attendant problems of graft rejection, drug therapy costs and the potential for the development of certain types of cancer.

Furthermore, there is always the potential for rejection of the tissue, but as the field of tissue engineering progresses, it inevitably will provide many improvements, as the costs of tissue harvest and postoperative patient costs will be reduced significantly.
By actually designing replacements to mimic the native tissue being reconstructed, the adequacy of tissue function will be optimized, leading to improved patient care at less expense.

As a world leader in organ transplantation, it is little wonder that Pittsburgh became a world-class center of excellence in tissue engineering.

**McGowan Institute for Regenerative Medicine**

To realize the vast potential of tissue engineering and other techniques aimed at repairing damaged or diseased tissues and organs, the University of Pittsburgh School of Medicine and UPMC Health System have established the McGowan Institute for Regenerative Medicine (MIRM). As an entity, the MIRM serves as a single base of operations for the university's leading scientists and clinical faculty working to develop tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ devices.

The mission of the new institute is to devise innovative clinical protocols, as well as to pursue rapid commercial transfer of its technologies related to regenerative medicine.

The faculty and programs of the McGowan Center for Artificial Organ Development have been incorporated into the MIRM, and other university faculty will join its forces as well. These include researchers working in tissue engineering, adult-derived stem cell research, wound healing and biomaterials research, among other branches.

The MIRM is considered to be the most ambitious tissue engineering program in the nation, coupling biology, engineering, organ transplantation and biomedical research in all facets of its work. One of the attractive features of the MIRM is that it enables cutting-edge basic and clinical research to be performed across disciplines, allowing organ and tissue engineering and cellular and regenerative therapies to be developed and swiftly evaluated in the clinical setting.
A number of projects are underway at the MIRM, including:

- an axial-flow left-ventricular assist system for patients with end-stage heart disease
- a respiratory assist device for patients with acute lung failure
- a biohybrid artificial lung intended for long-term use
- a novel blood additive that improves blood flow to oxygen-deprived tissues
- a bioengineered blood vessel and a myocardial patch of muscle cells intended to repair heart tissue damaged by heart attack

The new McGowan Institute for Regenerative Medicine and the former McGowan Center for Artificial Organ Development are named after the late William G. McGowan, who as chief executive officer at MCI Communications, underwent a successful heart transplant at the University of Pittsburgh Medical Center in 1987.

In 2003, the McGowan Institute announced a new Pre-Doctoral Tissue Engineering Program and worked on tissue-engineered solutions for heart disease. University of Pittsburgh surgeons were the first in the U.S. to use the Zeus robot during cardiac bypass surgery.

**National Tissue Engineering Center**

In 2002, the McGowan Institute established the National Tissue Engineering Center (NTEC) in Pittsburgh to serve the Department of Defense as a single base of operations for the leading civilian and military scientists and clinicians working to advance the science of tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ devices, and to translate these new technologies to clinical practice. The goal of
Tissue Engineering in the Pittsburgh Region (cont.)

the NTEC is to save lives and reduce soldier downtime. In order to meet this goal, its work centers on three general areas:

- wound healing
- cardiothoracic and vascular tissue engineering
- musculoskeletal tissue engineering

It is clear that optimal progress in developing new regenerative medicine methods only can be realized by multi-disciplinary teams that range across a wide spectrum of scientists, engineers and clinicians starting at the cellular level, such as cell biologists, through materials engineers, to clinical translation specialists and practicing clinicians. The National Tissue Engineering Center brings this wide expertise together.

University of Pittsburgh Department of Bioengineering

The University of Pittsburgh’s bioengineering department has an active, interdisciplinary graduate program in conjunction with faculty from the School of Medicine, the School of Health and Rehabilitation Sciences and the clinical staffs at the University of Pittsburgh Medical Center hospitals.

This program is directed toward engineering and life science education and research, with particular emphasis on the PhD. Its scope is broadly defined to incorporate the application of engineering principles, methods and technology in two broad areas:

- scientific inquiries into fundamental biological phenomena
- development of instrumentation, arterials, devices and systems relative to application in the biological sciences and medicine
Active, externally funded areas of research include, but are not limited to:

- computer processing of biologically derived signals
- development of prostheses, artificial organs and implantable sensors
- development of medically related instrumentation
- mathematical modeling of physiological systems
- tissue engineering
- biomaterials
- orthopedic biomechanics and sports medicine
- vascular mechanics
- other related fields

Thus, the bioengineering faculty is applying various forms of engineering principles, mathematics computation, technology and methodology to a broad variety of medical and life sciences problems.

**Bone Tissue Engineering Initiative at Carnegie Mellon University**

The need for bone substitutes is particularly important. They often are required to help repair or replace damaged or diseased tissues in cases that include congenital and degenerative diseases, cancer and cosmetic surgery.

There are approximately 500,000 surgical procedures performed every year in the U.S. that require bone substitutes. Currently available bone substitutes, including autografts, allografts and synthetic materials, are the most implanted materials second only to transfused blood products. However, these substitutes are far from ideal and have many associated problems. Autografting is expensive and can have significant donor site morbidity, and synthetic materials wear and do not behave like true bone. The goal of the Bone Tissue Engineering Initiative is to provide an alternative solution by creating large-scale, tissue-engineered bone.
Tissue Engineering in the Pittsburgh Region (cont.)

A major technology for creating tissue-engineered bone is an advanced computer-aided-design/computer-aided-manufacturing (CAD/CAM) bioreactor system capable of growing large-scale, customized bone substitutes. A CAD model of the desired bone substitute first would be derived from CAT scans or MRI data of the patient. The synthetic bone then would be fabricated, in-vitro, in an advanced CAM bioreactor by depositing layers of biodegradable scaffolding material, while simultaneously embedding donor cells and growth factors within the layers.

Synthetic vasculature also would be embedded within the scaffold as it is being built up, until the new bone was mature enough to be removed from the bioreactor and implanted into the patient. Such a system would also have applicability to other tissues and whole organs.

Current research involves not only laying the foundation for several of the components required for realizing such an advanced system, but also gaining knowledge and developing components that will have clinical relevance in the nearer term. Projects include scaffold materials, solid freeform fabrication scaffolds, synthetic vessels and growth factors.

The Pittsburgh Tissue Engineering Initiative

The mission of the Pittsburgh Tissue Engineering Initiative (PTEI) is to facilitate the recognition of Pittsburgh as an international center of excellence in tissue engineering research and education. The PTEI also fosters economic development by promoting the growth of a regional biotechnology industry rooted in tissue engineering.

The PTEI accomplishes its goals through:

- funding of research with clear potential commercial impact
- playing a leadership role in defining community strategies for regional development
- sponsorship of educational programs for a spectrum of students and professionals
- facilitating access to innovative technology transfer systems
Tissue Engineering in the Pittsburgh Region (cont.)

- promoting collaboration among Pittsburgh’s leading health and academic centers and within the larger field of tissue engineering
- global dissemination of tissue engineering-related information

In 2002, PTEI debuted a new Tissue Engineering Educational Program and Planetarium Show entitled “Tissue Engineering for Life.” The unique educational program focused on tissue engineering and its applications. Curriculum materials for use in classrooms, a K–12 outreach program and Web-based tools were features of the program.

“Tissue Engineering for Life” was funded by a $1.62 million Science Education Partnership Award from the National Institutes of Health—the largest award ever given for information science education. Regional partners involved with the project included:

- Carnegie Science Center
- Carnegie Mellon University’s STUDIO for Creative Inquiry
- Carnegie Mellon’s Center for Light Microscope Imaging and Biotechnology
- UPMC Health System
- University of Pittsburgh’s Bioengineering Department
- Pittsburgh Supercomputing Center

In January 2003, Catalyst Connection assisted the PTEI in obtaining a $300,000 award for the development of a life-science curriculum using the biotechnology program at the Community College of Allegheny County; the undergraduate research programs and biology programming at Duquesne University; the Technology Studies magnet school in the Pittsburgh School District and the professional-development training for middle and high school teachers provided through the PTEI.

Strategic industry partnerships fostered by PTEI aim to position and showcase Pittsburgh as a leader in the fields of regenerative medicine and tissue engineering. Partnerships include affiliation with The Society for Biomaterials, the Wound Healing Society, the
Society for Regenerative Medicine, the Tissue Engineering Society International and the Tissue Engineering Research Centers in Japan and North America.

Pittsburgh also is home to the Engineering Tissue Growth International Conference & Exposition (ETG), the world’s largest gathering of tissue engineering thought leaders, which attracts scientists from academia and industry, as well as representatives of government, business and economic development organizations. The PTEI organizes the conference annually. This unique tissue engineering event combines a comprehensive scientific program with an exhibition of products, services and technologies. The objectives of the conference are to stimulate the exchange of information and ideas, to foster collaborations for the advancement of the field and to accelerate the pace of scientific discovery so that tissue-engineered products can be more quickly developed to help patients worldwide.

The third annual ETG, which was held in Pittsburgh during the spring of 2003, attracted more than 650 thought leaders from North America, South America, Europe, Asia and the Pacific Rim. Attendees chose from more than 70 scientific sessions in seven focused tracks, and they attended keynote presentations by some of the world’s most preeminent scientists, in addition to several innovative panel presentations and roundtable discussions.

The Industry Cell

More than 75 life sciences firms call southwestern Pennsylvania home. Among these organizations, TissueInformatics, Inc. and Kytaron Technologies are two specializing in tissue engineering.

TissueInformatics provides pathologists and biomedical researchers with fully automated pathology software and services for the rapid, consistent and quantitative assessment of tissue. The company has revolutionized the tissue analysis process by making possible automated quantitative analysis of tissue resulting in new TissueAnalytics software and services. By integrating sophisticated tissue imaging with proprietary tissue analysis software,
the company is able to arrive at precise mathematical comparison of tissues resulting in greater speed, consistency and accuracy where precise tissue comparison is critical.

Kytaron Technologies is a Pittsburgh-based tissue engineering startup that aims to discover, develop and commercialize proprietary methods for stimulating organ regeneration in patients with potentially life threatening disorders. Using stem-cell-based cellular therapies, Kytaron will assist in the development of new treatments for liver, metabolic, endocrine and other diseases. Its cellular products also may be used for evaluating pre-clinical drug candidates and for use in drug metabolism studies, enzyme induction experiments and toxicology testing. Kytaron is one of five young biotech companies residing in the Pittsburgh Life Sciences Greenhouse incubator space.

The PTEI underscored its commitment to the development of a vibrant tissue engineering sector in southwestern Pennsylvania with the creation of its Senior Management Fund. The goal of the fund is to advance tissue engineering technologies toward clinical utility by financing strategy and business plan development, as well as by recruiting qualified senior management. The PTEI anticipates that investments by the Senior Management Fund will attract experienced leadership and significantly advance recipient companies’ commercial strategies to secure other sources of funding and investment.

Preserving the Human Face of Tissue Engineering

In November 2003, Duquesne University joined with the PTEI to present a symposium entitled Stem Cell Research: Science, Religion & Ethics. The event offered a forum for debate spanning theoretical, scientific, medical, political and ethical considerations resulting from tissue engineering efforts and its outgrowths. The Symposium was opened by Eric Cohen, director of the Biotechnology and American Democracy, Ethics and Public Policy Center.
Efforts like the Stem Cell Research symposium illustrate southwestern Pennsylvania’s acute attention to the underlying human, cultural and philosophical issues necessarily resulting from the application of new technologies and engineering practices to the physiological space. Each of Pittsburgh’s individual institutions is considered to be a world-class center of excellence. Together they form a solid, informed and noble foundation on which to build a global reputation for the region in tissue engineering.

Visit: www.ptei.org

www.etg-online.com
Electro-Optics in the Pittsburgh Region

A technical definition of electro-optics describes a technology associated with components, devices and systems designed to interact between the electromagnetic and visible light spectrum and the electronic state. It states that electro-optics uses applied electrical fields to generate and control optical radiation.

In the simplest sense, electro-optics is a technology based around the conversion of electricity into light and light into electricity. Human sight is perhaps the closest model for the conceptual processes involved in electro-optics.

Two primary categories of electro-optics exist: outside-in mechanisms, which include imaging and sighting devices, and inside-out mechanisms, which typically involve lasers and laser applications. As a broader term, electro-optics also is used to encompass laser, optics, fiber-optics and photonics technologies.

Typical electro-optic devices include concave and convex mirrors, convergent and divergent lenses, prisms, beam-splitters, optical filters, resonators and lasers. Components include semiconductor diodes, light-emitting diodes (LEDs), photodetectors, liquid crystal optics and multiplexers. Emerging fields within this cluster include fiber optic communications, which make up 40 percent of the total market, imaging acquisition products and optical disk storage.

The worldwide market for this industry cluster was estimated at $73 billion in 2000. The core of this cluster, with the exception of photonics and optics firms, contains 425 businesses nationwide with sales of more than $3 billion. The U.S. military historically has invested in and benefited the most from electro-optic research and development, and although the technology steadily has become more commercial, the federal government remains at the forefront of the industry.

The Army has used electro-optics for air defense systems, ground-based deep space surveillance equipment, night vision devices and a host of other optical tools. Powerful,
small weapons-grade electro-optic lasers are applied in military missile defense. For example, war fighter use of electro-optic uncooled sensors and flash ladar will improve weapons systems size, weight, power, costs and sensitivity. Flash ladar creates high-resolution three-dimensional images that enable robust target detection and identification with minimum collateral damage. Increasingly, our nation’s defense depends on electro-optical components because of the distinct advantages they afford.

But the larger field of electro-optics has been growing over the past 20 years. Light-emitting diodes used in video display screens are a recognizable application of electro-optics in the general public space. Other devices incorporating electro-optics include metalworking tools, surgery and medical devices, telecommunications equipment, night vision surveillance, art restoration and traffic lights. With LED technology, traffic bulbs will last 30 years and cost only 85 cents a month to operate, compared with five years and $6.00 a month for conventional bulbs.

According to a National Research Council report, large companies do not dominate the industry. Certainly Kodak, AT&T, IBM and other large corporations are very involved in the electro-optics industry, but it is small entrepreneurial companies that comprise the bulk of the cluster.

**The Electro-Optics Center**

Armstrong County in southwestern Pennsylvania is home to the Electro-Optics Center (EOC), the focal point for many of the nation’s cutting-edge research initiatives, including products for the Department of Defense (DoD) and U.S. industry. As such, it has the potential to become a formidable national and international resource.

Formally established in 1999 as the U.S. Navy’s Center of Excellence in Electro-Optics Manufacturing, the Kittanning-based Center is charged with ensuring excellence and world leadership in the emerging industry of electro-optics. The Electro-Optics Center
Electro-Optics in the Pittsburgh Region (cont.)

originally was established and managed by The Pennsylvania State University's Applied Research Laboratory (Penn State ARL) under an Office of Naval Research Manufacturing Technology (ManTech) initiative.

The Center’s vision is to become a manufacturing technology enabler. To realize this vision, EOC serves the needs of the Navy, the DoD and private industry through the development and execution of technical programs, workforce development activities and technology transfer efforts.

The four key services of the Electro-Optics Center include:

**Technical Project Development and Management**, which includes assistance in the development of technical solutions for industry electro-optics manufacturing issues and requirements.

**Manufacturing Technology Transfer and Deployment**, which develops resources and expertise that enable the transition from prototype demonstrations to production capability, resulting in the creation of new businesses or enhanced product lines.

**Workforce Development and Education**, which encompasses programs that provide skill-based training and academic courses in basic and advanced electro-optics manufacturing technologies. This service also operates a teaching and demonstration facility, and it conducts various outreach activities to heighten electro-optics awareness and opportunities.

**Electro-Optics Technical Resources**, which involve technical oversight and consulting, proposal evaluation, program management, prototype production demonstrations and acceptance tests.

Electro-Optics Center research projects generally have targeted laser technology and fiber optics. But each year, EOC expands the number of research and development projects it coordinates and in which it directly participates.
Electro-Optics in the Pittsburgh Region (cont.)

In 2002, $64.7 million was appropriated by the defense industry for EOC-coordinated efforts. Funding was used for R&D projects that included, but were not limited to:

- advanced multiband optical surveillance system ($4 million)
- advanced silicon carbide crystal device technology ($6 million)
- Avenger upgrade of the first generation of FLIR Systems’ infrared detection components ($3.4 million)
- dual band detector imaging technology for Army ($2.6 million) and for the U.S. Special Operations Command computer system ($4.3 million)
- high-energy laser/missile for ship self-defense ($6 million)
- imaging system upgrade development ($6 million)
- infrared space sensors ($3 million)
- aircraft missile warning sensors ($2.1 million)

Funding for general EOC operations in 2002 was $1.8 million, while $200,000 was provided for electro-optics workforce development initiatives.

Electro-Optics Alliance

The Electro-Optics Center is home to the Electro-Optics Alliance (EOA), with a roster of more than 240 member organizations spanning industry, university and government organizations. Some significant names include Honeywell, ITT Industries, Lockheed Martin, Northrop Grumman, Raytheon, Rockwell, Tyco and others.

The Alliance creates essential electro-optics infrastructure by promoting strategic partnerships among its members and by disseminating R&D findings to expand the electro-optics knowledge base and the commercialization of electro-optics technology. The Alliance also assists companies in obtaining ManTech funding and implementing technology developed under such programs.
Educational Outreach

Penn State ARL has demonstrated innovation and practicality in technology-based research through its involvement with the EOC. Penn State ARL is one of just four other U.S. Navy academic research centers in the country. While the lab itself has served as a center of excellence in undersea technology, it also has facilitated Penn State in becoming second among U.S. universities in industrial R&D funding.

Penn State also ranks 26th nationwide in National Science Foundation R&D awards for electro-optics research. Penn State offers a graduate degree in electro-optics with specializations in non-destructive inspection, high-precision surface metrology and vibration and ultrasonic-guided wave monitoring.

<table>
<thead>
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<th>University</th>
<th>Awards</th>
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<tr>
<td>Carnegie Mellon University</td>
<td>3</td>
<td>$415,294</td>
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Carnegie Mellon offers optics specialization in its electrical and computer engineering disciplines that focus on military target identification, Raman imaging and spectroscopy for environmental monitoring and polymer materials characterization for recycling.
The University of Pittsburgh's department of electrical engineering is the focal point for many electro-optics efforts within Pittsburgh. The department’s areas of research and development include:

- optically based computing using reconfigurable processors and optical cache memory system-level modeling for free-space interconnects and optical micro-electro-mechanical systems (MEMS)
- erbium-doped waveguide optical amplifiers
- zero insertion-loss beam splitters
- optoelectronic packaging technologies for high-speed optical communication
- integrated-optic ultraviolet detectors, based on wide band gap semiconductors

Indiana University of Pennsylvania (IUP) also forged a recent partnership with the EOC to further a new career-training program in electro-optics. To maximize its educational opportunities, IUP’s educational facilities for electro-optics will be housed in close proximity to the EOC at the Northpointe Technology Center in Armstrong County. Synergy with the EOC is expected to create unique student opportunities for advanced education and workforce training focused on emerging electro-optics technology.

Additional EOC partnerships exist with Lenape Vocational-Technical School and area secondary and post-secondary schools.

**Private Sector**

Numerous electro-optics companies are located in Armstrong County making it a prime location for future technology-cluster build-out. A short sampling of efforts at some of the prominent businesses illustrates the range of electro-optics activities already underway in southwestern Pennsylvania.

**II-VI** (pronounced Two-Six) is a public company that manufactures optics equipment for military and medical use. In June 2001, II-VI acquired a competitor, San
Diego-based Laser Power Corp., which boosted II-VI’s revenue by 66 percent. The acquisition also pushed the company’s military sales from 10 percent to 25 percent of its total revenues.

Armstrong Laser Technology develops laser equipment for defense contractors.

Brashear, LP provides optical systems and instrumentation to defense and scientific customers, domestically and internationally. Brashear was awarded a five-year, $8.1 million contract from Raytheon to manufacture 35 electro-optic systems for the Navy’s Phalanx Weapon System, a computerized laser and gun. The contract could extend to another 300 similar systems.

Raytheon is another regional producer of electro-optical systems. Raytheon produces focal plane detector arrays, which enable both high-performance military sensors and low-cost sensors for commercial applications.

Optical Systems Technology designs, manufactures and integrates high-performance, image-intensified, night vision products, stabilized gimbaled optical platforms, large optical assemblies and fiber-optic illumination engines. Its products are marketed under the STAR*TRON brand name associated with the largest and fastest night vision catadioptric lenses in continuous production for over 30 years.

The region also has key companies that either use electro-optic technology in their products or have compatible products. They include Draeger Safety, Mine Safety Appliances, ChemImage, Bridge Semiconductor and Westinghouse Electro-Mechanical Division, among others.
Regional Growth Efforts

The Electro-Optics Initiative is a program developed to combine the efforts of industry, education, community and government to make opportunities available for electro-optics companies to locate within Armstrong County.

In 2003, four new companies announced plans to locate in Armstrong County: Sabeus Sensor Systems, DRS Technologies, RAPT Industries, Inc. and ANALUX. Such development plans are positive indicators of electro-optic clustering in the region and help to further establish and expand wider incentives for future growth.

Sabeus Sensor Systems, a division of California-based Sabeus Photonics, manufactures fiber optic sensors. In 2003, Sabeus began development work on a new sensor in its Freeport facility.

The company expects to create up to 100 new jobs over the next two years.

DRS Technologies Inc. chose to open space in Armstrong County to focus on upgrading infrared technology used by the United States Armed Forces. The company has been awarded a contract to manufacture pre-production hardware for the Avenger and the AN/TAS-4 systems that will provide low-cost imaging technology upgrades. The company’s electro-optical systems group provides electro-optical sensors technology, components and systems for both the domestic and international military markets.

RAPT Industries specializes in a patented process called reactive atom plasma used for polishing and shaping optical, ceramic and semiconductor components. The RAPT system provides for non-contact work and can remove subsurface damage due to traditional polishing and grinding.

Finally, ANALUX, a Pittsburgh enterprise, expanded its facilities to foster new cooperative work in electro-optics. ANALUX makes hyper spectral cameras capable of seeing through
such inclement conditions as smoke, dense fog and heavily wooded areas. ANALUX, too, anticipates filling 50 to 100 jobs in its new facility.

As an industry, electro-optics requires access to precision machinists, casting makers, computer engineers and other specialized talent to help develop it further.

Armstrong County is equipped to serve these needs as home to more than 30 precision manufacturers. Some companies, such as Spark Technologies, specialize in the manufacture of custom components for electro-optics. Workforce development programs at the EOC also aggressively have striven to fill the talent pool.

**Northpointe**

The presence of the Electro-Optics Center has generated business growth throughout Armstrong County. To better serve and foster this growth, Armstrong County developed a state-of-the-art business and technology park at Northpointe. The park serves as a site for expanded partnerships between academic, industrial and government organizations in electro-optics and other areas.

Due to its own technical growth and workforce development advances, the Electro-Optics Center itself announced plans to relocate to Northpointe. The expanded facilities of the EOC are slated to open in August 2004.

**ARMTech**

Each year, the EOC joins forces with the Armstrong County Regional Manufacturing Initiative to host the ARMTech Showcase, a national trade show that draws national defense and aerospace contractors, medical researchers, regional electro-optics companies and advanced manufacturers.

In 2003, more than 60 exhibitors featuring nearly 80 interactive exhibits participated in ARMTech. Local, regional and national industry representation in advanced manufacturing,
Electro-Optics in the Pittsburgh Region (cont.)

medical research and defense-related industries participated. The Public Showcase displayed thermal imaging video cameras, combat helmets with night vision capabilities and body armor protection systems.

The Department of Defense has played and will continue to play an important role in the development and funding of the region’s electro-optics industry cluster. Many items the DoD uses are fairly easy to purchase commercially, however with optical equipment, there usually are sophisticated modifications required for military use.

Most recently, U.S. Representative John Murtha secured a $25 million contract for the Center to perform pioneering research on ways to improve Navy aircraft.

With military applications as a source of contracts and funding, the region’s electro-optics industry represents a promising emerging cluster. The penetration of electro-optics devices into the medical and industrial markets also will continue to add to the cluster’s growth.


The Applied Research Laboratory at The Pennsylvania State University at http://www.arl.psu.edu/capabilities.html
Robotics in the Pittsburgh Region

Japan is the world leader in industrial robotics, with approximately 50 percent of the world market. By 2004, the U.S. market share is projected to decrease to nine percent.

In a study conducted for the Defense Advanced Research Projects Agency (DARPA), a group of robotics experts predicted that 2006 will be the first year for successful commercialization of mobile robots, and that by 2005, revenues in this industry will reach $5.4 billion. The DARPA survey also predicted that by 2036, mobile robots will comprise a significant portion of the United States’ economy.

By the same token, the sales volume for medical robots is expected to reach $2.08 billion by 2010, and it could capture 10 percent of the minimally invasive surgery market by 2007. The International Federation of Robotics estimates that there currently are 1,600 medical robots in use around the globe and that an additional 4,800 units will be installed by 2004.

In the meantime, other robotics applications continue to span the gamut with a higher concentration of uses in industrial, commercial and defense applications. A significant number of applications address the “three Ds”—work that is dirty, dangerous or dull for humans.

While Pittsburgh has been somewhat slow to develop a large industry base in any single robotics field, the region has had and continues to foster a defining presence in the larger North American robotics community.

But Pittsburgh’s robotics development situation is not uncommon. Most North American activity in non-industrial and service robotics takes place around universities with substantial research programs, such as the University of California at Berkeley, MIT and Carnegie Mellon University. One reason for this trend is that research universities are simply better equipped than young start-ups to fund research and development programs.
Robotics in the Pittsburgh Region (cont.)

As the demand for non-industrial robots increases, Pittsburgh will be in a bright position to develop its industry base, due to unparalleled research resources.

Research Assets

Now entering its 25th year, the Robotics Institute at Carnegie Mellon University has made Pittsburgh a worldwide leader in robotics research.

Established in 1979 to conduct basic and applied research in robotics technologies relevant to industrial and human service tasks, Carnegie Mellon’s Robotics Institute aims to realize the potential of the robotics field. Seeking to combine the practical and the theoretical, the Robotics Institute undertakes diversified efforts and approaches to robotics science to achieve its mission.

The Robotics Institute also is the largest research facility of its kind in the United States. The umbrella organization features five distinct robotics-related sub-centers:

The Medical Robotics and Information Technology Center, also known as the MERIT Center, is a program aimed at fostering collaborations between Carnegie Mellon researchers and clinicians in the region’s health care community.

The Field Robotics Center focuses on the use of mobile robots in field environments, such as work sites and natural terrain, where the robots must safeguard themselves while performing non-repetitive tasks and objective sensing, as well as self-navigation in random or dynamic environments.

The Vision & Autonomous Systems Center is a large research group working in the areas of computer vision, autonomous navigation, virtual reality, intelligent manipulation, space robotics and related fields.
Robotics in the Pittsburgh Region (cont.)

The Center for Integrated Manufacturing Decision Systems is a loosely related group of eight laboratories performing research in manufacturing, scheduling, stereo displays, inspection robotics, sensor-based process control and information visualization.

The National Robotics Engineering Consortium (NREC) is an entity dedicated to the development of products incorporating advanced mobile robotics technologies. The NREC currently is developing robotic vehicles for the mining, earth moving, agricultural and industrial materials handling industries. The National Aeronautics and Space Administration (NASA) also is a partner in NREC research.

A part of Carnegie Mellon’s School of Computer Science, CMU’s Robotics Institute is the only institution in the country offering M.S. and Ph.D. programs, as well as an undergraduate minor in robotics. Stanford, MIT and Berkeley offer competitive robotics education programs, but they do not offer formal degrees.

Technology transfer is enabled through industry-research partnerships at the Robotics Institute. Affiliate companies participate by sponsoring specific research projects. In return, they receive research results prior to public release; access to highly trained research personnel; information on promising robotics talent and graduate students and access to the Institute’s vast library, archives, global affiliations and other additional resources and activities.

Pennsylvania was ranked third in the country in both number of awards and total National Science Foundation (NSF) funding for robotics research between 1989 and 2001.

Since 1989, the Pittsburgh region has received more than 40 grants, 35 of which were sponsored by Carnegie Mellon, accounting for nine percent of all robotics research funding awarded by the NSF between 1989 and 2001. This funding was more than any other institution.
Robotic in the Pittsburgh Region (cont.)

During the 2002 fiscal year, total research volume for Carnegie Mellon’s Robotics Institute alone was $33.5 million. Funds were obtained from a variety of sources including DARPA, NASA, the NSF, private industry and other federal and non-federal sources.

Robotics Talent

The Robotics Institute currently employs more than 350 faculty, staff, visitors and students; almost half of these positions (123) are research staff positions.

2002 Employment at the Robotics Institute and Its Affiliated Centers

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<tr>
<th>Institution</th>
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<td>Field Robotics Center</td>
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<td>The Vision and Autonomous Systems Center</td>
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<tr>
<td>The Center for Integrated Manufacturing Decision Systems</td>
<td>26</td>
</tr>
<tr>
<td>The National Robotics Engineering Consortium</td>
<td>27</td>
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</table>

A considerable robotics talent base could be built on the established reputation of regional robotics researchers. The U.S. Patent and Trademark Office awarded 1,917 patents for robotics-related technologies between January 1, 1996 and June 4, 2002. Of these patents, 26 were attributed to residents of Pittsburgh. Of Pittsburgh’s 26 patents, employees of Carnegie Mellon received 13. Nine patents were assigned to universities and companies in Pittsburgh, four of which were assigned to Carnegie Mellon.
Regional Industry Base

Research, talent and technology resources alone do not create a successful industry cluster. In the year 2003, Pittsburgh made significant efforts to translate its historic robotics research expertise into a working and thriving industry base.

The Robotics Foundry is a Pittsburgh-based, independent, non-profit economic development organization that directs programs and initiatives intended to accelerate the growth of agile robotics technologies and to establish a $1 billion industry cluster in the newly designated “RoboCorridor,” encompassing southwestern Pennsylvania.

The RoboCorridor, anchored by CMU’s Robotics Institute, encompasses a wide range of robotics-related organizations and initiatives, including the University of Pittsburgh School of Engineering and Swanson Center, the Software Engineering Institute and TIDE center in Pittsburgh, The Electro-Optics Center in Kittanning, the newly formed National Center for Defense Manufacturing and Machining in Latrobe, various defense-related engineering and manufacturing organizations based in Johnstown, and the Applied Research Laboratory at The Pennsylvania State University in State College.

The Robotics Foundry is the result of a merger between two previously independent economic development organizations focused on robotics, the Pittsburgh Robotics Initiative and the National Center for Defense Robotics (NCDR).

The Foundry’s mission is being implemented through three sets of activities: business development, technology transition and industry partnerships.

To date, funding for the Robotics Foundry includes $500,000 from regional foundations, a $1.6 million commitment from the Commonwealth of Pennsylvania and $1.5 million from the 2003 defense budget to fund initial NCDR-directed projects. The Foundry also has submitted $24 million in 2004 federal appropriation requests.
Currently the organization has a membership of 35 companies, the majority of them based in southwestern Pennsylvania. The Pittsburgh Technology Council has a current membership of about 14 businesses with a primary focus in robotics; however more than 60 companies extend the field into the wider arena of enabling technologies and automation, such as electro-optics. (See “Electro-Optics in the Pittsburgh Region” related article.)

At least two world leaders of robotic engineering are based in southwestern Pennsylvania — RedZone Robotics and McKessonHBOC Automated Healthcare.

RedZone Robotics is the world leader in robots and mobile equipment that work where people cannot. The company focus is on the construction and field service automation industry by developing innovative products that reduce costs, simplify operations, increase work quality and provide a safe work environment for customers. RedZone’s robots are especially designed to clean, inspect and rehabilitate pipes, tanks, nuclear facilities and other hazardous or hard-to-reach environments.

McKesson designs and manufactures hospital drug distribution systems that automate the storage, retrieval, dispensing, restocking and crediting of unit dose, bar-coded inpatient medications. The company’s products reduce medication errors, increase cost savings and improve the quality of care.

Other successful robotics and automation companies headquartered in the region include Aethon, a developer of personal robots for both home and office; AssistWare, a designer of robotic devices with consumer applications, such as one that prevents drowsy drivers from leaving the road; CASurgica, which develops computer-assisted technologies to enable more accurate and less invasive surgery; and Pittsburgh Roboscope, a developer of surgical robotics for abdominal, neuro- and orthopedic surgery.

National robotics companies with a presence in southwestern Pennsylvania include Fanuc, a global company with 175 different models of manufacturing robots; Cegelec...
Robotics in the Pittsburgh Region (cont.)

Corporation, a $2 billion contracting and industrial automation company that employs more than 26,000; and American Robot Corporation, a manufacturer of industrial robots and motion controllers serving the automotive, aerospace, defense and general manufacturing industries.

Front Lines of Defense

Recent regional robotics efforts support the development of a core expertise in robotics for the defense industry.

The Defense Department’s Future Combat Systems (FCS) program was formed to develop network-centric concepts for a multi-mission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining and highly survivable in combat. The FCS aims to develop an ensemble of manned and unmanned ground and air platforms by 2010. This “robotic army” would be enhanced with artificial intelligence, affording the U.S. military more lethal and tactical capabilities, while removing human troops from the line of fire.

The FCS project is divided into three phases, the first of which, concept and technology development, received $154 million in funding and was led by Boeing’s defense unit.

The program currently is in its $14.9 billion system development and demonstration phase.

Carnegie Mellon has had representation on FCS projects, and estimated spending on future phases in which local enterprises are well positioned to take part, is projected at $34 billion.

In 2002, the Pittsburgh Regional Alliance and Carnegie Mellon formed the NCDR to support entry into FCS and other defense-related projects. Located in Lawrenceville, the NCDR obtained start-up funding from state, local and federal governments, as well as from foundations, private sources and FCS funds.
Robotics in the Pittsburgh Region (cont.)

As a facilitator bringing together the manufacturing expertise of local companies and the research experience of Carnegie Mellon, the NCDR (now merged with the Robotics Foundry) began the task of establishing the region as a center for research, development and production of mobile robotics and related artificial intelligence technologies. Its efforts were focused on encouraging major defense contractors to build development and engineering centers in the region.

The Regional Industrial Development Corporation of southwestern Pennsylvania also recently has acquired a 25-building industrial site in Lawrenceville and plans to develop a $13 million facility where small, start-up robotic companies can develop and manufacture their products. These proposed facilities are located in very close proximity to the NCDR.

**Evolution**

Collaborative efforts are already beginning to pay off. In August, Wexford-based Applied Perception landed a $750,000 federal grant to continue work on a robot that can retrieve injured soldiers from the battlefield. Applied Perception is creating the hardware and software and sensors for navigation and patient detection.

Likewise, Carnegie Mellon’s Intelligent Software Agents Group has been working with DARPA on a $5 million, five-year project to develop different aspects of multi-agent systems, such as scalability, robustness, service discovery and semantic interoperation. In the process they have devised a mock evacuation plan of the U.S. embassy in Kuwait in which software agents monitor intelligence reports related to the crisis and design a route map to the airport, thereby avoiding rebel roadblocks.

Public educational efforts for robotics have not been overlooked by the region, either. The Carnegie Science Center has developed a traveling robotics exhibit that brings Pittsburgh’s rich robotics tradition to others across the county. A state-of-the-art Robotics
Hall of Fame also has been proposed for development in the City of Pittsburgh to further general robotics awareness.

In November 2003, an inaugural online prototype of the Robot Hall of Fame went live. The successful evolution of an industry from emerging to thriving requires a considerable amount of collaboration between the public and private sectors. The organizations and centers previously discussed aim to lead the way in these type of collaborations, by uniting the regional robotics community for the realization of this emerging cluster's potential.

Visit: Carnegie Mellon University’s Robotics Institute at http://www.ri.cmu.edu

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