REPORT OF THE
SECRETARY OF TECHNOLOGY

Developing Virginia's Research & Development Strategy and Improving the Intellectual Property Policies of our Universities and Federal Labs

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

SENATE DOCUMENT NO. 32

COMMONWEALTH OF VIRGINIA
RICHMOND
2001

COMMONWEALTH *of* VIRGINIA

Office of the Governor

James S. Gilmore, III
Governor

Donald W. Upson
Secretary of Technology

January 31, 2000

The Honorable James S. Gilmore, III
Governor of Virginia
and
The Joint Commission on Technology & Science
and The General Assembly of Virginia

Dear Governor Gilmore, Members of the Joint Commission on Technology & Science and Members of the General Assembly:

I am pleased to submit to you *Strategic, Statewide R&D Recommendations for the Commonwealth of Virginia,* and *Recommendations for Improving the Intellectual Property Policies and Practices in Virginia's Public Universities and Federal Laboratories.*

Senate Joint Resolution 502 (1999) requested the Secretary of Technology develop a comprehensive statewide research and development (R&D) strategy for the Commonwealth and include a review of the intellectual property policies and procedures of the institutions of higher education and federal laboratories, incentives to participate in joint ventures, and best practices by which intellectual resources can be linked to commercialization to benefit the economy of Virginia.

As a basis for the R&D study, Chmura Economics and Analytics conducted a study of high technology growth opportunities for Virginia for Virginia's Center for Innovative Technology (CIT). Members of the Virginia Research and Technology Advisory Commission (VRTAC) together with senior members of CIT's staff reviewed that study with Dr. Chmura and developed a draft set of R&D recommendations, which were presented to the full membership of VRTAC at their October 3, 2000 meeting. Members of VRTAC and CIT staff working with the Chairs of VRTAC and the President of CIT developed the final set of five (5) recommendations described here.

The recommended R&D strategy is based upon the intimation that Virginia's future economic competitiveness will stem from its ability to innovate new ideas and then commercialize for consumer consumption. These, in turn, will depend on developing the highest quality intellectual property and human capital. The major avenues for developing intellectual property and human capital are by performing research and developing products in federal, university/non-profit or industrial installations. The recommendations focus on actions the Commonwealth can take to increase R&D funding to our universities and to encourage the performance of R&D in our companies. They are a step aimed at maintaining and increasing the Commonwealth's position of global, technology leadership

In addition, please find the intellectual property review segment of the report. This document contains the recommendations portion of the Intellectual Property analysis, *An Assessment of the Intellectual Property Policies and Practices in Virginia's Public Universities and Federal Laboratories,* previously submitted to the Governor, the Joint Commission on Technology & Science and Members of the General Assembly. Upon completion, the initial report was submitted to the Virginia Research and Technology Advisory Commission (VRTAC) for review and comment. It was anticipated that this recently established commission could provide the most informed opinions with regard to recommendations designed to strengthen and improve Virginia's intellectual property policies.

The report sets forth six (6) recommendations for improving the transfer and commercialization of Intellectual Property (I.P.) from Virginia's public universities and federal laboratories to Virginia companies. In addition, the study findings and recommendations suggest ways that an increased awareness of these assets and mechanisms might result in greater collaborations. It is envisioned that improved policies and procedures will lead to an increase in private sector investment in R&D performed in Virginia's universities and also enhance the environment and opportunities for creating innovative start-up companies driving new economic growth in the Commonwealth.

Sincerely,

Donald W. Upson

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REPORT OF THE SECRETARY OF TECHNOLOGY
PREPARED BY The Virginia Research & Technology Advisory Commission AND Virginia's Center for Innovative Technology

STRATEGIC, STATEWIDE RESEARCH AND DEVELOPMENT RECOMMENDATIONS FOR THE COMMONWEALTH OF VIRGINIA

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

COMMONWEALTH OF VIRGINIA
RICHMOND
2000

Executive Summary

The recommended Research & Development (R&D) strategy for Virginia is grounded in the notion that Virginia's future economic competitiveness will stem from its ability to innovate and then commercialize. These skills, in turn, depend on developing the highest quality intellectual property and human capital. The major avenues for developing intellectual property and human capital are by performing research and developing products in federal, university/non-profit or industrial installations.

Currently, the most propulsive economic clusters in Virginia for innovation and growth are *information technology & telecommunications*, *aerospace*, and *biotechnology*. In addition, in each of these sectors there is an advanced manufacturing or process component. (See report in Appendix A.) These closely track the list of target technology sectors developed independently by the Virginia Research and Technology Advisory Commission (VRTAC).

In order to ensure Virginia's continued technology leadership, VRTAC and Virginia's Center for Innovative Technology (CIT) recommend the following steps as the basis for Virginia's R&D strategy:

1.) Establish VRTAC as a permanent, funded body, supporting the growth and development of Virginia's R&D infrastructure.

2.) Permanently appropriate the Commonwealth Research and Technology Fund (CTRF), expanding it to a level competitive with other states over the next two budget cycles.

3.) Provide R&D tax credits to Virginia companies for cooperative research with our universities, specifically targeting propulsive technology clusters.

4.) Provide economic development incentives that will encourage the relocation or expansion of R&D facilities.

5.) Change existing Intellectual Property law to simplify and streamline University – Industry interactions.

Introduction

The idea behind a strategic R&D plan and this set of recommendations is that Virginia's future economic competitiveness will derive from our ability to create new products and processes and commercialize them. Innovation and the commercialization of new products and processes, in turn, will depend on our first developing the ideas and conceptions behind these new products as well as having the talented workforce to bring them into the marketplace.

The major avenues to develop innovative technologies and the scientists and engineers essential to this endeavor are to perform R&D in federal, university/ non-profit, and industrial laboratories. Funding for this R&D is provided by federal, state, and industry sources as well as private foundations.

Categories of Research & Development

The only category where Virginia has excelled is in federally-funded federally-performed R&D. This category generally has the least economic impact because much of it is defense oriented. What is needed is a strategy that increases R&D spending in other categories, such as, federal support for university-based R&D and industry-funded industry-performed R&D.

In the table below , our recommendations are targeted in precisely this fashion, with the goal of providing the necessary funding and /or incentives to grow the research base for our most competitive clusters:

Performer	Funder			Recommendation
	Federal	State	Industry	
University/ Non-Profit & Federal	✓	✓		Establish VRTAC as a permanent, funded body, supporting the growth and development of Virginia's R&D infrastructure.
University/Non-Profit		✓		Permanently appropriate the Commonwealth Research and Technology Advisory Fund (CTRF), expanding it to a level competitive with other states over the next 2 budget cycles.
University/Non-Profit & Industry			✓	Provide R&D tax credits to Virginia companies for cooperative research with our universities, specifically targeting leading technology clusters.
Industry		✓		Provide economic development incentives that will encourage the relocation or expansion of R&D facilities.
University/Non-Profit			✓	Change existing Intellectual Property law to simplify and streamline University – Industry interactions, including the transfer of patent ownership.

4.) The Commonwealth needs to create and develop an environment conducive to the expansion of existing R&D facilities in Virginia or the relocation of R&D facilities here. In the short term, this means targeting existing economic development incentives, such as, the Governor's Opportunity fund, at R&D facilities. The Company Attraction component of the CTRF is a good example of existing incentives.

Targeting facilities in advanced manufacturing, such as, biotech manufacturing or Semiconductor fabrication facilities is particularly important here because these advanced manufacturing capabilities underpin the technology clusters important to Virginia's future

In the longer term, VRTAC through its membership needs to examine and recommend incentives focused on the most propulsive technology clusters. In biotechnology for example, Virginia may need to look at issues, such as, the availability of wet lab space or access to capital.

5.) Finally, unless existing Intellectual Property law is simplified and streamlined, recommendations focused on promoting University – Industry interactions will have little effect. A tax credit for sponsoring research in a university will make little sense to a company if the results of the research are difficult to exploit commercially.

The most important change Virginia universities could make is to develop a simple, statewide framework for the transfer or licensing of Intellectual Property to companies. Additionally, the legislature should change existing law to allow the universities' Boards of Visitors to transfer patents to companies on a case-by-case basis rather than requiring the petitioning of the Governor and his signature for such transfers.

Propulsive Technology Clusters

The report on "Identifying High-Tech Growth Opportunities in Virginia" by Chmura Economics & Analytics is attached as Appendix A to these recommendations. That report identifies *information technology & telecommunications*, *aerospace*, and *biotechnology* as the technology clusters that are important to Virginia's future. The report comes to its conclusions by looking at national and international opportunities and calibrating them against Virginia's potential. Clusters are made up of companies with buying, selling and R&D relationships. For example, the biotech cluster includes companies developing drugs as well as those testing drugs for federal approval. The aerospace cluster consists of interdependent companies including those that develop aircraft as well as those producing navigation and search equipment.

VRTAC, independently, found several broad technology areas of critical importance to Virginia. They include information technology & telecommunications, biotechnology, advanced materials & nanotechnology and technology contributing to advanced manufacturing on their list -- noting that these technologies will enable developments in areas such as, Internet Applications, communication security, new pharmaceuticals health diagnostics, new lubricants and remote sensors. Clearly VRTAC's list and Chmura's technology clusters are nearly congruent; moreover, when one recognizes the importance of advanced materials to the cluster Chmura identifies as aerospace, they are even closer.

Focus on these clusters or VRTAC's list of critical technologies clearly permeates the recommendations here from targeted tax credits to areas of focus for the CTRF. Beyond the recommendations listed here, it is also important for CIT to align its activities around these technologies. For example, CIT's funding of new Technology Innovation Centers in July 2001 should complement investments of the CTRF in our universities made in the same time period.

Identifying High-Tech Growth Opportunities in Virginia

Prepared for
Virginia's Center for Innovative Technology
October 2000

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* Justin P. Isaacs, Ph.D. Assistant Professor, Hampden-Sydney College prepared Appendix A and provided research support for the role of federal government, universities, and the private sector in research and development.

Recommendations

1.) VRTAC, as chartered last year, has broad responsibilities for developing and promoting an R&D agenda for the Commonwealth. Last March, prior to its appointment as a Gubernatorial commission, its members briefed Virginia's Congressional delegation individually on the Commonwealth's R&D priorities. These included both federal laboratories, such as, National Aeronautics & Space Administration facility at Langley and Thomas Jefferson National Laboratory, and the Commonwealth's research universities. Those same priorities are being used in the Request for Proposals for the CTRF.

VRTAC currently exists as a result of an Executive Order issued by Governor Gilmore last July. VRTAC needs to be established as a permanent body with its own funding from the Commonwealth.

2.) The CTRF is currently funded at $13 million matched on a one-to-one basis by the universities. Its administration is awkward -- the Department of Planning & Budget (DPB) administers the fund, with VRTAC providing R&D priorities and guidance on individual proposals, and Virginia's Center for Innovative Technology (CIT) providing technical and scientific reviews on individual proposals.

States, such as, Michigan and North Carolina, provide similar funding for R&D in the $50 million per year range. This fund needs to be made a permanent part of the Governor's budget with a level of funding that is competitive with other states in the next two budget cycles. The fund's administration should be simplified and streamlined – the involvement of VRTAC, DPB and CIT is unnecessarily complicated. CIT should administer the fund with VRTAC providing guidance to ensure the final selection of proposals reflects Virginia R&D priorities.

3.) Two types of R&D tax credits make sense for Virginia. The first is a state tax credit for research performed at an institution of higher leaning in the state by a company. This credit would promote the sponsoring of R&D by industry in our universities It would also encourage companies to locate significant parts of their operations in Virginia to take advantage of the tax credit. Often companies locate their R&D activities and divisions near universities where they sponsor R&D.

The second type of tax credit would be targeted at small start-up companies in the technology clusters pointed out in the Chmura report on " Identifying High-Tech Growth Opportunities in Virginia" -- information technology & telecommunications, aerospace, and biotechnology. (See Appendix A.) These credit would apply to internal R& D performed by the company but would be restricted to small start-ups. Because many start-ups have no revenues and for that reason pay no state tax, these credits need to be transferable or redeemable by the state. This tax credit is targeted to encourage the creation of new companies in leading technology clusters.

Preface

This study benefits from previous analysis that was sponsored by Virginia's Center for Innovative Technology concerning the growing high-tech industry in Virginia. For example, Pearson and Kulas (1997) found that between 1991 and 1996, employment at high-tech industries in Virginia grew at a slightly slower rate than that of all industries, but wages and salaries paid to high-tech workers were well above those for other industries in the state. Stough, Kulkarni, and Trice (2000) considered the distribution of high tech around the state and found that Northern Virginia contained the fastest growth and the greatest concentration of high-tech employment.*

The findings of earlier studies are confirmed in our research. The definition of a high-tech industry is one substantial difference between this report and previous studies of the high-tech industry in Virginia. Previous studies of technology in Virginia generally used a list of over 100 industries at the four-digit standard industrial classification level to define high-tech. One of the goals of this study, however, is to identify a definition of high-tech that is flexible and broad enough to change over time in a manner that captures the evolving high-technology industry. The definition of technology used in this study is explained on page 7 and in Appendix A.

* Historically, Virginia's Center for Innovative Technology has used the Modified Armington approach to define high-technology industries.

Executive Summary

- Technology has played a vital role in the economy over the last decade. The resulting acceleration in productivity enabled the economy to grow at a faster rate than otherwise and boosted living standards. The fastest growing metropolitan areas in Virginia possess the largest percentage of high-tech jobs.

- In Virginia, as with much of the nation, employment in the high-technology industry has grown at twice the pace of total employment over the last five years. In addition, high-tech industries in Virginia paid their employees an average $67,801 in wages and salaries in 1999 compared with an average of $33,069 for all industries in the state.

- There is a strong and distinct relationship between the Federal government and many high-technology firms in Virginia, which results in innovative products and services that ultimately make their way into the private sector. During 1998, Virginia received approximately $4.7 billion in research and development obligations from the federal government, which ranked it 4th in the nation.

- Virginia's seven major research universities and other institutions of higher education perform innovative research and contribute immeasurable amounts of human capital to the state that are necessary for a high-tech workforce. However, the state ranks only 17th in the amount its doctorate-granting institutions spend on research and development. In addition, none of the universities in Virginia were ranked among the 32 others in the nation that received 100 or more patents between 1995 and 1999. However, 5.5% of the state's patents in 1997 were issued to universities and colleges compared to an average 2.2% in the nation.

- Private industry is also an important source of innovation. Similar to the nation, patent awards in Virginia are increasing at a faster pace for high-tech industries than for all other industries. However, Virginia's pace of high-tech patent awards was slower than that of the nation from 1990 through 1998.

- Clusters of similar firms have located in close proximity to each other as the accelerated pace of innovation in the economy has increased the value of scientific research, education, and networking. Once established, these clusters have provided a powerful source of growth for regional economies.

- Looking to the future, Virginia's rising position as a high-tech leader in the nation will be dependent on the ability of entrepreneurs and mature businesses to turn innovations into marketable products. From the perspective of the current national economic environment and the capabilities of Virginia's high-tech industries, state support that further encourages the development of the following clusters are the most likely to provide the highest dividends to the Virginia economy:
    - Information technology and communications
    - Biotechnology and medical
    - Aerospace

- This study provides a high-level view of high technology in Virginia and should be supplemented with more detailed industry analysis to identify the needs and eliminate the inhibitors that will lead to increased innovation activity between industry, federal laboratories, and research universities.

Overview of Objective

Technology has played a vital role in the economy over the last decade. Not only have technology products provided more than half of the manufacturing output over the last five years; but by increasing the rate of productivity, technology has enabled the U.S. economy to grow at a faster rate and has raised the standard of living for Americans. Innovation is at the core of these trends. Research and development often leads to product discoveries that increase our productivity or enhance our living conditions. Society benefits, firms benefit, wage-earners benefit, and the economy grows.

Technology has played a vital role in the economy over the last decade.

Innovation is at the core of these trends. Research and development often leads to product discoveries that increase our productivity or enhance our living conditions.

The implication for regional economic growth is clear. Metropolitan areas with the highest concentration of high-tech industries experienced the fastest growth between 1990 and 1998 (DeVol, 2000, p. 10). In Virginia, employment in high-tech industries grew an annual average 6.3% from 1995 through 1999 while total employment increased an average 2.5% a year during the same period. Moreover, high-technology jobs pay much higher than average wages. In Virginia, the high-tech industries paid their employees an average $67,801 in wages and salaries[1] in 1999 compared with an average of $33,069 for all industries in the state.

In Virginia, employment in high-tech industries grew an annual average 6.3% from 1995 through 1999 while total employment increased an average 2.5% a year during the same period.

Although the implications for regional economic growth are clear, the practical application is not. Today's high-tech, high-growth industries may not be the stars of the next decade. Virginia's capabilities place it in a strong position among other states in today's high-tech environment. Yet, the question remains, how can state policies further the position of the Commonwealth for success in the coming decades?

The accelerated pace of innovation in the economy has increased the value of education and networking. In the new economy, lifelong learning has replaced task specialization, alliances and collaboration among firms is a more common theme than the independent ventures of the past, and invention is seen as a more important driver of growth than holdings in capital, labor, and land.[2] Consequently, one would expect a thriving, innovative economy to include increased interaction among businesses as well as with universities. From this perspective, geographic location is important. Thus, a technique known as cluster analysis is used in this study to identify groups of industries whose synergies are likely to promote further growth.

The accelerated pace of innovation in the economy has increased the value of education and networking.

[1] Wages and salaries include some stock options that were exercised.
[2] See Stough (2000, p. 9), for a more extensive comparison of the attributes of the old and new economies.

One quality of the old economy that has not died, however, is that only the best firms survive. Some industries outperform others. Changes in consumer spending patterns, new products, and labor-saving devices all affect the success of industries. Successful investors shift their funds to firms that are expected to experience the fastest growth. Similarly, government agencies steer grants toward firms that are expected to succeed.

One quality of the old economy that has not died, however, is that only the best firms survive.

This study seeks to identify Virginia's high-tech capabilities as well as the high-tech environment in which the state exists. The capabilities and external environment that are summarized will be used to identify industries that possess the greatest potential for being counted among the high-tech industries of the next decade. The goal of this process is to identify current and emerging high-tech industry clusters that can be targeted for increased federal and state research and development investment. Not all of the identified clusters are fully developed. Most of the clusters, for example, can benefit from additional research at local universities. As noted later, the quantitative process used here to target high-tech industries should be supplemented with input from industry participants and experts who can identify nuances of industry interactions that are not evident in the data.

This study seeks to identify Virginia's high-tech capabilities as well as the high-tech environment in which the state exists. The capabilities and external environment that are summarized will be used to identify industries that possess the greatest potential for being counted among the high-tech industries of the next decade.

An earlier study, "An Overview of the High-Tech Industry in Virginia," defines high-technology industries[3] and provides a view of the current structure of the high-tech industry in Virginia. This study builds on the foundation of the first study by assessing which high-tech industry clusters in the state, whether emerging or mature, have the greatest potential to thrive in the economic environment and the innovative infrastructure of the new economy while providing the greatest gains to the state's citizens.

[3] Industries qualify as high-tech if they possess at least double the percentage of employment in technology-oriented occupations as that of the average for all industries and if their percentage of employment in research and development is at least 80% of the industry average. See Appendix A of Chmura and Battle (2000) for more information.

Research, Innovation, and Firm Location

Innovation is a driving force of the new economy. Patents, which are a measure of innovation, show that the pace of innovation has accelerated and the product focus has shifted. From 1980 through 1989, patents grew at an annual average pace of 3.3% in the nation and 3.5% in Virginia. From 1990 through 1998, the annual average pace of patent awards increased to 8.8% in the nation and 4.4% in Virginia. Information technology[4] accounted for 9.0% of U.S. patents awarded in 1980 and grew to 25% by 1999, while health technologies accounted for 6.0% of U.S. patents awarded in 1980 and grew to 13% by 1999 (Hicks, Breitzman, Olivastro, and Hamilton, 2000, p. 4).

Innovation is a driving force of the new economy.

Innovations have the power to create new industries and reshape existing industries. In the process, some regional economies thrive by creating many new and often better paying jobs for every job that is eliminated by change. On the other hand, some regions struggle to restructure, when new jobs are not created fast enough to offset job losses in industries with declining competitive advantage. The ability of an economy to benefit from the transformation brought about by technological change is based on many factors.

Studies indicate that local scientific research is one of the factors important to the successful development of a region's high-tech industry (Hicks, Breitzman, Olivastra, and Hamilton, 2000, p. 11 and Keller, p. 27). This finding seems counter-intuitive in an age of increased access to information via the Internet. Even so, Hicks, Breitzman, Olivastra, and Hamilton report, "...we find evidence that technological development has strong links to local scientific research."

Where does local scientific research in a region take place? Universities can play a strong role. In addition, federal laboratories as well as federal contracting and grants for research and development create centers of scientific research. Private industry also supports scientific research through its own efforts to enhance products and services. Finally, state governments play a role in scientific research by providing grants for research and development and encouraging a collaborative relationship between firms, universities, and the federal government. In the next few sections of this report, the role of

Studies indicate that local scientific research is one of the factors important to the successful development of a region's high-tech industry.

[4] Information technology is defined in the Hicks et al. study as computers, peripherals, telecommunications, semiconductors, electronics, and software. Health technologies comprise biotechnology, pharmaceuticals, medical electronics and medical equipment.

federal government, state government, universities, and individual firms will be assessed with regard to their contribution of research and development to high-tech firms in Virginia.[5]

Local scientific research that occurs through the interaction of universities and government sectors with private enterprise can serve as a catalyst in innovation and high-tech growth in a region.

Local scientific research that occurs through the interaction of universities and government sectors with private enterprise can serve as a catalyst in innovation and high-tech growth in a region. Consequently, it is not surprising to find that the majority of the high-tech jobs in Virginia are found in metropolitan areas that are within close proximity to research universities.

In the current economy that places a premium on innovation, high-technology industries will remain vital to a region's economic health. As shown in the next few sections, the interaction of universities, businesses, and government entities plays a strong role in supporting that growth.

[5] By definition, the high-tech industry employs a larger proportion of research and development workers than other industries. High-tech industries are defined in this study as those that possess at least double the employment in technology-oriented occupations as that of the average for all industries and employ research and development scientists and engineers at a rate of at least 80% of the industry average for research and development performing industries. See Appendix A of Chmura and Battle, August 4, 2000, for more detail.

The Role of the Federal Government in Virginia's High-Tech Industry

There is a strong and distinct relationship between the Federal government and many high-technology firms in Virginia, which results in innovative products and services that ultimately make their way into the private sector.

The federal government supports research and development in a variety of ways that can lead to the creation of innovative products in the private sector. The majority of the support falls into two categories, which are addressed in this section: federal procurement contract awards and grants. Procurement contract awards are purchases of goods and services by various federal agencies. The focus in this study is on "research and development" purchases because of their important role in innovation and high-technology industries. Federal grants for research and development, which represent financial assistance to carry out approved activities, are also assessed.

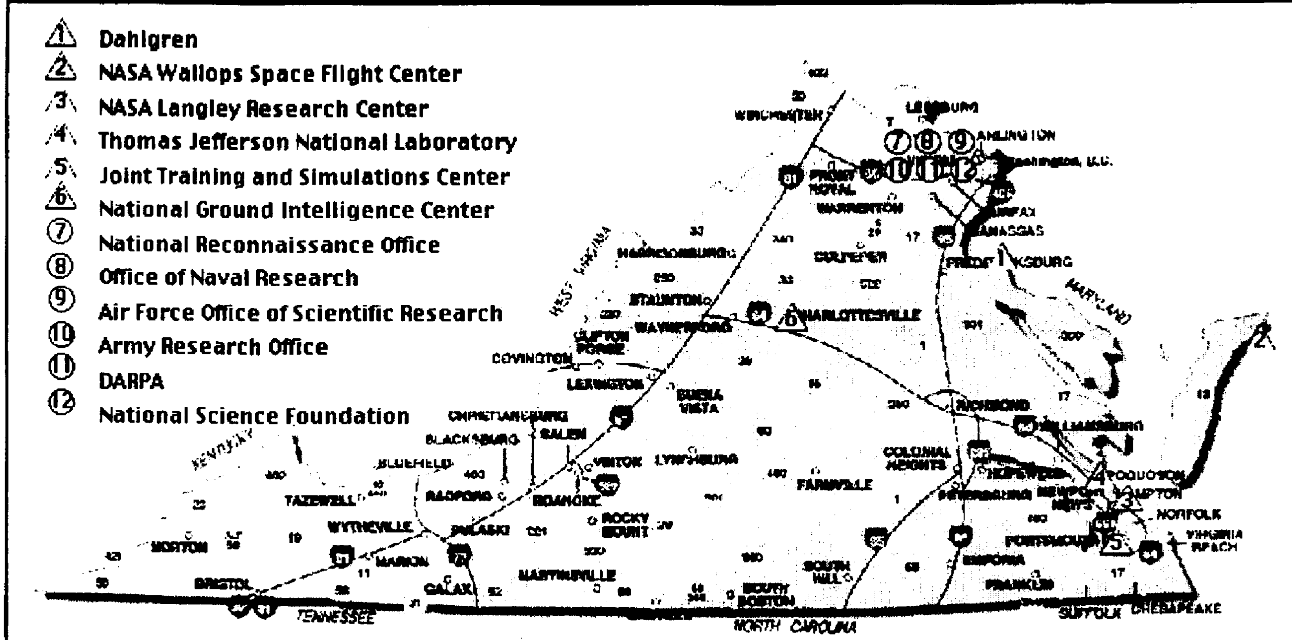
There is a strong and distinct relationship between the Federal government and many high-technology firms in Virginia, which results in innovative products and services that ultimately make their way into the private sector. The concentration of Internet firms in Northern Virginia is the most prominent example in Virginia of the benefit private firms have derived from the federal government—in this case, from the Pentagon.

The proximity of the state to the nation's capital is one of the factors encouraging the strong relationship between federal spending and Virginia's firms. The size and amount of Federal labs and installations that reside in Virginia (see Figure 1) also encourages the federal government to purchase from firms in Virginia. In fiscal year 1999, for example, Virginia received $18.6 billion in federal procurement contract awards or 10.7% of all awards in the nation. Virginia ranked second among the states behind California. At the firm level, six of the top ten companies in the nation that receive federal procurement contracts have a strong presence in Virginia.[6]

Approximately 12.3% or $24.5 billion of all federal procurement contracts in fiscal year 1999 were awarded for research and development. High-technology firms received $845.6 million or 3.4% of the research and development contracts awarded[7] in Virginia in fiscal year 1999 (see Table 1). As shown in Chart 1, 42.2% of the research and development contracts were awarded to engineering and architectural service firms and another 24.6% went to firms that provide research, development, and testing services in Virginia.

[6] The top 10 federal procurement contracts in fiscal year 1999 were (in order of largest, first): Lockheed Martin Corporation; Boeing Company; Raytheon Company, Inc.; General Dynamics; Northrop Grumman Corporation; The University of California; United Technologies Corporation; TRW, Inc; Litton Industries, Inc.; and CBS Corporation.
[7] State rankings are not available for federal contract awards to perform research and development that are awarded only to high-technology firms. However, in 1999 Virginia ranked 2nd in the nation for total federal contract awards to perform research and development with $2.2 billion. California was ranked first and Texas was ranked third.

Figure 1: Federal Laboratories, Centers, and Agencies in Virginia



Source: Virginia's Center for Innovative Technology.

Federal obligations, which includes grants, provide a broader measure of federal spending than contract awards; but these data are only available through fiscal year 1998. During 1998, Virginia received approximately $4.7 billion in research and development obligations from the federal government, which ranked it 4th in the nation behind California, Maryland, and Ohio (see Table 2). The Department of Defense provided 10.5% of the obligations to Virginia.

Defense Spending

From the 1940s until the recent end of the Cold War, much of the emphasis in federal science and technology funding was directed towards national security. In many cases, the federal government and the contractor firm anticipated that technologies originally developed for the military would become commercialized in private applications. Deep cuts in defense spending throughout the late 1980s and 1990s caused the federal government to encourage the defense industry to look towards commercial production (Hetrick, 1996, p. 60). Consequently, there has been a distinct shift away from large government funded projects to more directed technology areas, usually those providing the greatest commercial potential (KTEC, 2000, p. 32). Programs such as the Technical Reinvestment Project (TRP), with an initial funding of nearly a half-billion dollars, and

Table 1: Distribution of Federal Procurement Contract Awards for Research and Development to Virginia High-Tech Industries, 1999

		Dollars, Thousands	% of Total
273	Drugs	509	0.06
357	Computers and office equipment	1,621	0.19
366	Communications equipment	53,666	6.35
369	Miscellaneous electrical machinery	230	0.03
372	Aerospace	137	0.02
376	Guided missiles, space vehicles	38,321	4.53
381	Search and navigation equipment	125,802	14.88
382	Measuring and controlling devices	218	0.03
481	Telephone communications	465	0.06
737	Computer and data processing services	59,757	7.07
871	Engineering and architectural services	356,947	42.23
873	Research, development, and testing services	207,489	24.55
	Total	**845,162**	**100.00**

Source: U.S. General Services Administration, Federal Procurements FY 1999.

Small Business Innovation Research (SBIR) grants, which provide seed money for small businesses, reflects this change in emphasis.

Even though defense spending declined in real terms over the last decade, the large military complex in Virginia provides a catalyst for much of the federal research and development funding that occurs in Virginia today. High-tech industries in Virginia remain a significant beneficiary (See Chart 1). Defense expenditures on research and development in Virginia's technology industries accounted for 76.5% of the federal procurement contracts received in fiscal year 1999 varying from a low of 72.1% in the third quarter of 1999 and a high of almost 90% of all federal contract awards in the fourth quarter of 1998 (see Chart 2).[8]

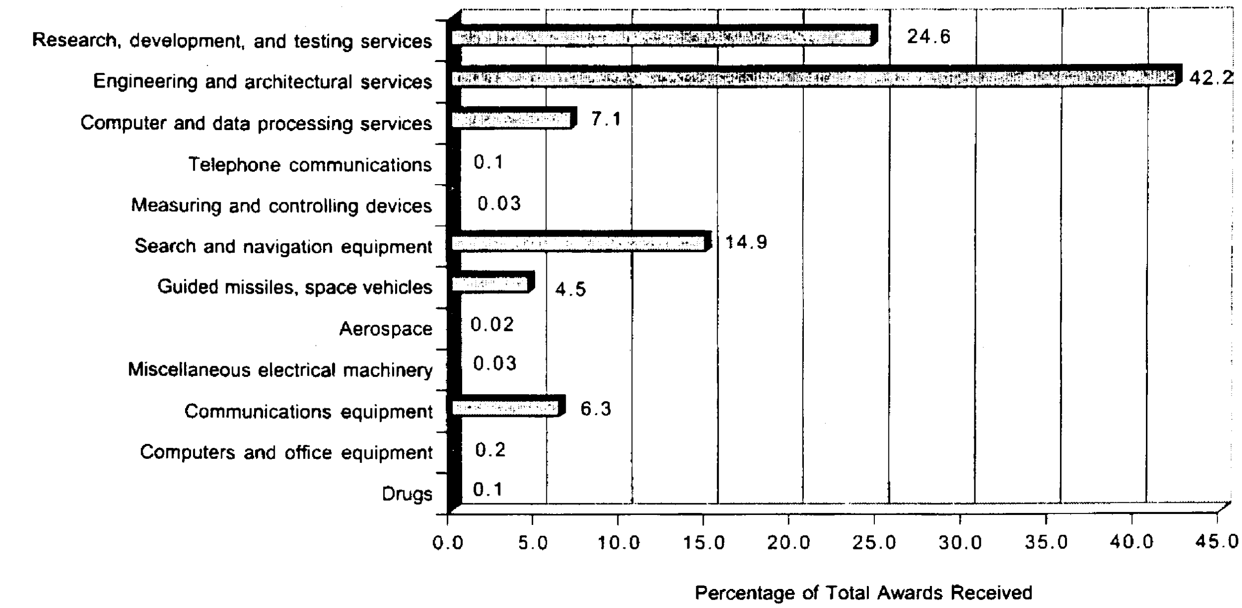
Even though defense spending declined in real terms over the last decade, the large military complex in Virginia provides a catalyst for much of the federal research and development funding that occurs in Virginia today. High-tech industries in Virginia remain a significant beneficiary.

<u>Small Business</u>

The growth of small firms and their success rate are important factors in high-technology industries, and they have also benefited from federal contract awards for research and development. In fiscal year 1999, 43.9% of federal research dollars went to high-tech firms classified as small businesses with the percentage varying from 16.1% of all federal research and development contracts awarded in Virginia in the fourth quar-

[8] This figure includes all work performed in the state, regardless of the firm's home office location.
[9] The small business classification refers to firms with fewer than 500 employees.

Chart 1: Distribution of Federal Procurement Contract R&D Awards to Virginia's High-Tech Industries, Fiscal Year 1999



Source: U.S. General Services Administration, Federal Procurements, FY 1997.

Table 2: Percentage Distribution of Federal Obligations for Research and Development Selected Agencies, Top Ten States, FY 1998

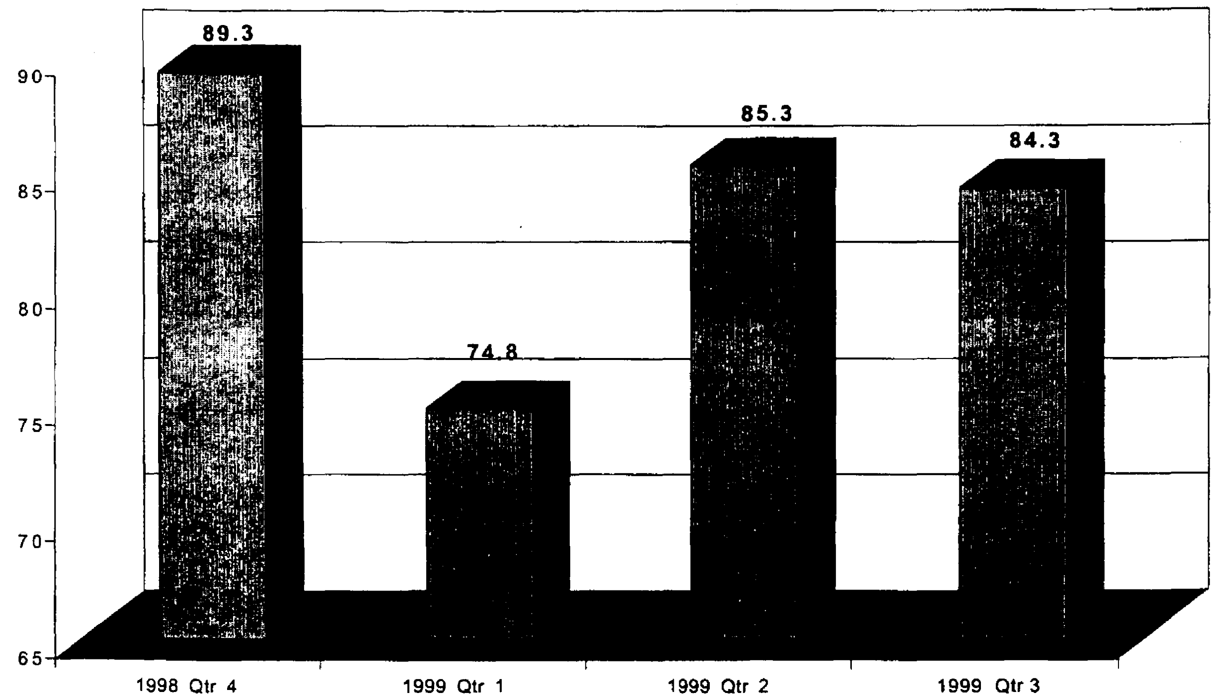
Rank	State (in order of total Federal research & development obligations)	(Thousands) Total	Total	Dept of Agriculture	Dept of Commerce	Dept of Defense1	Dept of Energy	Dept of Health & Human Services	Dept of the Interior	Dept of Transportation	EPA	NASA	National Science Foundation
	Total	**70,512,996**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
1	California	12,215,846	17.3	5.5	8.5	18.3	17.4	11.2	7.0	4.2	5.6	27.6	15.2
2	Maryland	7,964,210	11.3	9.6	36.7	7.7	1.0	23.7	2.3	4.3	1.4	14.3	2.7
3	Ohio	5,562,227	7.9	1.1	0.5	13.0	0.3	2.6	1.0	2.6	11.4	5.1	1.7
4	**Virginia**	**4,678,946**	**6.6**	**0.7**	**1.4**	**10.5**	**1.5**	**1.2**	**8.2**	**5.4**	**3.8**	**5.9**	**3.1**
5	Texas	4,110,756	5.8	4.4	1.3	3.1	0.4	3.8	4.3	2.2	2.6	23.8	3.1
6	Georgia	3,442,612	4.9	3.2	0.5	8.5	0.2	2.3	1.5	0.9	2.8	0.2	1.6
7	Massachusetts	3,112,271	4.4	1.6	4.7	4.1	1.7	8.2	1.1	6.7	3.4	1.5	7.6
8	Florida	2,752,371	3.9	2.5	4.9	5.6	1.0	1.1	5.4	1.1	1.6	3.9	2.9
9	New York	2,551,833	3.6	2.4	1.9	1.7	9.4	7.9	1.5	1.7	1.5	0.6	7.8
10	District of Columbia	2,229,086	3.2	11.7	1.7	3.1	4.8	1.3	0.4	25.7	12.5	2.1	3.3

1 Beginning with Vol. 40, Department of Defense (DoD) research is reported separately from DoD development. DoD states that more than 90 percent of its development reported for "universities and colleges" is performed at off-campus, university-affiliated laboratories that are not involved in teaching.

NOTE: Only the following 10 agencies are required to report to this section of the survey: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, and Transportation; the Environmental Protection Agency; the National Aeronautics and Space Administration; and the National Science Foundation. The obligations of the 10 major R&D supporting agencies included in this table represent approximately 98 percent of total Federal R&D obligations in fiscal year 1998.

Key: EPA = Environmental Protection Agency
NASA = National Aeronautics & Space Administration

Chart 2: Percentage of Federal Government Procurement Contract R&D Awards to Virginia Firms from the Dept. of Defense



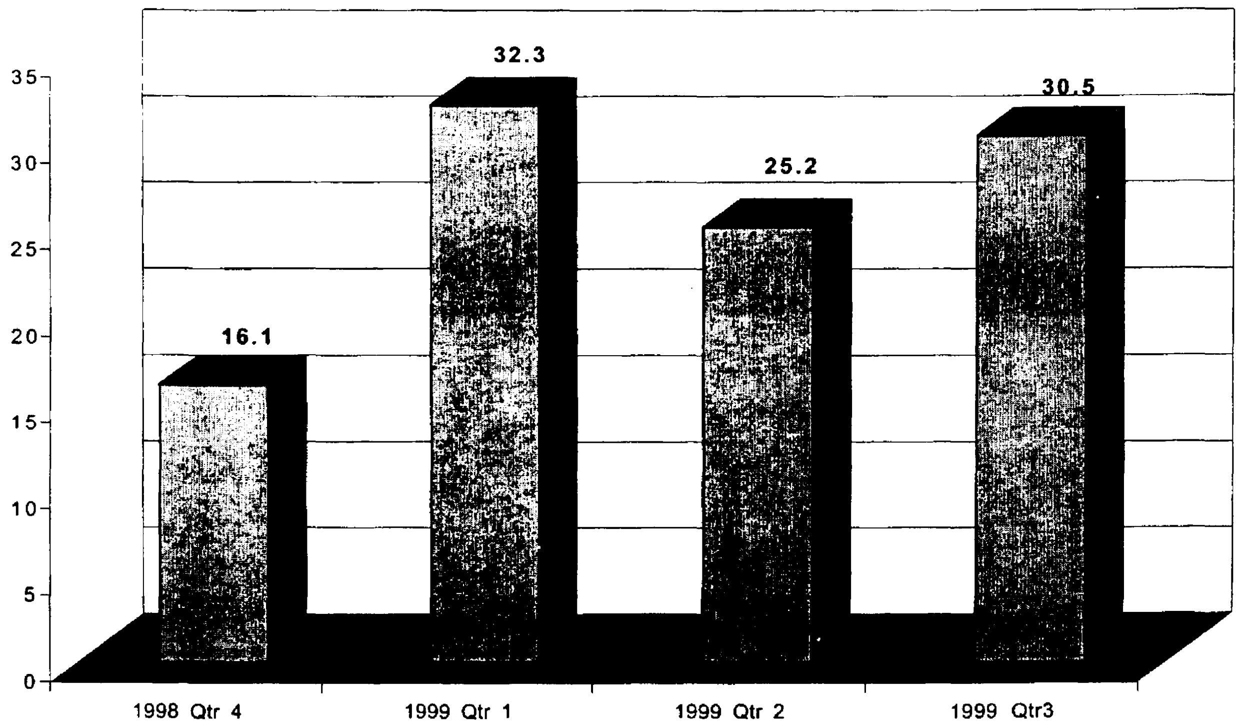
Source: U.S. General Services Administration, Federal Procurements, FY 1997.

ter of 1998 to 20.5% in the second quarter of 1999[9] (See Chart 3).

Virginia ranked third in the nation in SBIR awards from 1990 through 1997.

In addition to federal procurement contract awards for research and development, high-tech small business benefit from SBIR awards, which is seed money for firms with fewer than 500 employees. Under this program, research money is awarded in 'phases,' where phase I is designed to help in the development of an idea, phase II is intended to help in the production process, and phase III, if necessary, helps with commercialization of the product or service. Each subsequent phase is dependent on the success of the previous phase. As is to be expected, SBIR awards strongly favor technology areas where innovation can meet a national security need as well as have a future commercial impact. On the national level, information and communications made up 50% of SBIR funds from 1994 through1997, and components and materials made up 27% of SBIR awards (KTEC, 2000, p. 34). Virginia ranked third in the nation in SBIR awards from 1990 through 1997.

Chart 3: Percentage of Federal Government R&D Awards to Small Business Virginia Firms



Source: U.S. General Services Administration, Federal Procurements, FY 1997.

The Role of the State in Virginia's High-Tech Industry

Almost all states possess science and technology offices, many of which were not created until the mid-to-late 1980s (National Science Foundation, 1999, p. 1). Moreover, the National Science Foundation has found three common focuses among states (1999, p. 1):

- Maintaining and strengthening the research and development (R&D) capacity of the states' colleges and universities;
- Encouraging "home grown" businesses by providing support to entrepreneurs and small technology-based firms rather than seeking to recruit technology firms to locate within the state; and
- Facilitating the incorporation of new technology into processes and products.

Although CIT provides funding for research and development, another role that is just as vital in the new economy is the connectivity that it provides between universities and businesses as well as business-to-business.

The Commonwealth of Virginia focuses on each of the goals noted above. The state's role in strengthening research and development in its universities and colleges is addressed in the next section. The second and third goals noted above are largely accomplished by Virginia's Center for Innovative Technology (CIT), a state-chartered not-for-profit technology industry support center, which was created in 1984; and the Office of the Secretary of Technology, which was created in 1998. The Office of the Secretary of Technology is "...responsible to establish a policy environment for technology-led economic growth and an implementation of electronic government that will bring real value to the citizens of the Commonwealth" (www.sotech.state.va.us).

Although CIT provides funding for research and development, another role that is just as vital in the new economy is the connectivity that it provides between universities and businesses as well as business-to-business.[10] The Commonwealth Technology Research Fund (CTRF), for example, possesses the following three goals: (1) provide matching funds to leverage federal and private research investment in Virginia universities, (2) enhance the research capacity of academic departments with innovative research in technologies that have strong economic development potential, and (3) upgrade university research capacity in key departments in order to attract specific companies to expand or locate in Virginia. CTRF is administered by Virginia's Department of Planning and Budget while CIT is responsible for technical reviews of proposals.

[10] For an in-depth view of the role of CIT and the Secretary of Technology, see www.cit.org and www.sotech.state.va.us, respectively.

In addition, CIT supports a unique group of nine technology councils around the state that provide an opportunity for businesses to network. These councils offer a variety of support for technology firms—from informational meetings to directories that identify suppliers.

The Role of Research University in Virginia's High-Tech Industry

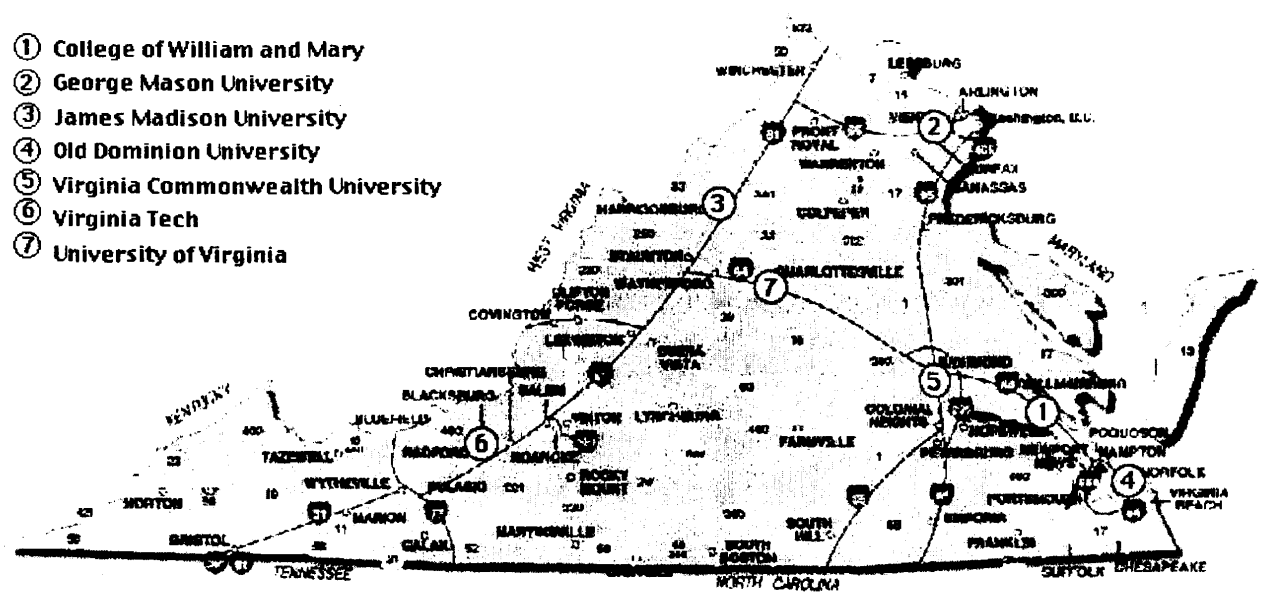
Research universities play a vital role in the success of the high-tech industry in ways that are clearly quantifiable and others that are difficult to measure. Specifically, institutions of higher learning not only perform innovative research and development, but they provide the education that is needed for a high-tech workforce.

Institutions of higher learning not only perform innovative research and development, but they provide the education that is needed for a high-tech workforce.

The Role of Education

Virginia's seven major research universities (see Figure 2) and other institutions of higher education contribute immeasurable amounts of human capital to the state. Technology industries, by definition, will thrive based on the education level of the labor force. Consequently, research and development performed by universities in Virginia not only brings dollars into Virginia, but also enhances the education of its workforce. While scientific research can lead to direct gains in productivity and economic competitiveness, technology transfer can also occur through the placement of graduates in the state's technology firms.

Figure 2: Virginia's Research Universities



Source: Virginia's Center for Innovative Technology

Table 3: R&D Expenditures at Doctoral-Granting Universities, By Rank, in Thousands of Dollars, 1998

Rank	State	Expenditures	Rank	State	Expenditures
1	California	3,301,972	27	Oregon	308,317
2	New York	1,881,994	28	Utah	249,147
3	Texas	1,667,654	29	South Carolina	238,872
4	Pennsylvania	1,333,226	30	District of Columbia	227,636
5	Massachusetts	1,322,092	31	New Mexico	226,071
6	Maryland	1,318,062	32	Kansas	211,465
7	Illinois	1,026,399	33	Oklahoma	206,627
8	Michigan	876,375	34	Kentucky	200,682
9	North Carolina	859,094	35	Nebraska	186,200
10	Ohio	805,015	36	Hawaii	148,007
11	Georgia	794,691	37	Mississippi	145,717
12	Florida	705,197	38	New Hampshire	117,323
13	Washington	527,805	39	Rhode Island	111,979
14	Wisconsin	527,286	40	Arkansas	111,173
15	New Jersey	484,260	41	Outlying Areas	86,622
16	Colorado	483,388	42	Nevada	83,888
17	Virginia	482,520	43	Alaska	75,606
18	Missouri	478,295	44	Montana	72,425
19	Indiana	424,722	45	Delaware	69,896
20	Arizona	405,999	46	Idaho	68,983
21	Connecticut	402,671	47	West Virginia	62,533
22	Alabama	402,610	48	Vermont	57,832
23	Minnesota	360,629	49	North Dakota	56,945
24	Iowa	357,927	50	Wyoming	48,500
25	Louisiana	340,741	51	Maine	33,106
26	Tennessee	340,444	52	South Dakota	25,140
	Total U.S.	**25,735,268**			

Source: National Science Foundation.

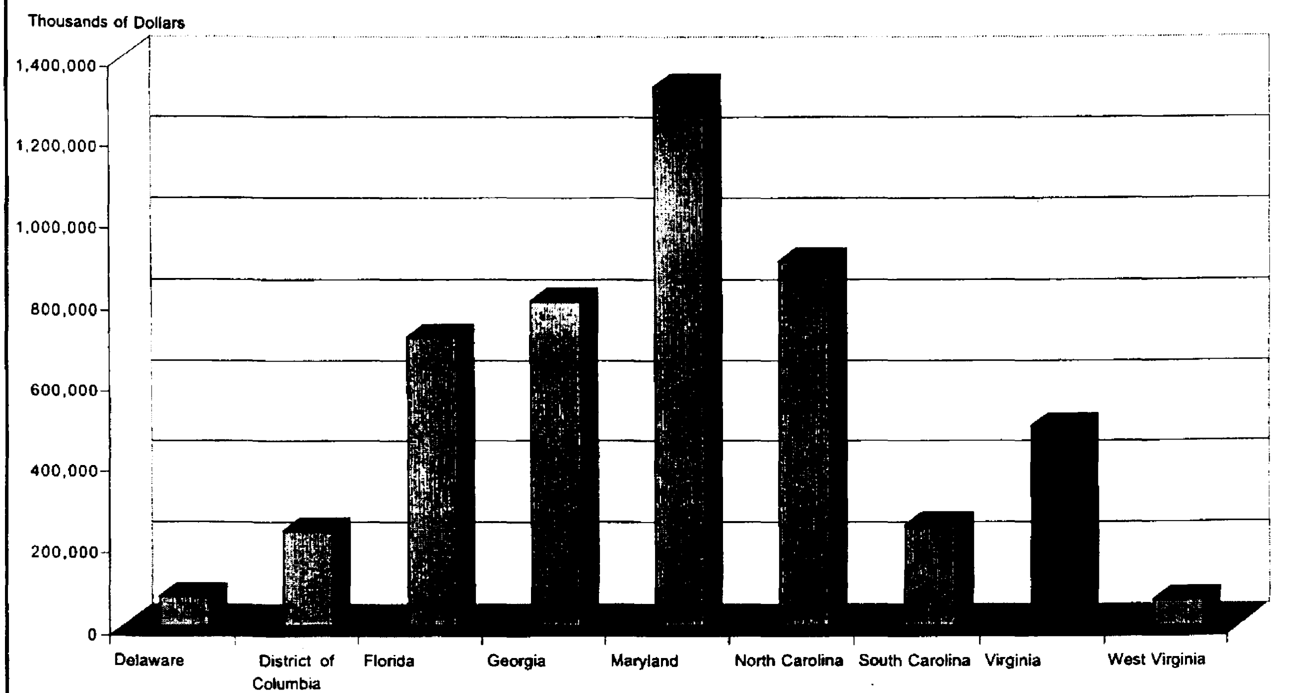
The location of a major research university within 30 miles of each of the largest metropolitan areas in Virginia is an important factor in the creation of high-tech clusters. As noted earlier, geographic proximity is one of the ingredients that has been found to spur the creation of marketable products from innovations. Not surprisingly, 87.3% of all high-tech jobs are in the seven major metropolitan areas in the Commonwealth (Chmura, 2000, p. 7).

The level of research and development at Virginia universities is strong but does not rank the state as highly as noted in the section on federal contract awards and grants.

Level of Research and Development at Virginia Universities

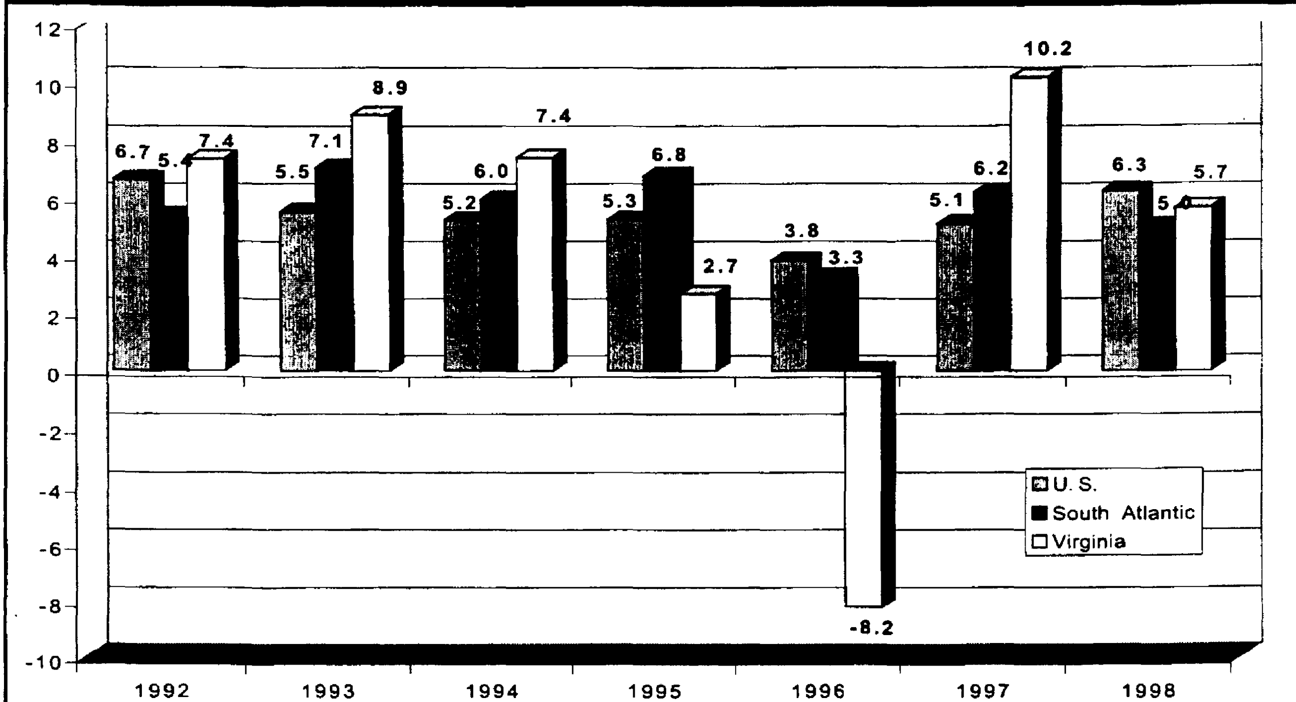
The level of research and development at Virginia universities is strong but does not rank the state as highly as noted in the section on federal contract awards and grants. Doctorate granting institutions in Virginia spent $482 million in research and

Chart 4: R&D Expenditures at Doctoral Granting Institutions in the South Atlantic Region, 1998



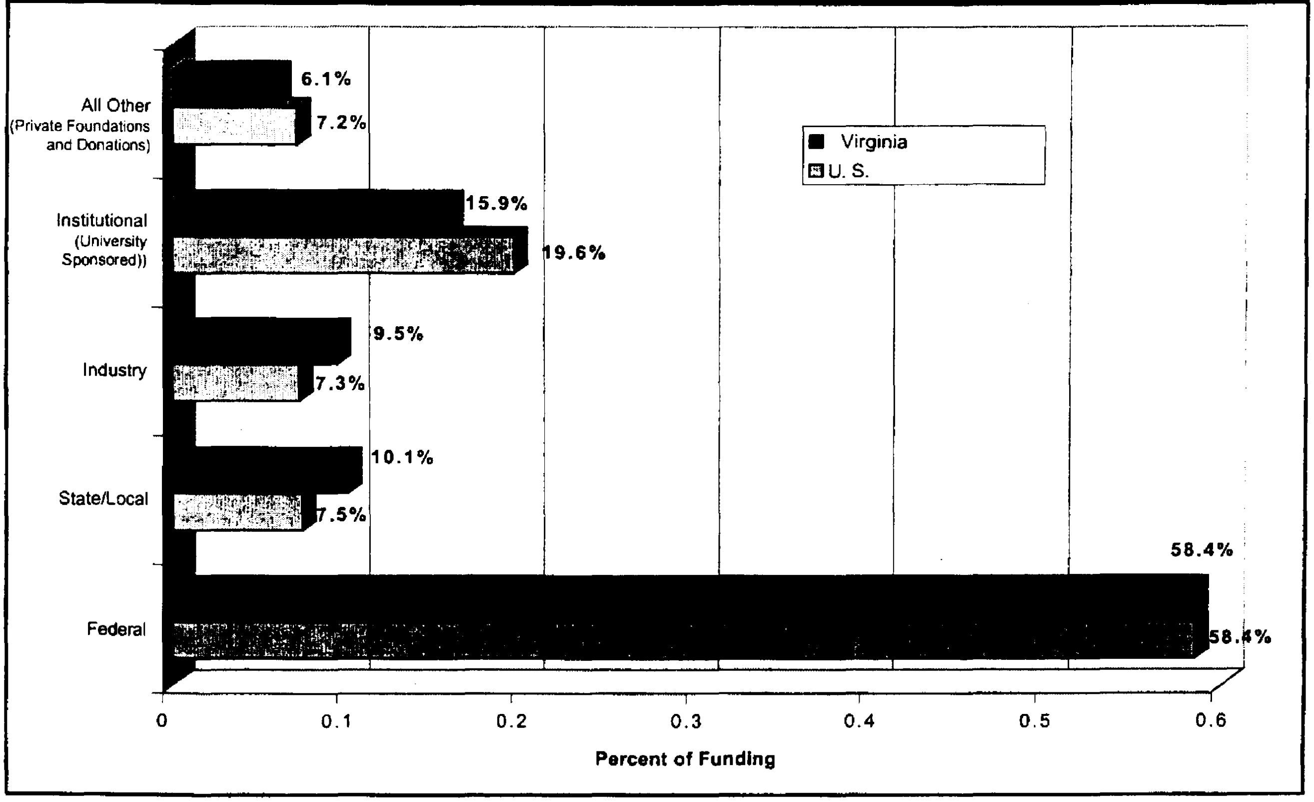
Source: National Science Foundation.

Chart 5: Annual Growth in R&D Expenditures at Doctoral Granting Institutions



Source: National Science Foundation.

Chart 6: Sources of R&D Funding at Doctoral Granting Universities, 1998



section on federal contract awards and grants. Doctorate granting institutions in Virginia spent $482 million in research and development in 1998 and ranked 17th among the states (See Table 3). As shown in Chart 4, Virginia ranks 5th out of nine states in research and development spending at doctoral universities when compared with its neighboring states in the South Atlantic region.

Since 1992, research and development expenditures in the nation and the South Atlantic states grew at least 5.0% a year (see Chart 5). Spending at Virginia universities outpaced the nation and South Atlantic during the early 1990s but experienced a sharp 8.2% decline in 1996.

Similar to the national average, the composition of research and funding at universities in Virginia leans heavily towards federal funding (see Chart 6) with nearly 60% of the funding originating from the federal government. Virginia universities rely more on industry, state, and local government for their funding of research and development. However, institutional (university sponsored) and other (private foundations and voluntary donations) funding falls short of the national average.

Similar to the national average, the composition of research and funding at universities in Virginia leans heavily towards federal funding (see Chart 6) with nearly 60% of the funding originating from the federal government.

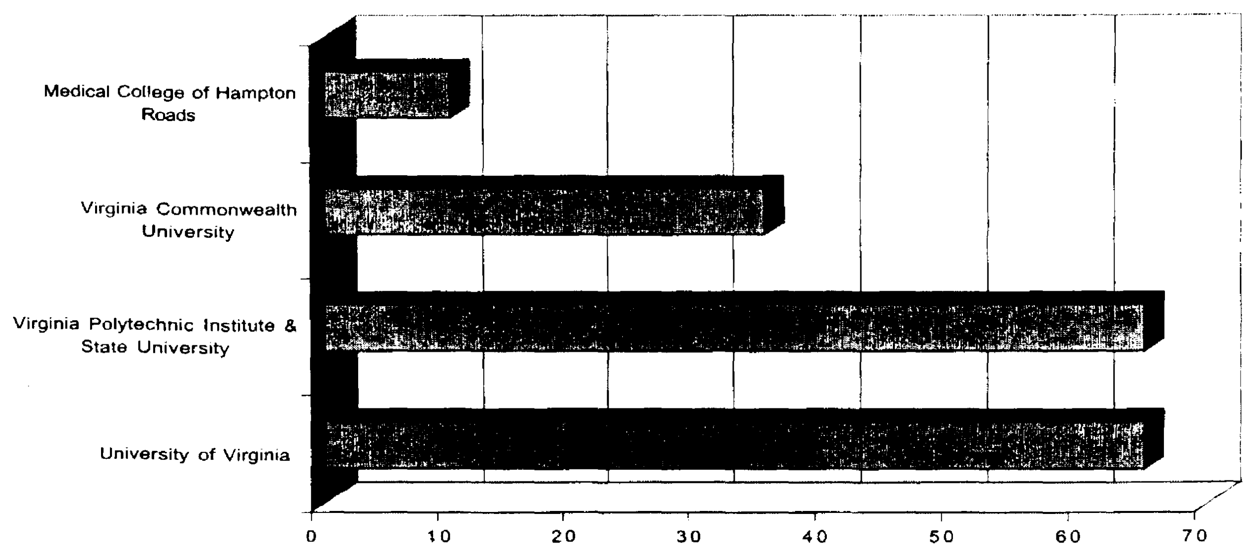
Patent Awards

The University of Virginia, Virginia Tech, and Virginia Commonwealth University lead other institutions in Virginia in the number of patents awarded from 1995 through 1999.

The number of patent awards granted is another measure of the level of research and development at universities and colleges. As a measure of research and development productivity, patents by universities suggest two key points. First, they suggest the obvious—an active level of research and development. Second, they measure the potential level of innovation and economic stimulation because patents are granted for new products and processes, which can, in turn, be used to generate economic development.

As shown in Chart 7, the University of Virginia, Virginia Tech, and Virginia Commonwealth University lead other institutions in Virginia in the number of patents awarded from 1995 through 1999. However, at a high of 65 patents for both the University of Virginia and Virginia Tech over this period, other universities in the country dwarf Virginia in the number of patents awarded in the last five years. The University of California,[11] at 1,568 patent awards, topped the national list of awards to a university system from 1995 through 1999. Other large recipients were: Massachusetts Institute of Technology (575), University of Texas (441), Wisconsin Alumni Research Center (336), Stanford University (327), California Institute of Technology (295), Johns Hopkins University (269), Cornell University (259), University of Pennsylvania (251), and the Research Foundation of the State University of New York (215).[12] In all, 32

Chart 7: Total Patent Award to Virginia Universities and Affiliates, 1995 - 1999



This chart reflects universities in Virginia that have received at least 5 patents in the five-year period shown above.
Source: U.S. Patent and Trademark Office.

[11] Includes the various locations of the University of California throughout the state.

universities were each awarded more than 100 patents from 1995 through 1999.

In all, 32 universities were each awarded more than 100 patents from 1995 through 1999.

Even though Virginia's universities and colleges lag other states in the number of patent awards, there has been a significant upward trend in the number of patents granted to Virginia's universities and colleges over the last five years. The seven universities shown in Chart 7 received a total of 19 patents awards in 1995 and 58 awards in 1999. As Hicks, et al. (2000, p. 8) notes, growth in university patenting across the country has been the norm. In fact, at the start of the 1990s, colleges and universities surpassed government laboratories in patenting. In addition, 2.2% of all patents issued in 1997 were assigned to a U.S. college, university or association of U.S. colleges and universities in 1997 compared with 0.8% of the total in 1984 (U.S. Patent and Trademark Office, 1998, p. 5). By comparison, 5.5% of all patents awarded in Virginia in 1997 were issued to universities and colleges in the state.

Growth in university patenting across the country has been the norm.

Fields of Study: University Strengths

Only two of Virginia's research universities are ranked in the top 100 for research and development expenditures from fiscal years 1991 through 1998: Virginia Tech, ranked 48th, and the University of Virginia, ranked 71st (National Science Foundation website, Table B-32, "total R&D expenditures at universities and colleges"). Virginia Commonwealth University is ranked 104th in the nation.

Virginia universities and colleges spend the majority of their research funds in the following three areas in fiscal year 1998: life sciences and medicine (51.2%), engineering (18.0%), and environmental sciences (12.0%), which suggests that Virginia universities are well placed to provide research support in technology industries such as drugs and medicine, medical equipment, engineering and architectural services, and research, development and testing services. However, Virginia's universities and colleges only devote 4.0% of research and development expenditures to math and computer sciences. In contrast, computer equipment and computer data processing services are substantial high-tech firms in Virginia. Yet, expenditures for all universities are colleges in the nation are similar: math and computers (4.1%), life sciences and medicine (56.6%), engineering, (15.8%), and environmental sciences (6.3%) (National Science Foundation website, Table B-31, "R&D expenditures at universities and colleges").

Only two of Virginia's research universities are ranked in the top 100 for research and development expenditures from fiscal years 1991 through 1998: Virginia Tech, ranked 48th, and the University of Virginia, ranked 71st

[12] The universities with the most patent awards are not necessarily the same universities that spend the most on research and development. The top ten Universities in 1998 regarding research and expenditures are (in descending order of expenditures): Johns Hopkins University, University of Michigan, University of California at Los Angeles, University of Wisconsin at Madison, University of Washington, University of California at Berkeley, University of California at San Diego, Massachusetts Institute of Technology, Stanford University, and Texas A&M University.

Research and Development in the Private Sector

Investment in research and development, when successful, leads to new products, procedures, and/or processes. With such technologies, companies can expand and create jobs and improve operating productivity. However, until research and development investments produce marketable goods or services, they provide little economic utility to the firm.

The amount that firms choose to invest in research and development becomes a matter of costs and benefits within the framework of its corporate strategy and philosophy on innovation.

Further, technology spillovers can conceivably be different for manufacturing firms versus research firms. Manufacturing firms generally utilize the technology directly in their products and processes, which can spillover into new companies and other innovations as competitors seek to create similar products. Research firms, on the other hand, can improve their service potential, contract related research and development, seek patents or licenses, and apply for more external funding (Barnett, Reutter, and Thompson, 2000). Technology firms may also receive intra-industry spillover by increasing their 'learning' or 'absorptive' capacity. Specifically, greater expenditures in research and development in technology industries may increase the firm's ability to exploit outside knowledge at an intermediate. This knowledge may then be used for applied development (Cohen and Levinthal, 1989, pp. 569-570).

<u>Research Intensity</u>

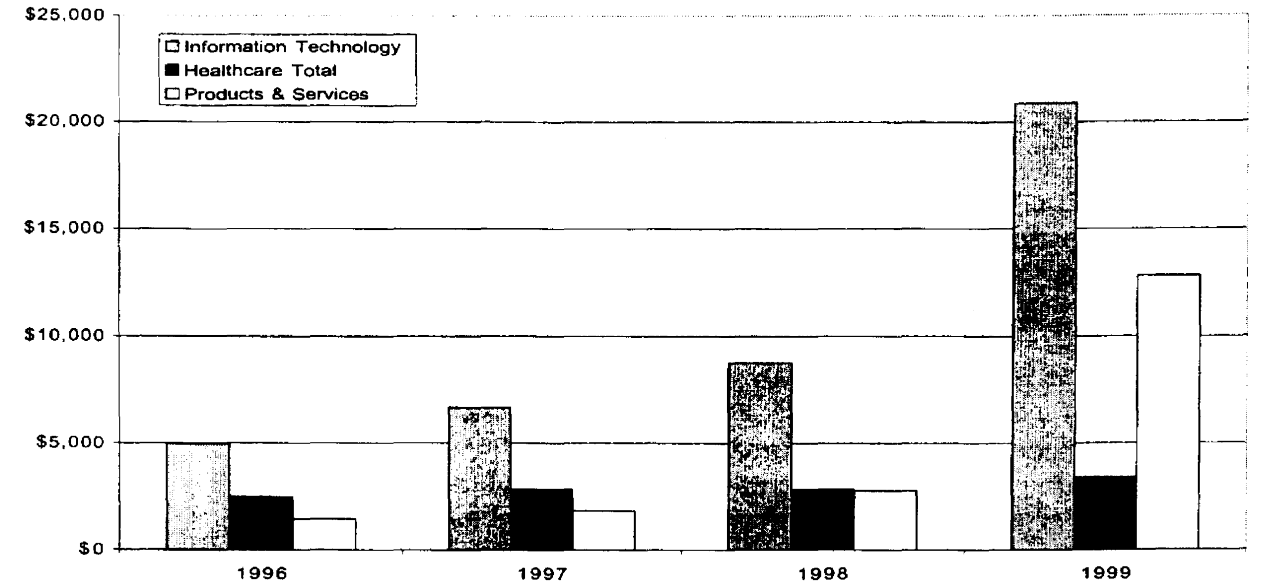
The amount that firms choose to invest in research and development becomes a matter of costs and benefits within the framework of its corporate strategy and philosophy on innovation. Short of an inclusive survey mechanism to determine firm-specific technology investment, the best proxies for firm behavior with respect to technology investment are: venture capital flows, patent awards, and federal assistance.

<u>Venture Capital Investments</u>

At the firm level, venture capital is a sign that the market believes in the future profitability of a company. At the industry level, investment capital flows suggest that investors believe in long-term growth for all of the firms in the industry. Over the last four years, venture capital investments have favored information technology (see Chart 8). As Chart 9 shows, information technology has remained important over the past four quarters with 53% of the funds going to information technology, 33% to products and services, and 14% to health care. Venture capital to Virginia firms in the second quarter of 2000

At the firm level, venture capital is a sign that the market believes in the future profitability of a company.

Chart 8: National Growth Trend of Venture Capital Funding



Source: PriceWaterhouseCoopers.

reflects this national trend. It is interesting to note, however, that of the $560 million raised in Virginia, $540 million (96%) went to firms in the Northern Virginia metro area (PriceWaterhouseCoopers, 2000, www.pwc.com). Such flows of capital to the information and technology industry suggest that Virginia, and Northern Virginia in particular, is well placed for continued growth in this industry.

From 1990 through 1998, patents to high-tech industries grew an annual average 4.4% in Virginia compared with an 8.8% growth rate in the nation.

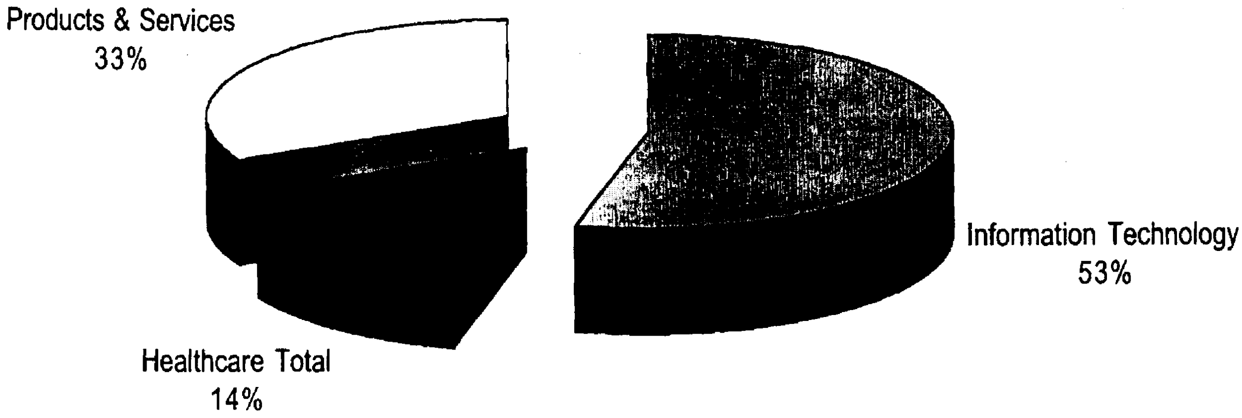
Patent Awards

Patents demonstrate a new product, procedure, or process. Firms that are granted patents are given exclusive rights to the particular product or process. Therefore, at a general level, patents measure the inventive output of firms (Hall, Jaffe, and Trajtenberg, 2000, p. 1). For the study in hand, patents, and the exclusive rights they provide helps to identify industries that may experience, at least in the short-run, economic growth.

As shown in Table 4,[13] Virginia industries produced a total of 1,051 utility patents in 1998. Almost 690 of the patents were awarded to high-tech industries in Virginia while 365 were awarded to non-high tech firms. During 1998, patents awarded to high-tech firms in Virginia grew by 44.7% compared with 33.1% in the nation. The long-term growth trend of patents is not as favorable in Virginia, however. From 1990 through 1998, patents to high-tech industries grew an annual average 4.4% in Virginia compared with an 8.8% growth rate in the nation.

[13] Table 4 also includes a small number of patents that were awarded to universities.

Chart 9: Number of Venture Capital Deals in 1999



Source: PriceWaterhouseCoopers.

Table 4: Patent Awards to High-Tech Industries in Virginia

	1994	1995	1996	1997	1998	TOTAL
SIC 13,29 Petroleum and natural gas extraction and refining	4	3	3	4	4	18
SIC 281,286 Basic industrial inorganic and organic chemicals	12	1	5	2	3	23
SIC 282 Plastic materials and synthetic resins	16	15	12	12	12	67
SIC 283 Drugs and medicines	16	20	28	39	50	153
SIC 285 Paints and allied products	7	3	2	2	4	18
SIC 286 Industrial organic chemistry	26	18	25	27	15	111
SIC 287 Agricultural Chemical	11	14	13	17	19	74
SIC 289 Miscellaneous chemical products	4	5	8	11	19	47
SIC 348, 3795. Ordnance except missiles	11	10	2	7	15	45
SIC 351 Engines and Turbines	5	6	9	3	10	33
SIC 355 Special industry machinery, except metal working machinery	36	37	29	31	27	160
SIC 356 General industrial machinery and equipment	29	30	24	22	38	143
SIC 357 Office computing and accounting machines	38	30	42	32	63	205
SIC 361, 3825 Electrical transmission and distribution equipment	19	25	18	15	21	98
SIC 362 Electrical indusrtria apparatus	13	7	13	5	18	56
SIC 365 Radio and television receiving equipment	9	8	10	10	20	57
SIC 366-367 Electronic components and accessories	128	136	136	122	185	707
SIC 369 Miscellaneous electrical machinery	7	5	7	3	7	29
SIC 372 Aircraft and parts	5	6	10	7	11	39
SIC 376 Guided missiles and space vehicles and parts	2	2	2	0	2	8
SIC 38 (Except 3825) Professional and scientific instruments	109	98	104	103	143	557
Total high-tech industries	**507**	**479**	**502**	**474**	**686**	**2,648**
All other (non-high-tech) industries	351	342	357	344	365	1,759
All industries	**858**	**822**	**859**	**818**	**1,051**	**4,408**

Source: U.S. Patent Office
*See notes to Table 7 in Appendix C. SIC 381 makes up 30% of employment for SIC 38 in Virginia.
Note: This list is missing SICs 481, 737, 871, and 873, which correspond to high-tech industries. These industries do not have corresponding patent classifications because they are service and design oriented.

Summary of Research and Development in the High-Tech Industry in Virginia

Virginia's high-tech industries benefit from research and development funded by the federal and state government as well as universities. The federal government, and particularly the Department of Defense plays a strong role by purchasing research and development services from businesses and universities in the state. With regard to Department of Defense contracts, Virginia ranks the second in the nation in the dollar amount of awards received.

The state does not rank as well with regard to research or innovation at its state universities. The Virginia university that spends the most on research and development ranks 48th in the nation. Consequently, it is not surprising that the state's universities rank low on the number of patents awarded over the last five years. In addition, the total patent awards in Virginia, which includes those from private business, have increased at a slower rate than that of the nation.

Although research and development at businesses, universities, and federal and state government, play a central role in the success of high-tech industries in Virginia, data are not available to directly quantify that role. Consequently, the next section of this study uses a variety of other indicators to identify Virginia's high-tech capabilities as well as the high-tech environment in which the state exists. As noted earlier, the goal of this process is to identify current and emerging high-tech industry clusters that can be targeted for increased federal and state research and development investment.

Identifying High-Tech Investment Opportunities in Virginia

The ultimate goal of this study is to provide the state with an economic rationale for the targeted allocation of research and development investment to high-tech industries that stand the best chance of enhancing the economic well-being of Virginians. The most effective strategy for this investment is to promote those industries that have the greatest potential for growth, based on recent and expected trends, and also have a significant impact on other industries in the Commonwealth. Fortunately, there is abundant economic information to incorporate in this decision-making process, but at the same time we recognize that valuable insight should be solicited from industry participants and experts who can identify nuances of industry interactions that are not evident in the data.

The concept of strategic industry clusters is familiar to economic development practitioners and other partners in the promotion of regional economic growth. An industry cluster is broadly defined as a group of entities that share an interdependence through trade relationships, shared labor pools, and the use of similar technologies. The entities that form a cluster go beyond industries to include research universities, state and local government, federal laboratories, and professional organizations.

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In contrast to policies that target a single industry in a region, industry cluster analysis results in targeted groups of industries that share a defined relationship and are, in many respects, self-perpetuating through their linkages to each other. Furthermore, the existence of strategic industry clusters enhances a region's dynamism by supporting a continuous flow of information, goods, skills, services, and capital (Rosenfeld, p.62). In effect, entrepreneurial activity is multiplied through the encouragement of clusters. It is with this effect in mind that we seek to identify clusters of high-tech industries as opposed to individual technology industries.

In effect, entrepreneurial activity is multiplied through the encouragement of clusters.

The identification of strategic industry clusters relies on a mix of hard economic data and expert knowledge of the intricacies of interindustry relationships. This analysis comprises an important and necessary component of cluster identification, but should not stand alone. An earlier study, "An Overview of the High-Tech Industry in Virginia" (Chmura and Battle, pp. 43-51), defined high-technology industries and identified central technology industries that would *likely* form part of several strategic clusters of high-technology industries in the state. The preliminary identification of these central technology industries relies on several economic measures to summarize each industry's performance in terms of specialization relative to the nation, importance to the regional economy, and the potential for growth. In this study we expand this quantitative process to include measures of the innovative potential of industries and the value added to the local economy. These indicators are grouped into two broad areas: (1) the external climate and (2) Virginia's capabilities.

The growth potential of any given industry in Virginia depends on the larger external environment of the nation and, to a lesser extent, the global economy. National trends and projections provide a good indicator of the growth potential for industries in Virginia because so much of the state's trade in goods and services takes place with the rest of the country as trading partner. The national market provides either a positive or negative climate for growth, but from the perspective of an individual industry or of the state, the national climate is outside of their control.

Given the external climate provided by national and global trends, we assess the competitive advantage of Virginia's industries, or their ability to grow given regional resources and historical growth trends. The combined factors of industrial concentration, historical employment and wage growth, and value added to the state's economy create Virginia's capabilities.

The following section develops a quantitative process of assessing Virginia's high-tech industries along these two broad areas of measure: (1) the external climate and (2) Virginia's capabilities.

External Climate

National and global trends provide a more favorable climate for some regional industries than for others and it is important to understand this context to determine the capacity for growth in Virginia's high-tech industries. Both the external climate and, in the following section, Virginia's capabilities, are measured

The growth potential of any given industry in Virginia depends on the larger external environment of the nation and, to a lesser extent, the global economy.

Given the external climate provided by national and global trends, we assess the competitive advantage of Virginia's industries, or their ability to grow given regional resources and historical growth trends. The combined factors of industrial concentration, historical employment and wage growth, and value added to the state's economy create Virginia's capabilities.

National and global trends provide a more favorable climate for some regional industries than for others and it is important to understand this context to determine the capacity for growth in Virginia's high-tech industries.

by quantifiable data that enable us to construct a single index measure for each. The External Climate Index and the Virginia Capabilities Index contain components to evaluate high-tech industries in terms of three areas: (1) economic performance, (2) innovative potential, and (3) value added. The specific information that comprises each index is outlined below and in Table 5. The data used to create these indexes are shown in Tables 6 and 7.

The External Climate Index and the Virginia Capabilities Index contain components to evaluate high-tech industries in terms of three areas: (1) economic performance, (2) innovative potential, and (3) value added.

Economic Performance

The national outlook for growth in industrial output provides a good indicator of the future market for an industry's good or service. Output growth projections reflect anticipated supply and demand shifts and thereby encompass important changes such as productivity growth and consumer preferences. Growth in industrial output serves to meet domestic market needs as well as global demand.[14] However, it also makes sense to include export growth separately to recognize those industries that have a growing foreign market that could enhance their opportunities for expansion and mitigate some of their risk in the event of a slowdown in the domestic economy.[15]

Table 5

External Climate	Virginia Capabilities
Economic Performance	
1. National Projections for Output Growth, 1998-2008	1. Concentration of employment in Virginia relative to the nation (Location Quotient, 1998)
2. Export Growth, 1995-1999	2. Change in Location Quotient, 1995-1998
	3. Employment Growth, 1995-1999
	4. Relative Wage, 1999
	5. Relative Wage Growth, 1995-1999
Innovation Potential	
1. Patents Granted in U.S., % change 1995-1998	1. Patents Granted in Virginia, % change 1995-1998
2. Research and Development Spending by all U.S. Companies, % change 1995-1998	2. Federal R&D Contract Awards to Virginia Firms, industry share FY1999
Value Added	
Total Value Added - Industry Multipliers for U.S.	Total Value Added - Industry Multipliers for Virginia

[14] Ideally, export growth from Virginia firms should be included in the Climate-Capabilities Matrix. Unfortunately, such data are not available on a timely basis. Even so, the overall trends for Virginia industry growth incorporate export activity.
[15] Our recent experience has been to the contrary, with the U.S. serving to mitigate the downturn in Asian economies, but generally speaking, developing economies have faster rates of growth than the United States and are increasingly opening their economies to trade and foreign investment.

Innovation Potential

Research and development spending on the part of firms reflects a commitment to create new products and processes that will ensure the vitality and growth of the industry. At the national level, trends in research and development spending signal industries that are already viable and fast-growing or industries that may emerge to be the leaders in the future. Similarly, patents obtained by industry at the national level indicate that the intellectual fruits of the research and development spending have ripened into a product that can be taken to market or a process that improves quality or efficiency in production.

Research and development spending on the part of firms reflects a commitment to create new products and processes that will ensure the vitality and growth of the industry.

Value Added to the National Economy

Increased production within one industry benefits individuals who work within that industry, whether employees or owners (proprietors), as well as individuals who work for or own industries that are suppliers to the industry. In other words, additional income[16] is generated throughout the national economy because of increased production in any given industry. A value added multiplier[17] is used to measure the additional income generated throughout the economy for each additional dollar of output from the industry. The value added multiplier is a concise measure of the degree to which a specific industry exerts a "pull" on other industries or the extent to which it is connected to the economy at large. The higher the multiplier value, the greater the additional income created from expansion of output in the industry.

The value added multiplier is a concise measure of the degree to which a specific industry exerts a "pull" on other industries or the extent to which it is connected to the economy at large.

Virginia's Capabilities

Virginia's high-tech industries differ in their positioning to take advantage of a favorable external climate or, conversely, they differ in their ability to compensate for an unfavorable external climate. The relative strengths and weaknesses of the Virginia high-tech industries are referred to as "capabilities." As with the eternal climate indicators, Virginia's capabilities provide a measure to evaluate high-tech industries in terms of economic performance, innovative potential, and value added. The components of the Virginia Capabilities Index mirror the eternal climate indicators where possible and provide greater detail for Virginia where appropriate.

The relative strengths and weaknesses of the Virginia high-tech industries are referred to as "capabilities."

[16] Income referred to here consists of the following components: wages, salaries, and benefits paid to employees; income received by self-employed persons; other property income such as rents, dividends, and profits; and indirect business taxes paid by individuals to businesses.
[17] Specifically, a Type I multiplier for each high-tech industry was provided from the widely accepted IMPLANPro software package (Minnesota IMPLAN Group, Inc.).

Table 6: External Climate Indicators

Code	Industry	Economy: Exports — Average Annual % Change: 1995-99	Economy: Output — ForecastAverage Annual % Change: 1998-08	Innovation Potential: R & D — Average Annual % Change: 1995-98	Innovation Potential: Patents — Average Annual % Change: 1995 98	Value Added, Multiplier — Type I Multiplier value	External Climate Index — max=120
131	Crude petroleum and natural gas	202.1	1.0	0.9	-6.6	1.46	17
281	Industrial inorganic chemicals	4.2	0.6	8.0	1.8	1.87	33
282	Plastic materials and synthetics	12.4	3.4	8.0	0.1	2.74	75
283	Drugs	8.4	3.4	7.2	33.4	1.71	52
285	Paint and allied products	13.2	0.5	4.1	2.9	2.49	46
286	Industrial organic chemicals	(9.1)	0.6	8.0	11.0	2.72	65
287	Agricultural chemicals	(0.1)	1.9	4.1	18.4	2.66	62
289	Miscellaneous chemical products	30.6	3.4	4.1	11.3	2.23	61
291	Petroleum refining	60.2	0.8	0.9	-6.6	4.20	57
348	Ordnance and accessories	18.2	1.8	n.a.	0.8	1.57	16
351	Engines and turbines	(0.2)	1.9	6.2	1.0	2.88	57
355	Special industrial machinery	3.8	4.4	6.2	6.8	2.32	64
356	General industrial machinery	2.1	3.4	6.2	6.3	2.24	49
357	Computers and office equipment	76.1	14.5	23.7	35.7	2.43	100
361	Electric distribution equipment	18.6	2.7	7.2	6.5	1.75	53
362	Electrical industrial apparatus	7.3	3.2	7.2	16.0	2.20	67
365	Household audio and video equipment	0.0	2.3	10.8	14.7	2.05	52
366	Communications equipment	42.8	8.0	38.3	14.4	1.93	85
367	Electronic components and accessories	12.7	10.9	0.5	14.4	2.01	64
369	Miscellaneous electrical machinery	21.7	1.4	7.2	9.8	2.18	49
372	Aircraft, engines and parts	11.8	4.1	-2.4	6.3	2.70	59
376	Guided missiles, space vehicles, parts	12.6	4.1	-2.4	22.6	2.70	77
381	Search and navigation equipment	4.4	2.2	-1.5	12.8	2.56	55
382	Measuring and controlling devices	15.3	5.0	-1.5	12.8	2.44	72
384	Medical equipment, instruments, and supplies	30.9	4.6	8.3	12.8	2.77	103
386	Photographic equipment and supplies	(0.6)	1.8	8.3	12.8	2.91	72
481	Telephone communications	19.7	5.1	-29.2	n.a.	1.57	37
737	Computer and data processing services	18.2	10.3	18.7	n.a.	1.39	77
871	Engineering and architectural services	19.6	3.6	-7.4	n.a.	1.83	40
873	Research, development, and testing services	13.9	6.7	33.8	n.a.	1.47	74

Sources: Exports: U.S. Census Bureau, available from Strategis (Canada): www.strategis.ic.gc.ca

R&D: National Science Foundation, Table E-4, Company and Other (except federal) funds for industrial R&D performance.

Patents: U.S. Patent and Trademark Office.

N.A. = Not available.

Table 7: Virginia Capabilities Indicators

Code	Industry	Economy					Innovation Potential		Value Added	Virginia Compe-tencies Index
		Concentration		Employment	Wages		R & D	Patents	Multiplier	
		LQ 1998	Change in LQ, 1995-98	Average Annual % Change: 1995-99	Industry Share in Total Wages	Industry Relative Wage Growth 1995-99	Share of Federal Awards Total High-tech R&D	Average Annual % Change 1995-1998	Type I Multiplier value	max=120
131	Crude petroleum and natural gas	0.11	0.07	27.1	2.3	0.8	0.0	10.1	1.20	22
281	Industrial inorganic chemicals	0.38	-0.02	-1.7	1.7	1.0	0.0	14.5	1.47	53
282	Plastic materials and synthetics	2.76	-0.07	-2.9	1.7	1.0	0.0	-7.2	1.72	61
283	Drugs	0.47	0.06	5.8	1.7	1.0	0.1	35.7	1.37	66
285	Paint and allied products	0.71	0.12	3.5	1.3	0.9	0.0	10.1	1.82	56
286	Industrial organic chemicals	0.26	0.03	-14.7	2.0	0.8	0.0	-5.9	1.62	42
287	Agricultural chemicals	0.40	0.13	5.9	0.9	0.8	0.0	10.7	2.19	57
289	Miscellaneous chemical products	0.90	-0.04	0.0	1.4	0.9	0.0	56.0	1.78	72
291	Petroleum refining	0.11	0.00	-3.0	2.1	1.0	0.0	10.1	1.97	63
348	Ordnance and accessories	0.02	-1.02	-63.2	0.8	0.6	0.0	14.5	0.00	15
351	Engines and turbines	0.33	0.10	10.5	1.8	0.8	0.0	18.6	1.24	33
355	Special industrial machinery	0.65	0.17	0.3	1.2	0.9	0.0	-10.0	1.57	43
356	General industrial machinery	0.48	0.04	4.5	1.2	1.0	0.0	8.2	1.42	37
357	Computers and office equipment	0.43	0.13	14.4	1.0	0.8	0.2	28.1	2.63	84
361	Electric distribution equipment	1.01	-0.08	-2.2	1.1	0.9	0.0	-5.6	1.29	21
362	Electrical industrial apparatus	1.09	-0.07	-3.4	1.3	1.0	0.0	37.0	1.42	50
365	Household audio and video equipment	0.32	0.14	19.6	0.8	0.8	0.0	35.7	1.40	42
366	Communications equipment	0.84	-0.38	-7.6	1.3	0.8	6.3	10.8	1.60	73
367	Electronic components and accessories	0.62	0.03	1.5	1.3	0.8	0.0	10.8	1.46	44
369	Miscellaneous electrical machinery	1.17	0.14	-35.1	0.9	0.6	0.0	11.9	1.47	55
372	Aircraft, engines and parts	0.14	0.05	22.4	1.7	0.8	0.0	22.4	1.42	52
376	Guided missiles, space vehicles, parts	0.57	0.23	11.6	1.9	0.9	4.5	0.0	1.42	52
381	Search and navigation equipment	0.83	0.48	24.8	1.8	1.1	14.9	13.4	1.97	109
382	Measuring and controlling devices	0.45	-0.02	3.2	1.3	1.0	0.0	13.4	1.69	66
384	Medical equipment, instruments, and supplies	0.26	0.03	12.8	0.9	0.9	0.0	13.4	2.05	59
386	Photographic equipment and supplies	0.37	0.11	6.4	0.8	0.9	0.0	13.4	2.75	64
481	Telephone communications	1.40	0.01	4.7	2.3	1.3	0.1	n.a.	1.31	66
737	Computer and data processing services	2.37	-0.01	16.8	2.3	1.2	7.1	n.a.	1.23	67
871	Engineering and architectural services	1.72	-0.16	2.9	1.6	1.0	42.2	n.a.	1.48	88
873	Research, development, and testing services	1.45	-0.04	-5.6	1.5	0.9	24.6	n.a.	1.24	63

Sources: Exports: U.S. Census Bureau, available from Strategis (Canada): www.strategis.ic.gc.ca

Employment: U.S. Department of Labor and Virginia Employment Commission Covered Employment and Wages.

R&D: National Science Foundation, Table E-4, Company and Other (except federal) funds for industrial R&D performance.

Patents: U.S. Patent and Trademark Office.

Economic Performance

The competitiveness of an industry relative to the nation was measured using a common tool of regional analysis called the *location quotient*. Specifically, the location quotient measures the degree to which an industry is concentrated or specialized in a region relative to the nation, using employment shares as the input. A location quotient less than one indicates that an industry is less concentrated in the region than in the nation, while a value of one indicates that the industry is exactly as concentrated in the region as it is in the nation. Finally, a value for the location quotient above one indicates that the industry is more concentrated in the region than in the nation—with a location quotient in excess of 1.25 generally indicating a regional specialization in that particular industry (Bergman and Feser, p. 6). In addition to the level of concentration at a specific point in time[18], the change in the location quotient was also calculated to gauge whether an industry was increasing in its specialization for the region, or decreasing in specialization.

The competitiveness of an industry relative to the nation was measured using a common tool of regional analysis called the location quotient.

A value for the location quotient above one indicates that the industry is more concentrated in the region than in the nation—with a location quotient in excess of 1.25 generally indicating a regional specialization in that particular industry.

Employment growth and industry wage growth relative to the region suggest the importance of a particular industry to the region. Employment growth provides the best indication of current economic activity, since income measures, such as gross state product, are released with a significant lag. Industry-specific wages relative to the regional average wage measures the contribution to regional income associated with wages paid in a particular industry. In addition, a rise in the relative wage suggests that labor in the industry is relatively more productive than the regional average.[19] The level of this relative wage suggests the current contribution of an industry to regional income, while the growth in relative wages measures the contribution of the industry over time. Also, higher wages increase the standard of living for a region's citizens.

Innovation Potential

Virginia firms that receive federal research and development contract awards or patent grants are well-positioned to grow through their commitment to innovation, commercialization of new products, and implementation of improved processes. Some high-tech industries in Virginia would appear to be farther along in terms of innovation potential relative to their national counterparts, while others lag behind. Two indicators capture this difference among industries: patents granted to

Industry-specific wages relative to the regional average wage measures the contribution to regional income associated with wages paid in a particular industry.

[18] The location quotient is based on 1998 data so that we could use comparable employment data at the regional and national level.
[19] The higher wages could actually reflect greater productivity or higher prices for the industry's final product.

Virginia high-tech industries and federal research and development contracts awarded to Virginia firms.

Some high-tech industries in Virginia would appear to be farther along in terms of innovation potential relative to their national counterparts, while others lag behind. Two indicators capture this difference among industries: patents granted to Virginia high-tech industries and federal research and development contracts awarded to Virginia firms.

Value Added to the Virginia Economy

Previous discussion focused on the importance of "value added" as a measure of a particular industry's impact on total income in the local economy. Where the value added multipliers for the United States were used in the External Climate Index, the Virginia Capabilities Index includes the value added multipliers for Virginia. In other words, we now capture the additional income created in Virginia for an additional dollar of output produced in a Virginia industry.[20] Using value added to rank Virginia industries provides useful information in its own right, but comparing this ranking to the same information for the United States may reveal additional information to help fill out clusters of high-tech industries in Virginia. Specifically, an industry that ranks high for the U.S. but lower for Virginia, aerospace is an example, suggests that there are additional supplier chains that are reflected in the U.S. multiplier that do not yet exist in Virginia, but may have the potential to emerge as part of an aerospace cluster.

Identifying High-Tech Clusters: The Climate-Capabilities Matrix[21]

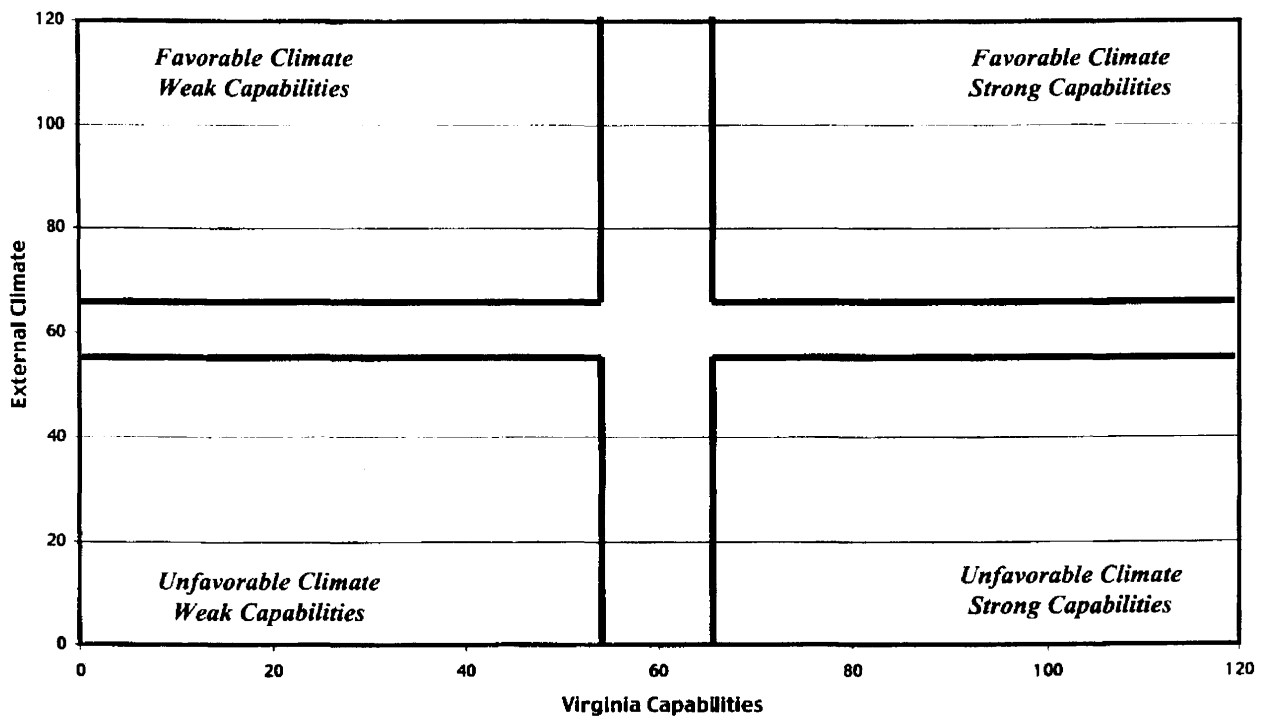
As noted earlier, our focus is on data that are quantifiable. However, we recognize that valuable subjective insight, such as the informed opinion of industry experts, would serve well to round out the analysis provided here. The previous section developed two summary measures to concisely quantify many pieces of economic data and channel the complexity of the data into a simple decision-making aid.

Specifically, an industry that ranks high for the U.S. but lower for Virginia, aerospace is an example, suggests that there are additional supplier chains that are reflected in the U.S. multiplier that do not yet exist in Virginia, but may have the potential to emerge as part of an aerospace cluster.

Ideally, the state should invest in those high-tech industries that have the greatest potential for growth given national and global trends, as measured by the External Climate Index, and given the strengths and specialization of Virginia's industries, as measured by the Virginia Capabilities Index. Essentially, investment in research and development in Virginia's industries can benefit the state economy by pushing industries to the right in the Climate-Capabilities Matrix.[22] No amount of investment in Virginia can cause a high-tech industry to move upward in the matrix because such a movement is controlled by the external climate.

[20] For the U.S. and for Virginia the value added multipliers for all high-tech industries are ranked in descending order. For most industries the value of the multiplier for the U.S. will be larger than the value for Virginia, but it is the industry ranking that is relevant for this analysis.
[21] See Appendix B for the weighting scheme for the Climate-Capabilities Matrix.
[22] The External Climate and Virginia Capabilities indices provide a *relative* ranking of industries. Over time, the relative position of an industry, as measured by the Virginia Capabilities Index, can improve and this would result in a rightward movement in the Climate-Capabilities Matrix.

Chart 10: Climate-Capabilities Matrix



The interplay of the two indices in a Climate-Capabilities Matrix is depicted graphically in Chart 10. The upper right area of the graph contains industries that face a favorable external climate and also exhibit great strength and/or specialization in Virginia. The lower right area exhibits strong capabilities in Virginia but a weak external climate. In contrast, the upper left quadrant reflects a favorable climate in the nation but weak capabilities among Virginia's industries. The lower, left area reflects both an unfavorable external climate and weak capabilities in Virginia. The band between the quadrants provides a buffer zone where the industries may be viewed in either quadrant. The buffer zone reflects the fact that although the axes are split equally to create the quadrants, the division point remains subjective.

The buffer zone reflects the fact that although the axes are split equally to create the quadrants, the division point remains subjective.

The Climate-Capabilities Matrix suggests several strategies with regard to targeting research and development to industries in Virginia that would provide the greatest probability of further economic growth:

1. Provide research and development for the industries in the upper right quadrant because they generally possess the largest concentration in Virginia relative to the

nation, pay relatively high wages, and are projected to experience the fastest growth in the nation.

2. Provide research and development for the industries in the lower right quadrant if output in these industries is expected to grow at a strong rate. This quadrant represents strong Virginia capabilities relative to the nation. Such a situation could reflect a specialization in Virginia's high-tech industries that far exceeds that of the nation.
3. Provide research and development for the industries that possess a strong external (U.S.) climate but whose Virginia Capabilities Index is weak. These industries, which are either in the upper left quadrant or the buffer surrounding that matrix would benefit greatly by improving their capabilities in Virginia.

The quantitative aspect of the cluster selection process involves two stages. The first stage identifies exceptional economic performers using the combination of a favorable external climate and a high level of capabilities in Virginia.

Virginia High-Tech Clusters

The quantitative aspect of the cluster selection process involves two stages. The first stage identifies exceptional economic performers using the combination of a favorable external climate and a high level of capabilities in Virginia. The relative strength of individual industries according to the Climate-Capabilities Matrix is shown in Chart 11. A second, and equally important, stage examines the interdependence of industries based on supplier relationships or the purchases of individual industries from other industries. An essential characteristic of a cluster is the trade between the industries that are grouped together as a cluster. We begin by examining the supplier relationships[23] of all of the industries that scored in the quadrant of "Favorable Climate/Strong Capabilities" or "Favorable Climate/Weak Capabilities" or, with some qualification, "Unfavorable Climate/Strong Capabilities". [24] Based on this two-stage approach, the following high-tech clusters were identified for Virginia:

(1) Information Technology and Communications
(2) Biotechnology and Medical
(3) Aerospace

Tables C-1 through C-4 of Appendix C summarize the supplier relationships for all of the industries included in the clusters by ranking the top ten suppliers to each industry. Table C-5 identifies the metropolitan areas in which the industries are concentrated.

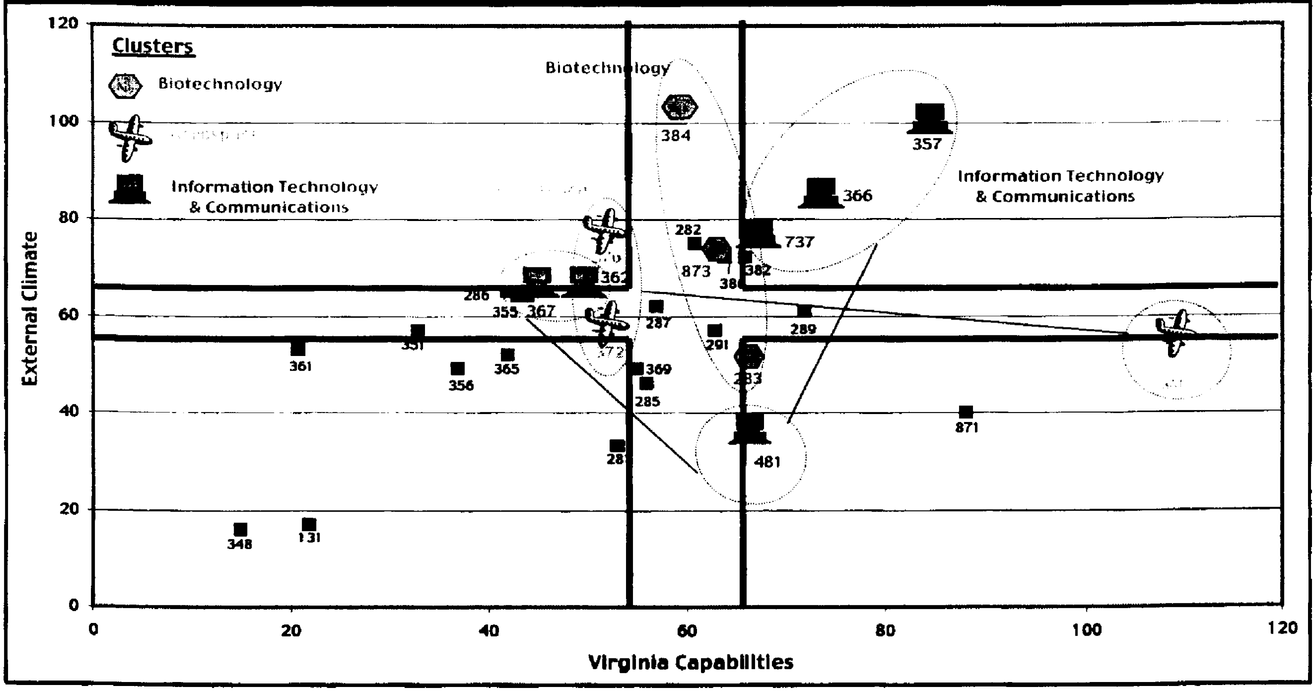
A second, and equally important, stage examines the interdependence of industries based on supplier relationships or the purchases of individual industries from other industries.

Based on this two-stage approach, the following high-tech clusters were identified for Virginia: (1) Information Technology and Communications (2) Biotechnology and Medical (3)Aerospace

[23] Input-output analysis provides the necessary data on interindustry purchases to summarize these relationships (see Chmura and Battle, p. 45-50). Data from IMPLANPro software, MIG, Inc.

[24] In the case of industries in the "Unfavorable Climate" or its buffer area, the projected output growth for 1998-2008 had to exceed 1.5%, which is approximately half of the growth rate expected for all industries in the nation, in order move to the second stage of scrutinizing supplier relationships.

Chart 11: Virginia High-Tech Clusters



Information Technology and Communications Cluster

By far the largest of the three technology clusters identified in this study, the informational technology and communications cluster accounted for roughly 63% of total high-tech employment in Virginia in 1999.

The information technology and communications cluster consists of the following high-tech industries:[25]

- Computer and Data Processing Services
- Computers and Office Equipment
- Telephone Communications
- Communications Equipment
- Electronic Components and Accessories
- Electrical Industrial Apparatus

By far the largest of the three technology clusters identified in this study, the informational technology and communications cluster accounted for roughly 63% of total high-tech employment in Virginia in 1999. Three of the cluster's industries are stellar performers by virtue of their location in the upper right quadrant of the Climate-Capabilities Matrix: computers and office equipment, communications equipment, and computer and data processing services.

Computer and data processing services is the largest high-tech industry in Virginia, employing 42.0% of all high-tech workers in the state in 1999 and accounting for 67.0% of employ-

[25] All industries listed as members of each cluster correspond to 3-digit SIC code definitions.

ment in the information technology and communications cluster. It is also the high-tech industry with the greatest concentration in Virginia relative to the nation—with a location quotient of 2.37, this industry is nearly 140% more concentrated in Virginia than it is in the nation.

With a location quotient of 2.37, the information technology and communications cluster is nearly 140% more concentrated in Virginia than it is in the nation.

Only one of the industries in this cluster, telephone communications, faces an external climate that is unfavorable by our measures. This is primarily due to a low value added multiplier for the industry and low rates of research and development spending and patent growth. Nonetheless, telephone communications belongs in this cluster when one considers the interdependence among industries. If we simply look at the purchases of the computer and data processing services industry, 31.0% of all its purchases from other industries are comprised of three of the industries in this cluster.[26] In fact, these three industries—electronic components, communications, and computers and office equipment—are among the top five suppliers to the computer and data processing services industry.

Aside from being the largest cluster, the information technology and communications cluster also "looks" unmistakably like a cluster by virtue of the numerous purchasing relationships among all of the industries. Table C-1 of Appendix C illustrates this point, with shaded industries depicting purchases from within the cluster. In fact, this cluster contains a number of two-way exchanges, such as purchases of electronic components by the computer and data processing services industry and vice versa.

Biotechnology Cluster

The biotechnology cluster is something of a paradox because the three component industries do not have strong supplier relationships to each other, with the exception of the drug industry and its link to research, development and testing services.

The biotechnology cluster consists of the following high-tech industries:

- Drugs
- Medical Equipment, Instruments, and Supplies
- Research, Development, and Testing Services

The biotechnology cluster is something of a paradox because the three component industries do not have strong supplier relationships to each other, with the exception of the drug industry and its link to research, development and testing ser-

[26] This percentage is based on purchases net of the purchases within the same industry.

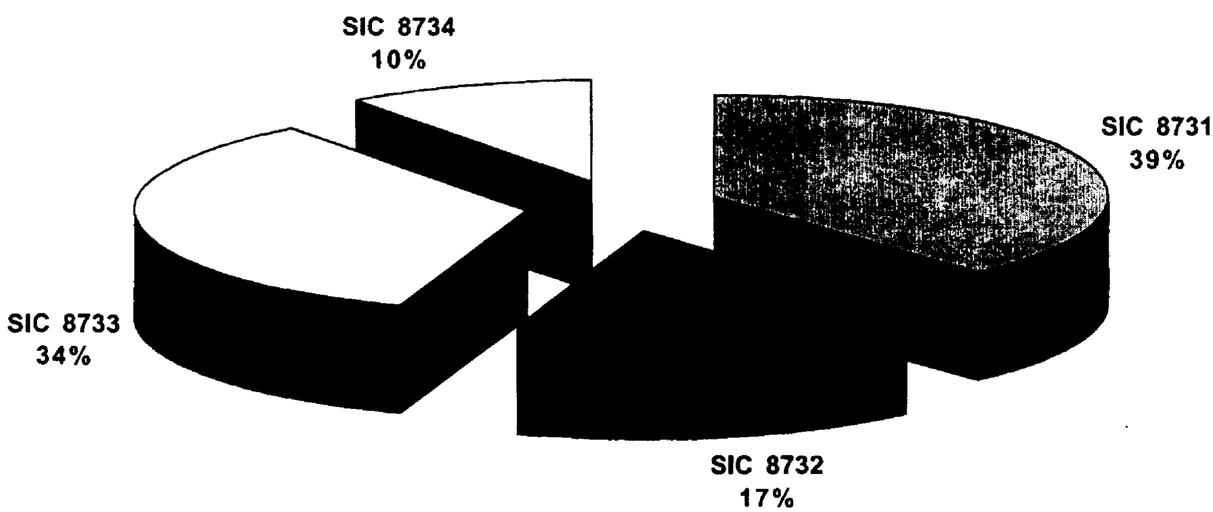
vices (see Table C-2 in Appendix C).[27] Nonetheless, the definition of biotechnology as a "set of biological techniques developed through basic research and now applied to research and product development" (see www.biospace.com) arguably applies to all three industries.

Clearly, these industries perform well in terms of the external climate and Virginia's capabilities. Although the drug industry is pulled down by its low valued added, its regional strength and importance is the highest of any of the industries in the cluster.

The largest industry in this cluster—75.7% as measured by employment—is research, development, and testing services, and deserves special mention for its inclusion in the biotechnology cluster. When taken to the 4-digit standard industrial classification (SIC) code level, one particular industry, "commercial physical and biological research" (SIC 8731), clearly pertains to biotechnology, whereas the other 4-digit industries may only pertain in part. In fact, commercial physical and biological research accounted for 38.0% of the employment in research, development, and testing services in 1999 (see Chart 12). If the cluster definition is narrowed down to include only

Chart 12: Research, Development, and Testing Services Industry: 4-Digit SIC Industry Composition, 1999 4th Quarter Employment

SIC 8731: Commercial Physical and Biological Research
SIC 8732: Commercial Economic, Sociological, and Educational Research
SIC 8733: Noncommercial Research Organizations
SIC 8734: Testing Laboratories



[27] For the drug industry, 5.9% of their purchases from other industries come from research, development, and testing services, making this industry the fourth largest supplier to the drug industry.

SIC 8731 as opposed to all of 873, then research, development, and testing still accounts for 55.5% of employment in the cluster for 1999. However, the definition that includes 8731 cuts the size of the biotechnology cluster nearly in half so that its employment accounts for 4.5% of total high-tech employment in Virginia.

Virginia's Capabilities Index in search and navigation equipment is the highest of any of the high-tech industries.

Aerospace Cluster

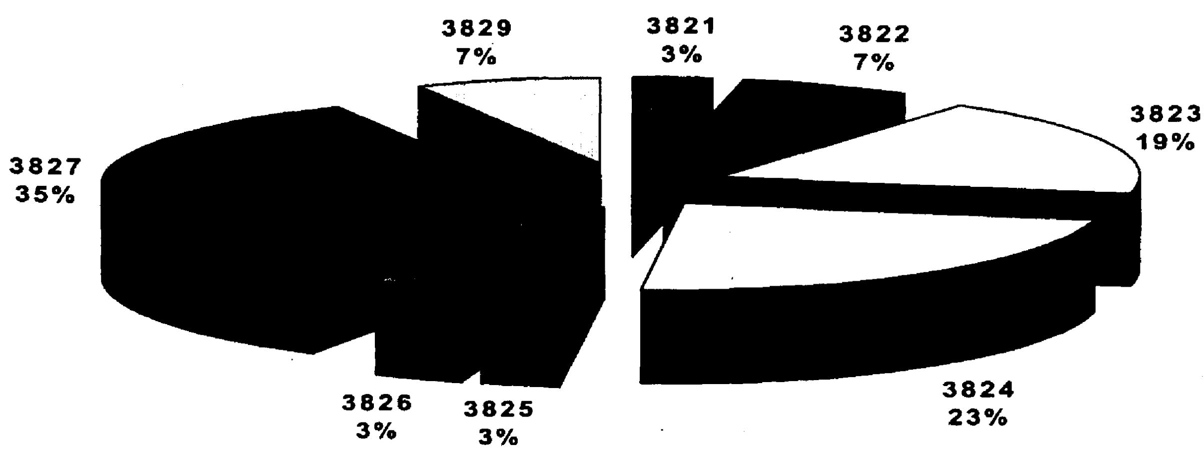
The aerospace cluster consists of the following high-tech industries:

- Aircraft, engines, and parts
- Guided Missiles, Space Vehicles, and Parts
- Search and Navigation Equipment

Two of the industries in the aerospace cluster—aircraft and guided missiles, space vehicles, and parts—are moderate performers in terms of Virginia capabilities, with strong employment growth and high wages. Moreover, both industries are less concentrated in Virginia than in the nation. However, Virginia's Capabilities Index in search and navigation equipment is the highest of any of the high-tech industries. The

Chart 13: Measuring and Controlling Devices Industry: 4-Digit SIC Industry Composition, 1999 4th Quarter Employment

SIC 3821: Laboratory Apparatus and Furniture
SIC 3822: Automatic Controls for Regulating Residential and Commercial Environments and Appliances
SIC 3823: Industrial Instruments for Measurement, Display, and Control of Process Variables; and Related Products
SIC 3824: Totalizing Fluid Meters and Counting Devices
SIC 3825: Instruments for Measuring and Testing of Electricity and Electrical Signals
SIC 3826: Laboratory Analytical Instruments
SIC 3827: Optical Instruments and Lenses



external climate is more favorable for guided missiles, space vehicles, and parts, as compared with the other two industries, because of a high rate of growth in patents granted to the industry nationally.

The aerospace cluster, as it is currently measured, represented only 2.4% of total high-tech employment in Virginia in 1999 and is the smallest of the clusters identified in this study. Search and navigation equipment accounted for half of the employment in this cluster in 1999.

Another industry, measuring and controlling devices, has a supplier relationship with the aerospace cluster, but not with any of the other cluster-member industries. However, the measuring and controlling devices industry is quite diverse, as indicated by the employment shares at the 4-digit SIC code level (see Chart 13). Optical instruments and lenses accounts for 35% of employment, followed by totalizing fluid meters and counting devices with 23% of employment. Such diversity suggests that additional industry information is required to assign this industry to a cluster. The supplier relationships for the measuring and controlling devices industry, as well as other industries that have not been assigned to a cluster, appear in Table C-3 of Appendix C. The following section discusses several additional industries that were not assigned to clusters in this study.

Several industries performed well in terms of the Climate-Capabilities Matrix but did not belong to any particular cluster at this point in time. It is possible that these industries provide goods and services to such a broad range of industries that one cluster does not stand out in its relevant supplier relationships. An alternative possibility is that the industry is in the early stages of transformation to high-tech status and may be too young to have a strong tie to just one cluster.

"Unassigned" Industries

Several industries performed well in terms of the Climate-Capabilities Matrix but did not belong to any particular cluster at this point in time. It is possible that these industries provide goods and services to such a broad range of industries that one cluster does not stand out in its relevant supplier relationships. An alternative possibility is that the industry is in the early stages of transformation to high-tech status and may be too young to have a strong tie to just one cluster. Photographic equipment and supplies is a prime example of the former type of industry. Table C-4 in Appendix C shows that the photographic equipment and supplies industry purchases inputs from the electronic components industry (information technology and communications cluster), research, development, and testing services industry (biotechnology and medical cluster), as well as individual high-tech industries. Since the photographic equipment and supplies industry also does not appear as a supplier to any of the clusters or any of the non-cluster individual industries, it would be difficult to assign this particular industry to a specific cluster.

The plastic materials and synthetics industry may play a supporting role in the manufactured products that make up the information technology and communications cluster, however, that connection is not supported by the supplier relationships in Tables C-1 through C-4. On the other hand, a cluster of industries that might form a "chemicals" cluster, of which plastic materials and synthetics would form a crucial part, does find support in the interindustry purchase information provided here. A chemicals cluster was not designated, however, because most of the industries that would form the cluster grouping are projected to have output growth of less than half the national average from 1998 through 2008. In fact, these industries are projected to be the slowest growing of any of the high-tech industries defined in this study.

A chemicals cluster was not designated, however, because most of the industries that would form the cluster grouping are projected to have output growth of less than half the national average from 1998 through 2008.

Finally, the engineering and architectural services industry deserves mention because of its exceptional performance in terms of Virginia's capabilities. The supplier relationships in Tables C-1 through C-4 reveal two-way trade in goods and services between the engineering and architectural services industry and the information technology and communications cluster as well as the biotechnology and medical cluster. Again, it would be difficult to assign this industry to one particular cluster despite its relative strength in the Climate-Capabilities Matrix because of its input to many industries.

In sum, the three clusters selected here encompass a set of industries in which Virginia excels in terms of regional strength and favorable external climate. Together, these industries represent 70% of the high-tech employment and 6.3% of the total employment in Virginia. By the very nature of technology-oriented industries, the clusters identified in the study are evolving and their composition should be updated at least annually based on quantifiable data as well as informed expert opinion.

The three clusters selected here encompass a set of industries in which Virginia excels in terms of regional strength and favorable external climate. Together, these industries represent 70% of the high-tech employment and 6.3% of the total employment in Virginia.

Identifying Emerging Technology Industries

By definition, emerging technology industries are difficult to identify because they are new. However, even emerging technologies can typically be identified with existing industries and products. For example, the microprocessor was invented by

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scientists at Texas Instruments, which is identified as the "electronic components and accessories" industry. Today, microprocessors are used in many devices from microwave ovens to automobiles. Going back further in time, the invention of electricity enabled the creation of many new products and industries. If industry classifications were available when electricity was invented, then the "firm" that created electricity probably would have been classified as "research, development, and testing services"—one of the high-tech industries that exists today.

Given the broad range of potential applications and the infancy of the technology, however, research and development of nanotechnology appears most likely to be classified at this point as research, development, and testing services

Nanotechnology[28] is an emerging technology that is in its infancy but has the potential to infiltrate many products and disciplines. In that sense, it is similar to electricity in the late 1800s and microprocessors in the late 1900s. As noted earlier, industries are defined as high-tech in this study if they possess at least double the percentage of employment in technology-oriented occupations as that of the average for all industries and if their percentage of employment in research and development is at least 80% of the industry average.[29] For that reason, it is likely that nanotechnology is captured in the high-tech industries used in this study.

There are many areas in which nanotechnology is likely to be identified. When nanotechnology develops to the point where it is being manufactured into devices, then it will be classified in a particular manufacturing industry, which may range from pharmaceuticals to electronic devices.[30] Given the broad range of potential applications and the infancy of the technology, however, research and development of nanotechnology appears most likely to be classified at this point as research, development, and testing services[31] which is called "professional, scientific, and technical services" in the new North American Industry Classification System (NAICS) and is defined as

> Industries in the Professional, Scientific, and Technical Services subsector group establishments engaged in processes where human capital is the major input. These establishments make available the knowledge and skills of their employees, often on an assignment basis, where an individual or team is responsible for the delivery of services to the client. The individual industries of this subsector are defined on the basis of the particular expertise and training of the services provider.

[28] According to NASA, "nanotechnology is the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers), and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale." For further information see, www.ipt.arc.nasa.gov/gallery.html or www.foresight.org.

[29] See Appendix A of Chmura and Battle (2000) for more detail.

[30] Popper, Wagner, and Larson (2000, pp. 138-139) identify several information/communications and manufacturing firms with micro-/nanotechnology subsections.

[31] In fact, one of the companies in Virginia that is known to be working with nanotechnology is classified as research development and testing.

> The distinguishing feature of the Professional, Scientific, and Technical Services subsector is the fact that most of the industries grouped in it have production processes that are almost wholly dependent on worker skills. In most of these industries, equipment and materials are not of major importance, unlike health care, for example, where "high tech" machines and materials are important collaborating inputs to labor skills in the production of health care. Thus, the establishments classified in this subsector sell expertise. Much of the expertise requires degrees, though not in every case.[32]

The example of nanotechnology brings out the flexibility of the high-technology definition used in this study as well as the need for informed experts in the field to provide supplemental information.

More specifically, nanotechnology research is probably occurring within a subgroup of the above that is called "scientific research and development services" and is defined as:

> This industry group comprises establishments engaged in conducting original investigation undertaken on a systematic basis to gain new knowledge (research) and/or the application of research findings or other scientific knowledge for the creation of new or significantly improved products or processes (experimental development). The industries within this industry group are defined on the basis of the domain of research; that is, on the scientific expertise of the establishment.[33]

The example of nanotechnology brings out the flexibility of the high-technology definition used in this study as well as the need for informed experts in the field to provide supplemental information. First, the reliance of the high-tech definition on industries that possess a proportion of employment equivalent to at least 80% of the industry average increases the probability that an emerging technology is going to be produced within one of the high-technology industries already identified. Second, the opinion of industry leaders and experts is necessary to identify the nascent trends that have not yet been formalized into products and industries.

[32] NAICS Desk Reference, p. 194.
[33] NAICS Desk Reference, p. 200.

Conclusions

The current Information Age, which has been likened to the Industrial Revolution, holds much promise for the U.S. economy in the upcoming decades.[34] From a regional perspective, the development of a strong high-tech sector is a strategy that will increase the probability of economic growth. Moreover, the innovation and entrepreneurial spirit needed as the foundation of such an economy can be encouraged by state policies that develop the interaction of businesses, universities, and federal labs.

The current Information Age, which has been likened to the Industrial Revolution, holds much promise for the U.S. economy in the upcoming decades.

Virginia possesses many capabilities that place it in a strong position when compared with other states. During 1998, the last year for which state data are available, Virginia ranked seventh in the nation in terms of the percentage of high-tech employment (Chmura and Battle, p 15). The state's link to defense and federal government has supported its research and development efforts. However, Virginia's universities do not compare as favorably with regard to research and development spending or patent awards.

Virginia possesses many capabilities that place it in a strong position when compared with other states.

Looking to the future, Virginia's rising position as a high-tech leader in the nation will be dependent on the ability of entrepreneurs and mature businesses to turn innovations into marketable products. Information technology and communications, biotechnology and medical, and aerospace make up three clusters of industries that have emerged in Virginia as high-technology clusters. Each of these clusters possesses the potential to evolve as innovation transforms the industry. From the perspective of this study, state support that further encourages the development of the information technology and communications, biotechnology and medical, and aerospace clusters are the most likely clusters to provide dividends to Virginia's economy.

Looking to the future, Virginia's rising position as a high-tech leader in the nation will be dependent on the ability of entrepreneurs and mature businesses to turn innovations into marketable products.

This study creates a process that allows Virginia to identify emerging technology industries over time and to track their performance. First, the definition of high-technology industries can be updated on an annual basis to incorporate industries whose percentage of technology occupations equal at least twice that of the average industry and whose proportion of research and development employment is at least 80% of the industry average. Second, updating the performance indicators in the Climate-Capabilities Matrix enables the state to track

[34] For a historical comparison of the Information Age and the Industrial Revolution, see Cox and Alm, 1999.

the progress of its high-tech industries and clusters. Third, surveys and/or interviews with industry experts in high-technology will provide the detail needed to identify the research and development needs as well as the inhibitors that should be eliminated to encourage the development of innovate products through improved linkages with private enterprise, universities, and federal labs.

Glossary

Elasticity: A measure of the relative responsiveness of one variable to a change in another variable; the percentage change in a dependent variable divided by the percentage change in the independent variable. In this study the elasticities are calculated as the percent change in total employment divided by the percent change in external federal funding, as well as, the percent change in total wages divided by the percent change in external federal funding.

Federal Assistance: means the transfer of money or the assumption of risk, the principal purpose of which is to accomplish a public purpose of support or stimulation authorized by Federal statute. Assistance includes, but is not limited to, grants, cooperative agreements, direct payments, loans, loan guarantees, scholarships, mortgage loans, insurance, subsidies, or other types of financial assistance. For the purpose of this study we only look at project grants.

Federal Obligations: The amounts reported for each year are expressed in obligations or outlays incurred, or expected to be incurred, in that year, regardless of when the funds may have been authorized, appropriated, or received by an agency, and regardless of whether the funds are identified in an agency's budget specifically for research, development, or R&D plant.

Data for 1998 are actual, representing completed transactions. Data for 1999 and 2000 are estimated because they do not represent final actions. The Survey of Federal Funds for Research and Development was conducted during the third quarter of fiscal year 1999. The amounts reported for 1999 reflect congressional appropriation actions as of that period, as well as apportionment and reprogramming decisions as of that time.

Federal Procurement: All purchasing decisions of the federal government in excess of $25,000.

Location Quotient: The location quotient measures the degree to which an industry is concentrated or specialized in a region relative to the nation, by computing the ratio of the share of industry i's employment in region j to the same industry's share of employment in the nation.

$$LQ = \frac{\text{Employment industry in area} \,/\, \text{Total employment in area}}{\text{Total U.S. employment in industry} \,/\, \text{Total U.S. employment}}$$

Project Grants: The funding, for fixed or known periods, of specific projects or the delivery of specific services or products without liability for damages for failure to perform. Project grants include fellowships, scholarships, research grants, training grants, traineeships, experimental and demonstration grants, evaluation grants, planning grants, technical assistance grants, survey grants, construction grants, and unsolicited contractual agreements. These grants are obligations or contingent liability of the Federal Government, not the actual amount of payment. Applies to cooperative agreements as well.

Small Business: Classified as any business with less than 500 employees.

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Sources of Data

Exports: Industry Canada, http://strategis.ic.gc.ca and U.S. Census Bureau.

Federal Grants: Federal Assistance Awards Data System FY1998-FY1999, Office of Money and Budget.

Firms: Firms are defined as the number of companies at the State level obtained from the Virginia Employment Commission Covered Employment and Wages (ES-202).

Industry Employment: Unless otherwise noted, Virginia employment totals were obtained from the Virginia Employment Commission Covered Employment and Wages (ES-202).

National Research and Development Funds: National Science Foundation, Division of Science Resources Studies.

Patents: United States Patent and Trademark Office.

Projected Output Growth: Bureau of Labor Statistics.

Venture Capital: The Money Tree, PriceWaterhouseCooopers, www.pwcmoneytree.com, Q2 2000.

Virginia Research and Development Funds: All contracted work by a federal agency for projects marked as research and development as taken from the Federal Procurement Data System FY1998-FY1999, U. S. Census Bureau.

Appendix A: A Statistical View of the Effects of External Funding on the High-Tech Industry in Virginia

The purpose of this appendix is to assess whether there is a quantifiable relationship between research and development expenditures and economic growth in Virginia.

Ideally, the impact of research and development would be analyzed at the firm level. Such an analysis requires firm-specific data such as external (federal and state government) and internal (company-specific) research and development funding as well measures of firm growth such as revenue, profit, employment, and wages. Firm-specific data were not available for internal research and development expenditures, revenues or profits. However, firm-specific data in Virginia were available for employment and wages as well as federal contract awards for research and development.

The data sample was limited by the number of firms in Virginia that received federal procurement awards for research and development. From fiscal year 1998 through 1999, 562 firms were awarded federal contracts. Of these firms, 75 were from an industrial classification outside those defined as technology. These firms were dropped from the sample. Using the address of the firm cited for the award, the corresponding employment and wages were identified from the Virginia Employment Commission covered wages and employment database.

A model was developed to test the responsiveness of wages to external research and development funding. Because the majority of the firms in the sample received no external awards, the level of responsiveness was measured using the change in variables between periods—in this case quarters.[35] This model allows us to measure the responsiveness (elasticity) of the level of total wages to changes in the level of external research and development funding. The following model was estimated separately for each industry in which at least one firm received federal research and development funding.[36] The model is specified as:

$$dwages = a + demp + dfunds + Q_{i}$$

Where 'dwages' is the difference in total wages between quar-

[35] This methodology differs slightly from an elasticity. Where an elasticity measures responsiveness as a percentage change between variables, "differences" measure responsiveness as the level of change between variables.
[36] Unfortunately, less than half of the industries specified as technology-intensive in this study received external R & D funding.

ters, 'demp' is the difference in total employment between quarters, 'dfunds' is the difference in external research and development funding between quarters and 'Q' is a set of three dummy variables taking on the value of 1 for a specific quarter of the fiscal year. These dummy variables are used to account for any seasonal effects contained in the data, as well as the entry of new firms.

Table A-1 provides the estimation results for each industrial class that is relevant. In each model the employment variable behaves as expected. The positive signs and the values of the coefficients verify hypotheses about the role total employment plays on total wages. The coefficients for the dfunds variables, however, are less informative. External research and development funds is insignificant at the 10% level, suggesting that the models would explain just as much variation in total wages without the dfunds variable being included.[37] This is a telling result in its own right because it suggests that, for the two years tested, industries as a whole did not receive any benefit from federal research and development.[38]

Two issues play a role in these results.[39] First, a measure for internal research and development funding or total research and development funding was not available. For every research and development firm there must be a presumed reliance on internal research and development funds (Link, 1993, p.3). Without any ability to measure the level of internal funding it becomes difficult to make unambiguous statements, both statistically and qualitatively, about the effect of external research and development funds. Unfortunately, the only way to perform such a study is to survey the firms in the industry. While both time consuming and expensive, the information provided should lend better, more informative, results.

The second issue deals with the nature of firms that seek federal funds. A number of industries receive no federal funds earmarked specifically for research and development. Other industries may receive large amounts of external funding, but it only goes to one or two firms within that industry. This lack of variance in between firms in the same industry causes extreme bias downwards in both the magnitude of the variable as well as the significance of the results. To illustrate this point, Table A-2 shows the descriptive statistics for the 1999 quarter 3 cross-

[37] The insignificance of the variable means that the coefficient is meaningless and has no predictive power.
[38] This is not to suggest that at the firm level a company does not receive direct benefits from receiving external funds, nor that these external funds don't increase the amount of money put into the economy as wages. However, at the industry level significant results were not forthcoming.
[39] Measurement error may be a third issue to be addressed. Many firms report their employment and wage statistics under multiple industry classifications, while the Federal procurement data uses the industrial classification code to define the nature of the product, not the firm performing the project. As a result, you may have inter-industry competition for federal awards that the measurement techniques of the data cannot account for.

section of the sample. What becomes apparent is the difference between the number of firms in an industry and the number of contracts.

Table A-1: Estimation Results from Firm Specific Data

Industry	DEMP	DFUNDS
Communications Equipment	16963.33*	0.24
	(6.12)	(.12)
Aerospace	12511.72*	4.28
	(29.9)	(.38)
Guided Missiles, Space Vehicles, Parts	19483.26*	-1.79
	(2.01)	(.18)
Search and Navigation Equipment	14339.16*	0.128
	(15.02)	(1.15)
Computer and Data Processing Services	45309.8*	-1.1
	(6.73)	(-.59)
Engineering and Architectural Services	15306.2*	0.024
	(3.48)	(.29)
Research, Development, and Testing Services	19102.42*	0.79
	(3.81)	(.95)

* Significant at the 1% level.

Table A-2: Descriptive Statistics, 1999 Quarter 3

SIC 357	demp	dwages	dfunds
Mean	116.39474	921216.95	53
Standard Error	60.724689	427822.34	N.A
Minimum	0.3333333	2371	N.A
Maximum	1891.3333	12564895	N.A
Count	38	38	1

SIC 366	demp	dwages	dfunds
Mean	100.27869	1045415.2	12686
Standard Error	46.437835	462748.8	N.A.
Minimum	0.6666667	2773	N.A.
Maximum	2736	27119173	N.A.
Count	61	61	1

SIC 381	demp	dwages	dfunds
Mean	274.74359	3836474.9	2069.3333
Standard Error	126.84186	1829812.7	824.57349
Minimum	1	1385	1185
Maximum	1560.6667	22436588	3717
Count	13	13	3

SIC 384	demp	dwages	dfunds
Mean	51.22	349548.3	34
Standard Error	15.106991	104291.75	N.A.
Minimum	0.3333333	0	N.A.
Maximum	505.66667	4262095	N.A.
Count	50	50	1

SIC 737	demp	dwages	
Mean	34.367391	391899.12	510.78571
Standard Error	2.1603625	31577.556	209.41924
Minimum	0.5	0	33
Maximum	4297	108334653	3154
Count	5520	5520	14

SIC 871	demp	dwages	dfunds
Mean	19.839695	252761.09	1050.1707
Standard Error	1.0707772	15490.423	309.12384
Minimum	0.3333333	0	-34
Maximum	910.33333	17247415	10951
Count	2358	2358	41

SIC 873	demp	dwages	dfunds
Mean	21.893922	258464.27	833.51613
Standard Error	2.7211139	28465.913	226.26364
Minimum	0.3333333	0	2
Maximum	1649	10200632	10571
Count	861	861	62

Appendix B: Weighting Scheme for Climate-Capabilities Matrix

The construction of the External Climate Index and the Virginia Capabilities Index follows a relatively simple and transparent scheme that consists of two steps:

Step 1:
Each component of the index—economic performance, innovative potential, and value added–is assigned an equal weight of 10 points. Within each area the 10 point weight is divided in a way that reflects the importance and availability of the data. The tables below list the assigned weights. In the case of innovative potential, for both indices research and development spending and patents are given equal weight. In the case of economic performance, the External Climate Index gives greater weight to national projections of industrial output, given the large size of the U.S. domestic market relative to trade with the rest of the world. For the Virginia Competencies Index, the location quotient and its change receives half of the weight, while employment and wage growth receives the other half, thus giving equal weight to industry concentration and regional growth.

Step 2:
Each indicator listed below is calculated for every high-tech industry for which the data are available and then that indicator is sorted in descending order. The industries are then divided into quintiles and the indicator values are assigned a score, from 0 to 4. The highest quintile receives a score of 4 and the lowest quintile receives a score of zero. Ranking by quintiles compress the range of values on each axis and allow easier visual comparisons. In the final computation of the indices, the indicator weight is multiplied by the indicator score and the resulting products are summed for all indicators in the index.

External Climate Index	weight
Economic Performance Indicators: 1. National Projections for Output Growth, 1998-2008 2. Export Growth, 1995-1999	 7 3
Innovative Potential Indicators: 1. Patents Granted in U.S., growth 1995-1998 2. Research and Development Spending by all U.S. Companies, growth 1995-1998	 5 5
Total Value Added: Type I Industry Multipliers for U.S.	 10

Virginia Capabilities Index	weight
Economic Performance Indicators: 1. Concentration of employment in Virginia relative to the nation (Location Quotient, 1998) 2. Change in Location Quotient, 1995-1998 3. Employment Growth, 1995-1999 4. Relative Wage – industry as share of state average, 1999 5. Relative Wage Growth, 1995-1999	 4 1 1 2 2
Innovative Potential Indicators: 1. Patents Granted in Virginia, growth 1995-1998 2. Federal R&D Contract Awards to Virginia Firms, industry share FY1999	 5 5
Total Value Added: Type I Industry Multipliers for Virginia 10	

Appendix C

NOTES for TABLE 6
EXTERNAL CLIMATE INDICATORS
Data sources for all variables are listed in the text on p. 48.
These notes indicate where an exact matching of data by 3-digit SIC code was not possible.

SIC	COMMENTS:
National Output Projections by Industry:	
Data Source: BLS employment and output projections, 1998-2008	
131	also includes SIC 132
281	used value of combined industries - 281 and 286
286	used value of combined industries - 281 and 287
481	also includes 482 and 489
372	used value of combined industries - 372 and 376
376	used value of combined industries - 372 and 377
Research and Development Spending by Companies:	
Data Source: National Science Foundation, Division of Sciecne Resource Studies	
131	used value of combined industries - 13 and 29
281	used value of combined industries - 281-282, 286
282	used value of combined industries - 281-282, 286
285	used value of combined industries - 284-285, 287-289
286	used value of combined industries - 281-282, 286
287	used value of combined industries - 284-285, 287-289
289	used value of combined industries - 284-285, 287-289
291	used value of combined industries - 13 and 29
351	used value of combined industries - 351-356, 358-359
355	used value of combined industries - 351-356, 358-359
356	used value of combined industries - 351-356, 358-359
361	used value of combined industries - 361-364, 369
362	used value of combined industries - 361-364, 369
369	used value of combined industries - 361-364, 369
372	used value of combined industries - 372, 376
376	used value of combined industries - 372, 376
381	used value of combined industries - 381-382
382	used value of combined industries - 381-382
384	used value of combined industries - 384-387
386	used value of combined industries - 384-387
Patents Granted by Industry:	
Data Source: United States Patent and Trademark Office	
131	used value of combined industries - 13 and 29
291	used value of combined industries - 13 and 29
348	also includes data for SIC 3795
361	also includes data for SIC 3825
366	used value of combined industries - 366-367
367	used value of combined industries - 366-367
381	used value for 2-digit SIC 38 (except 3825)
382	used value for 2-digit SIC 38 (except 3825)
384	used value for 2-digit SIC 38 (except 3825)
386	used value for 2-digit SIC 38 (except 3825)
Value Added Multiplier:	
Data Source: IMPLANPro, 1997 data	
372	used value of combined industries - 372, 376
376	used value of combined industries - 372, 376

NOTES for TABLE 7
VIRGINIA CAPABILITIES INDICATORS

Data sources for all variables are listed in the text on p. 48.
These notes indicate where an exact matching of data by 3-digit SIC code was not possible.

SIC COMMENTS:

Patents Granted by Industry:

Data Source: United States Patent and Trademark Office

- *131 used value of combined industries - 13 and 29*
- *291 used value of combined industries - 13 and 29*
- *348 also includes data for SIC 3795*
- *361 also includes data for SIC 3825*
- *366 used value of combined industries - 366-367*
- *367 used value of combined industries - 366-367*
- *381 used value for 2-digit SIC 38 (except 3825)*
- *382 used value for 2-digit SIC 38 (except 3825)*
- *384 used value for 2-digit SIC 38 (except 3825)*
- *386 used value for 2-digit SIC 38 (except 3825)*

Value Added Multiplier:

Data Source: IMPLANPro, 1997 data

- *372 used value of combined industries - 372, 376*
- *376 used value of combined industries - 372, 376*

Table C-1: Information Technology & Telecommunications Cluster Supplier Relationships

Computer and Data Processing Services Industry in Virginia — Supplier Industries:	% of Purchases
Electronic Components	14.8%
Real Estate	10.5%
Communications, Except Radio and TV	8.9%
Wholesale Trade	8.0%
Computers and Office Equipment	7.1%
Other Business Services	5.5%
Legal Services	5.2%
Personnel Supply Services	4.1%
Advertising	4.1%
Banking	3.0%
Total Purchases from Other Industries	$ 1,471

Computers and Office Equipment Industry in Virginia — Supplier Industries:	% of Purchases
Electronic Components	49.9%
Wholesale Trade	20.9%
Computer and Data Processing Services	4.0%
Advertising	2.5%
Real Estate	2.5%
Legal Services	2.0%
Maintenance and Repair Other Facilities	1.9%
Hotels and Lodging Places	1.6%
Electrical Industrial Apparatus	1.6%
Banking	1.5%
Total Purchases from Other Industries	$ 333

Communications Equipment Industry in Virginia — Supplier Industries:	% of Purchases
Electronic Components	55.7%
Wholesale Trade	11.5%
Computer and Data Processing Services	3.0%
Real Estate	2.4%
Maintenance and Repair Other Facilities	2.4%
Advertising	2.2%
Hotels and Lodging Places	1.9%
Banking	1.8%
Legal Services	1.6%
Communications, Except Radio and TV	1.5%
Total Purchases from Other Industries	$ 517

Computer and Data Processing Services Industry in U.S. — Supplier Industries:	% of Purchases
Electronic Components	11.6%
Computers and Office Equipment	10.7%
Communications, Except Radio and TV	10.3%
Real Estate	9.8%
Wholesale Trade	8.5%
Other Business Services	5.2%
Legal Services	4.8%
Advertising	3.6%
Personnel Supply Services	3.6%
Banking	3.2%
Total Purchases from Other Industries	$ 39,647

Computers and Office Equipment Industry in U.S. — Supplier Industries:	% of Purchases
Electronic Components	41.0%
Wholesale Trade	23.1%
Computer and Data Processing Services	3.7%
Electrical Industrial Apparatus	2.5%
Real Estate	2.4%
Miscellaneous Plastics Products	2.4%
Advertising	2.3%
Legal Services	1.9%
Banking	1.7%
Hotels and Lodging Places	1.4%
Total Purchases from Other Industries	$ 47,770

Communications Equipment Industry in U.S. — Supplier Industries:	% of Purchases
Electronic Components	44.2%
Wholesale Trade	12.3%
Miscellaneous Plastics Products	3.3%
Computer and Data Processing Services	2.7%
Real Estate	2.3%
Banking	2.0%
Advertising	2.0%
Communications, Except Radio and TV	1.7%
Metal Stampings, N.E.C.	1.7%
Maintenance and Repair Other Facilities	1.6%
Total Purchases from Other Industries	$ 34,924

KEY:

Shaded areas represent high-tech industries included in this cluster

Bold (but not shaded) represent high-tech industries that are not included as part of this cluster

Source: IMPLAN, 1997 data (most recent available)

Telephone Communications Industry in Virginia — Supplier Industries:	% of Purchases
Maintenance and Repair Other Facilities	19.0%
Computer and Data Processing Services	9.9%
Engineering, Architectural Services	7.3%
Advertising	6.2%
Electronic Components	5.9%
Accounting, Auditing and Bookkeeping	4.9%
Motion Pictures	4.8%
Real Estate	4.8%
Communications Equipment	3.9%
Banking	3.4%
Total Purchases from Other Industries	$ 1,706

Electronic Components and Accessories Industry in Virginia — Supplier Industries:	% of Purchases
Wholesale Trade	20.1%
Maintenance and Repair Other Facilities	6.3%
Advertising	5.7%
Legal Services	5.0%
Computer and Data Processing Services	4.9%
Real Estate	3.9%
Electric Services	3.5%
Hotels and Lodging Places	3.0%
Banking	2.9%
Primary Nonferrous Metals, N.E.C.	2.7%
Total Purchases from Other Industries	$ 373

Electrical Industrial Apparatus Industry in Virginia — Supplier Industries:	% of Purchases
Wholesale Trade	24.2%
Electronic Components	11.9%
Advertising	6.6%
Motor Freight Transport and Warehousing	5.2%
Maintenance and Repair Other Facilities	3.4%
Banking	3.3%
Real Estate	3.1%
Hotels and Lodging Places	3.0%
Electric Services	2.9%
Computer and Data Processing Services	2.2%
Total Purchases from Other Industries	$ 194

Telephone Communications Industry in U.S. — Supplier Industries:	% of Purchases
Maintenance and Repair Other Facilities	14.4%
Computer and Data Processing Services	9.7%
Engineering, Architectural Services	6.7%
Advertising	6.0%
Motion Pictures	5.8%
Electronic Components	5.2%
Real Estate	5.0%
Accounting, Auditing and Bookkeeping	4.5%
Banking	4.1%
Communications Equipment	3.5%
Total Purchases from Other Industries	$ 65,841

Electronic Components and Accessories Industry in U.S. — Supplier Industries:	% of Purchases
Wholesale Trade	18.6%
Plating and Polishing	6.2%
Maintenance and Repair Other Facilities	5.0%
Advertising	4.4%
Legal Services	4.0%
Miscellaneous Plastics Products	3.9%
Computer and Data Processing Services	3.8%
Real Estate	3.2%
Banking	2.7%
Electric Services	2.6%
Total Purchases from Other Industries	$ 46,436

Electrical Industrial Apparatus Industry in U.S. — Supplier Industries:	% of Purchases
Wholesale Trade	16.7%
Electronic Components	6.1%
Miscellaneous Plastics Products	5.7%
Blast Furnaces and Steel Mills	5.4%
Nonclay Refractories	4.9%
Nonferrous Wire Drawing and Insulating	4.8%
Advertising	3.8%
Metal Stampings, N.E.C.	3.1%
Banking	2.3%
Motor Freight Transport and Warehousing	2.3%
Total Purchases from Other Industries	$ 14,078

Table C-2: Biotechnology and Medical Cluster Supplier Relationships

Drug Industry in Virginia Supplier Industries:	% of Purchases	**Medical Equipment, Instruments, and Supplies Industry in Virginia** Supplier Industries:	% of Purchases	**Research, Development, and Testing Services Industry in Virginia** Supplier Industries:	% of Purchases
Advertising	21.7%	Wholesale Trade	18.0%	**Computer and Data Processing Services**	17.1%
Wholesale Trade	18.3%	**Electronic Components**	15.5%	**Engineering, Architectural Services**	11.7%
Accounting, Auditing and Bookkeeping	6.2%	Advertising	8.4%	Management and Consulting Services	9.3%
Research, Development & Testing Services	5.9%	Legal Services	4.6%	Real Estate	7.1%
Legal Services	4.2%	Paperboard Containers and Boxes	4.6%	Other Business Services	6.0%
Paperboard Containers and Boxes	4.0%	Real Estate	3.7%	**Electronic Components**	5.6%
Maintenance and Repair Other Facilities	3.3%	Maintenance and Repair Other Facilities	3.4%	Personnel Supply Services	4.7%
Industrial Chemicals	3.0%	Motor Freight Transport and Warehousing	3.4%	**Communications, Except Radio and TV**	3.4%
Other Business Services	2.6%	Job Trainings & Related Services	3.4%	Wholesale Trade	2.8%
Hotels and Lodging Places	2.4%	Hotels and Lodging Places	2.8%	Accounting, Auditing and Bookkeeping	2.6%
Total Purchases from Other Industries	*$ 157*	*Total Purchases from Other Industries*	*$ 99*	*Total Purchases from Other Industries*	*$ 400*

Drug Industry in U.S. Supplier Industries:	% of Purchases	**Medical Equipment, Instruments, and Supplies Industry in U.S.** Supplier Industries:	% of Purchases	**Research, Development, and Testing Services Industry in U.S.** Supplier Industries:	% of Purchases
Wholesale Trade	19.1%	Wholesale Trade	13.8%	**Computer and Data Processing Services**	15.9%
Advertising	18.8%	**Electronic Components**	10.0%	**Engineering, Architectural Services**	10.2%
Miscellaneous Plastics Products	5.6%	Miscellaneous Plastics Products	7.1%	Management and Consulting Services	8.6%
Research, Development & Testing Services	5.1%	Advertising	4.6%	Real Estate	7.1%
Accounting, Auditing and Bookkeeping	5.1%	Metal Coating and Allied Services	4.1%	Other Business Services	6.1%
Legal Services	3.8%	Legal Services	3.5%	**Electronic Components**	4.9%
Industrial Organic Chemicals	3.3%	Metal Stampings, N.E.C.	3.0%	Personnel Supply Services	4.3%
Paperboard Containers and Boxes	2.6%	Nonwoven Fabrics	2.9%	**Communications, Except Radio and TV**	4.2%
Other Business Services	2.5%	Real Estate	2.8%	Wholesale Trade	3.1%
Banking	2.3%	**Computers and Office Equipment**	2.5%	Banking	2.6%
Total Purchases from Other Industries	*$ 28,154*	*Total Purchases from Other Industries*	*$ 29,974*	*Total Purchases from Other Industries*	*$ 17,181*

KEY:

Shaded areas represent high-tech industries included in this cluster

Bold (but not shaded) represent high-tech industries that are not included as part of this cluster

Source: IMPLAN, 1997 data (most recent available)

Table C-3: Aerospace Cluster Supplier Relationships

Aerospace* Industry in Virginia Supplier Industries:	% of Purchases
Search & Navigation Equipment	19.3%
Wholesale Trade	11.1%
Computer and Data Processing Services	7.6%
Electronic Components	6.1%
Maintenance and Repair Other Facilities	4.8%
Banking	3.3%
Hotels and Lodging Places	3.2%
Motor Freight Transport and Warehousing	2.9%
Measuring & Controlling Devices	2.8%
Communications Equipment	2.8%
Total Purchases from Other Industries	*$ 64*

Search & Navigation Industry in Virginia Supplier Industries:	% of Purchases
Electronic Components	34.9%
Research, Development & Testing Services	19.1%
Wholesale Trade	6.6%
Communications Equipment	5.7%
Advertising	3.6%
Computer and Data Processing Services	2.8%
Real Estate	2.1%
Maintenance and Repair Other Facilities	1.8%
Hotels and Lodging Places	1.7%
Other Business Services	1.6%
Total Purchases from Other Industries	*$ 313*

Aerospace* Industry in U.S. Supplier Industries:	% of Purchases
Search & Navigation Equipment	15.3%
Wholesale Trade	9.8%
Computer and Data Processing Services	5.6%
Electronic Components	4.0%
Miscellaneous Plastics Products	3.6%
Banking	3.0%
Maintenance and Repair Other Facilities	2.7%
Industrial Machines N.E.C.	2.6%
Hotels and Lodging Places	2.2%
Air Transportation	2.1%
Total Purchases from Other Industries	*$ 48,342*

Search & Navigation Industry in U.S. Supplier Industries:	% of Purchases
Electronic Components	28.9%
Research, Development & Testing Services	17.6%
Wholesale Trade	7.3%
Communications Equipment	4.8%
Advertising	3.3%
Computer and Data Processing Services	2.6%
Real Estate	2.1%
Banking	1.8%
Communications, Except Radio and TV	1.7%
Other Business Services	1.7%
Total Purchases from Other Industries	*$ 20,322*

*Note: 372 and 376 cannot be separated out in IMPLAN, so aerospace here is the combination of the 2 SIC codes:
372=Aircraft, engines, and parts
376=Guided missiles, space vehicles, parts

KEY:
Shaded areas represent high-tech industries included in this cluster
Bold (but not shaded) represent high-tech industries that are not included as part of this cluster

Source: IMPLAN, 1997 data (most recent available)

Table C-4: Unassigned Industries

Measuring & Controlling Devices - VA	SIC 382	Photographic Equipment and Supplies - VA	SIC 386	Engineering and Architectural Services - VA	SIC 871
Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases
Electronic Components	30.7%	Wholesale Trade	20.0%	Other Business Services	26.0%
Wholesale Trade	13.0%	**Electronic Components**	18.8%	Accounting, Auditing and Bookkeeping	18.5%
Advertising	6.8%	**Research, Development & Testing Services**	9.2%	Management and Consulting Services	10.2%
Computer and Data Processing Services	4.2%	Paperboard Containers and Boxes	4.3%	**Computer and Data Processing Services**	8.2%
Accounting, Auditing and Bookkeeping	3.6%	Job Trainings & Related Services	3.7%	Real Estate	6.9%
Maintenance and Repair Other Facilities	2.9%	Motor Freight Transport and Warehousing	3.5%	**Research, Development & Testing Services**	5.9%
Glass and Glass Products, Exc Containers	2.9%	**Plastic Materials and Synthetics**	3.2%	Personnel Supply Services	5.3%
Real Estate	2.7%	Banking	2.8%	Hotels and Lodging Places	2.3%
Electrical Industrial Apparatus	2.7%	**Industrial Organic Chemicals**	2.8%	Banking	2.3%
Hotels and Lodging Places	2.3%	Maintenance and Repair Other Facilities	2.7%	**Communications, Except Radio and TV**	2.0%
Total Purchases from Other Industries	*$ 165*	*Total Purchases from Other Industries*	*$ 62*	*Total Purchases from Other Industries*	*$ 1,184*

Measuring & Controlling Devices - US	SIC 382	Photographic Equipment and Supplies - US	SIC 386	Engineering and Architectural Services - US	SIC 871
Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases
Electronic Components	20.7%	Wholesale Trade	18.8%	Other Business Services	27.2%
Wholesale Trade	11.7%	**Electronic Components**	13.1%	Accounting, Auditing and Bookkeeping	16.7%
Advertising	5.1%	**Research, Development & Testing Services**	7.1%	Management and Consulting Services	9.7%
Miscellaneous Plastics Products	3.9%	Miscellaneous Plastics Products	4.9%	**Computer and Data Processing Services**	7.8%
Sheet Metal Work	3.7%	**Industrial Organic Chemicals**	3.5%	Real Estate	7.1%
Electrical Industrial Apparatus	3.5%	Paper Coated & Laminated N.E.C.	2.9%	**Research, Development & Testing Services**	5.7%
Computer and Data Processing Services	3.2%	Banking	2.7%	Personnel Supply Services	5.1%
Accounting, Auditing and Bookkeeping	2.5%	Paperboard Containers and Boxes	2.5%	Banking	2.7%
Glass and Glass Products, Exc Containers	2.2%	Paper Mills, Except Building Paper	2.4%	**Communications, Except Radio and TV**	2.5%
Real Estate	2.2%	Metal Stampings, N.E.C.	2.3%	Hotels and Lodging Places	2.1%
Total Purchases from Other Industries	*$ 28,179*	*Total Purchases from Other Industries*	*$ 13,846*	*Total Purchases from Other Industries*	*$ 41,765*

KEY:

Bold represents high-tech industries that are not included as part of this cluster

Source: IMPLAN, 1997 data (most recent available)

Plastic Materials and Synthetics - VA	SIC 282	Miscellaneous Chemical Products - VA	SIC 289	Agricultural Chemicals - VA	SIC 287
Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases
Industrial Organic Chemicals	26.7%	Motor Freight Transport and Warehousing	15.8%	Motor Freight Transport and Warehousing	19.6%
Wholesale Trade	10.9%	**Industrial Organic Chemicals**	14.4%	Wholesale Trade	11.9%
Industrial Inorganic Chemicals	8.1%	Wholesale Trade	10.9%	**Industrial Organic Chemicals**	9.3%
Motor Freight Transport and Warehousing	6.4%	**Plastic Materials and Synthetics**	9.1%	**Natural Gas & Crude Petroleum**	6.3%
Accounting, Auditing and Bookkeeping	3.8%	**Industrial Inorganic Chemicals**	4.1%	Railroads and Related Services	4.2%
Maintenance and Repair Other Facilities	3.5%	Paperboard Containers and Boxes	3.5%	Advertising	4.0%
Electric Services	3.4%	**Engineering, Architectural Services**	3.4%	Maintenance and Repair Other Facilities	3.0%
Misc Chemicals	3.3%	Railroads and Related Services	3.3%	**Industrial Inorganic Chemicals**	2.8%
Legal Services	2.6%	Advertising	3.0%	Banking	2.7%
Engineering, Architectural Services	2.5%	Legal Services	2.9%	Electric Services	2.6%
Total Purchases from Other Industries	*$ 1,008*	*Total Purchases from Other Industries*	*$ 147*	*Total Purchases from Other Industries*	*$ 37*

Plastic Materials and Synthetics - US	SIC 282	Miscellaneous Chemical Products - US	SIC 289	Agricultural Chemicals - US	SIC 287
Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases	Supplier Industries:	% of Purchases
Industrial Organic Chemicals	31.7%	**Industrial Organic Chemicals**	10.1%	**Industrial Organic Chemicals**	11.5%
Industrial Inorganic Chemicals	10.5%	Wholesale Trade	9.4%	Motor Freight Transport and Warehousing	11.3%
Wholesale Trade	9.4%	Motor Freight Transport and Warehousing	7.7%	**Natural Gas & Crude Petroleum**	11.2%
Miscellaneous Plastics Products	7.2%	**Petroleum Refining**	5.7%	Wholesale Trade	10.6%
Motor Freight Transport and Warehousing	3.6%	**Industrial Inorganic Chemicals**	4.9%	**Industrial Inorganic Chemicals**	3.8%
Misc Chemicals	2.6%	**Plastic Materials and Synthetics**	3.4%	Potash, Soda, and Borate Minerals	3.1%
Accounting, Auditing and Bookkeeping	2.5%	**Paints and Allied Products**	3.3%	Advertising	3.0%
Electric Services	2.3%	**Engineering, Architectural Services**	2.3%	Railroads and Related Services	2.6%
Maintenance and Repair Other Facilities	2.0%	Legal Services	2.3%	Banking	2.5%
Legal Services	2.0%	Advertising	2.1%	Wet Corn Milling	2.3%
Total Purchases from Other Industries	*$ 36,301*	*Total Purchases from Other Industries*	*$ 13,127*	*Total Purchases from Other Industries*	*$ 11,957*

Table C-4: Unassigned Industries Continued

SIC 287 % of Purchases	Miscellaneous Electrical Machinery - VA Supplier Industries:	SIC 369 % of Purchases
19.6%	**Electronic Components**	28.7%
11.9%	Wholesale Trade	20.2%
9.3%	Motor Freight Transport and Warehousing	4.1%
6.3%	Paperboard Containers and Boxes	3.6%
4.2%	Advertising	3.3%
4.0%	**Plastic Materials and Synthetics**	2.8%
3.0%	Primary Nonferrous Metals, N.E.C.	2.8%
2.8%	Maintenance and Repair Other Facilities	2.2%
2.7%	Banking	2.2%
2.6%	Real Estate	2.0%
$ 37	*Total Purchases from Other Industries*	$ 239

SIC 287 % of Purchases	Miscellaneous Electrical Machinery - US Supplier Industries:	SIC 369 % of Purchases
11.5%	**Electronic Components**	19.1%
11.3%	Wholesale Trade	18.0%
11.2%	Miscellaneous Plastics Products	10.4%
10.6%	Advertising	2.5%
3.8%	Nonferrous Wire Drawing and Insulating	2.5%
3.1%	Motor Freight Transport and Warehousing	2.4%
3.0%	Banking	2.0%
2.6%	Paperboard Containers and Boxes	2.0%
2.5%	**Electrical Industrial Apparatus**	2.0%
2.3%	Fabricated Metal Products, N.E.C.	1.8%
$ 11,957	*Total Purchases from Other Industries*	$ 13,879

Table C-5: Percentage Distribution of Employment in Cluster Industries By Region, 1999

	Virginia	Northern Virginia	Hampton Roads	Richmond-Petersburg	Lynchburg	Roanoke	Charlottes-ville	Danville	Bristol Portion of VA	Non-Metro Areas
Information Technology and Communications	**100.0**	**67.3**	**9.2**	**7.5**	**2.3**	**2.4**	**1.7**	**0.1**	**0.1**	**9.4**
737 Computer and data processing services	100.0	80.8	7.2	4.5	0.3	0.9	0.6	0.0	0.1	5.5
357 Computers and office equipment	100.0	9.1	82.0	1.8	0.1	0.0	0.0	0.0	0.0	7.1
481 Telephone communications	100.0	56.3	8.6	11.6	0.8	2.4	1.3	0.2	0.2	18.6
366 Communications equipment	100.0	22.8	0.8	0.0	47.1	8.3	N.D.	N.D.	0.0	8.0
367 Electronic components and accessories	100.0	18.5	10.8	38.5	5.8	7.0	12.3	0.0	0.0	6.9
362 Electrical Industrial Apparatus	100.0	1.6	1.9	4.1	7.7	31.1	N.D.	N.D.	N.D.	51.8
Biotechnology and Medical	**100.0**	**48.1**	**18.8**	**13.5**	**1.9**	**2.5**	**2.3**	**0.1**	**0.1**	**12.8**
283 Drugs	100.0	2.2	N.D.	48.5	N.D.	N.D.	0.1	0.0	0.0	36.9
384 Medical Equipment, instruments, and supplies	100.0	20.3	11.2	21.5	1.1	8.5	N.D.	N.D.	N.D.	36.7
873 Research, development, and testing services	100.0	60.4	23.3	5.9	0.5	1.8	2.9	N.D.	N.D.	5.0
Aerospace	**100.0**	**57.4**	**20.8**	**0.0**	**0.1**	**0.0**	**10.9**	**0.1**	**0.0**	**10.8**
372 Aircraft, engines, and parts	100.0	10.6	56.4	0.0	N.D.	0.0	0.1	N.D.	0.0	32.4
376 Guided missiles, space vehicles, parts	100.0	87.1	10.9	0.0	0.0	0.0	0.0	0.0	0.0	2.0
381 Search and navigation equipment	100.0	75.3	N.D.	0.0	0.0	0.0	21.6	0.0	0.0	N.D.

N.D. = Not disclosed.

REPORT OF THE SECRETARY OF TECHNOLOGY
PREPARED BY The Virginia Research & Technology Advisory Commission AND Virginia's Center for Innovative Technology

RECOMMENDATIONS FOR IMPROVING THE INTELLECTUAL PROPERTY POLICIES AND PRACTICES IN VIRGINIA'S PUBLIC UNIVERSITIES AND FEDERAL LABORATORIES

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

COMMONWEALTH OF VIRGINIA
RICHMOND
2000

Executive Summary

The purpose of this study is to suggest improved policies and procedures that will lead to an increase in private sector investment in R&D performed in Virginia's universities and also enhance the environment and opportunities for creating innovative start-up companies driving new economic growth in the Commonwealth.

The Intellectual Property (IP) Subcommittee of Virginia's Research and Technology Advisory Commission (VRTAC) reviewed IP policies and procedures in place at Virginia's public research universities with the view towards improving the linkages between the research institutions and the private sector. The IP subcommittee was represented by VP-level R&D management at four of Virginia's research universities, senior management from three companies in the private sector, legal counsel from a major federal laboratory, and a senior manager from Virginia's Center for Innovative Technology.

Briefly summarized, the subcommittee considered and debated a broad range of IP issues and ultimately developed a series of recommendations. These recommendations should be recognized as only the beginning of an evolutionary process for improving management of Virginia's IP resources:

1. Research universities should develop draft "common term sheets" for both industry-sponsored research agreements and intellectual property agreements so that there is a common base from which industry/university relationships can be built and negotiated.

2. To simplify regulation and to speed up the development of industry/university partnerships, the Virginia legislature should delete all sentences beyond the first in §23-4.4 of the Virginia Code, allowing the Universities' Boards of Visitors the ability to assign companies the ownership of Intellectual Property developed at the Universities.

3. CIT should complete and fully implement an user-friendly, website based, statewide comprehensive Intellectual Property database, including the Commonwealth's research universities and federal laboratories.

4. To improve access to Virginia-developed technologies, especially those at smaller institutions, the Academic Licensing Community of Virginia (ALCOVe) should be provided with Commonwealth resources and institutional support to broaden awareness of its existence and user access to its database and other intellectual property information.

5. There should be a Commonwealth-wide Intellectual Property Coordinator, funded by and located at CIT.

6. VRTAC should organize and sponsor a workshop in the late spring of 2001 to enhance awareness and understanding of intellectual property opportunities and management throughout the Commonwealth.

Virginia Research & Technology Advisory Commission

Report of the Intellectual Property Subcommittee

RECOMMENDATIONS FOR IMPROVING THE INTELLECTUAL PROPERTY POLICIES AND PRACTICES IN VIRGINIA'S PUBLIC UNIVERSITIES AND FEDERAL LABORATORIES

Intellectual Property Subcommittee Members

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November 2000

Introduction

The objective of the Intellectual Property (IP) Subcommittee of Virginia's Research and Technology Advisory Commission (VRTAC) was to review IP policies and procedures in place at Virginia's public research universities with the view towards improving the linkages between the research institutions and the private sector. It is anticipated that improved policies and procedures will lead to an increase in private sector investment in R&D performed in Virginia's universities and also enhance the environment and opportunities for creating innovative start-up companies driving new economic growth in the Commonwealth.

The IP subcommittee was represented by VP-level R&D management at four of Virginia's research universities, senior management from three companies in the private sector, legal counsel from a major federal laboratory, and a senior manager from Virginia's Center for Innovative Technology. The deliberations coming from the IP subcommittee are intended to inform VRTAC of the issues and allow VRTAC as a whole to develop specific recommendations for the Secretary of Technology. The specific recommendations contained herein will be for the Governor and General Assembly to consider for improving the Commonwealth's IP management.

The IP subcommittee held five meetings over the twelve-week time period from June 20th to September 29th, 2000. In addition to its members, the subcommittee heard from a number of outside guests, including the authors of the Interim Report of the Secretary of Technology, "AN ASSESSMENT OF THE INTELLECTUAL PROPERTY POLICIES AND PRACTICES IN VIRGINIA"S PUBLIC UNIVERSITIES AND FEDERAL LABORATORIES", a representative from Arizona, where innovative IP management has recently been developed, a delegate from the General Assembly's Joint Commission on Technology and Science (JCOTS), and other individuals from the research universities, CIT and the private sector.

Briefly summarized, the subcommittee considered and debated a broad range of IP issues and ultimately developed a series of six recommendations contained herein. Along with each recommendation there is a brief rationale and set of follow-up actions.

The subcommittee is mindful of the fact that conclusions and recommendations needs to be in place to allow for sufficient discussion with appropriate Commonwealth agencies (e.g., JCOTS) prior to the 2001 legislative session. Therefore, the report is submitted by VRTAC to the Secretary of Technology at this time.

Finally, the process and recommendations contained herein should be recognized as only the beginning of an evolutionary process for improving management of Virginia's IP resources. Some of the recommendations below provide a means for continuing the process – to the mutual benefit of Virginia's public research institutions and the private sector.

Recommendations

Recommendation #1: Research universities should develop draft "common term sheets" for both industry-sponsored research agreements and intellectual property agreements so that there is a common base from which industry/university relationships can be built and negotiated.

Background and Rationale: Companies in Virginia will on occasion suggest that confusion can occur in research contract negotiations because the various state universities have different agreement documents for sponsored projects; these agreements will many times also include agreements on intellectual property rights that also vary. Since the state universities must abide by the same state statutes and the differences frequently result from standard operating practices at the individual universities, considerable uniformity of these agreements seems a reasonable goal, especially for the more routine sponsored project and intellectual property agreements. The primary goals of the documents are to facilitate efficient and uniform contract negotiations, and to negate to a large extent any substantial variations among industry-supported contracts involving the state-supported universities. This common starting point for initial negotiations will also enhance the perception that Virginia is an easy place for companies to do business.

Required Actions and Follow-up. A group consisting of the chief research officers at the seven major Virginia research universities, along with individuals from each university's sponsored programs and intellectual properties offices, should prepare and distribute draft "common term sheets" for both industry-sponsored research and intellectual property agreements. This group should make its recommendations to the VRTAC by February 15, 2001.

Recommendation #2: To simplify regulation and to speed up the development of industry/university partnerships, the Virginia legislature should delete all sentences beyond the first in §23-4.4 of the Virginia Code, as indicated below:

§ 23-4.4. Authorization to transfer interest~~; Governor's approval required under certain circumstances~~.

The Boards of Visitors, the State Board for Community Colleges, or their designees may transfer any interest they possess in patents and copyrights or in materials in which the institution claims an interest under its patent or copyright policy~~. However, the Governor's prior written approval shall be required for transfers of such property developed wholly or significantly through the use of state general funds and either (i) such property was developed by an employee of the institution acting within the scope of his assigned duties, or (ii) such property is to be transferred to an entity other than the Innovative Technology Authority, an entity whose purpose is to manage intellectual properties on behalf of nonprofit organizations, colleges and universities, or an entity whose purpose is to benefit the respective institutions. The Governor may attach conditions to these transfers as he deems necessary. In the event the Governor does not approve such transfer, the materials shall remain the property of the respective institutions and may be used and developed in any manner permitted by law. The State Council of Higher Education~~

~~working in cooperation with the state-supported institutions of higher education and in accordance with § 23-9.10:4 shall adopt a uniform statement defining (i) the conditions under which a significant use of general funds occurs and (ii) the circumstances constituting an assigned duty.~~

Background and Rationale: Ownership of intellectual property (IP) generated by Virginia's public universities was noted as a critical issue in the Interim Report of the Secretary of Technology, "An Assessment of the Intellectual Property Policies and Practices in Virginia's Public Universities and Federal Laboratories", issued in early 2000. As pointed out in that report, there appears to be significant confusion between industry and universities on whether IP generated either collaboratively with industry or solely at the university can be assigned to private industry. Universities turn to §23-4.4 of the Virginia code as shown above and several have taken the position that they cannot assign IP to any third party other than the 501(c)(3) foundations that manage the IP. The confusion of interpretation in §23-4.4 stems from the fact that the term "significant use of general funds" has never been defined anywhere in the Virginia Code, even though the State Council of Higher Education was directed to work with the state-supported institutions of higher education to adopt a uniform statement defining the term. While many larger firms are willing to accept exclusive license, IP can be a major asset of many high tech start-ups and spin-offs who rely on its ownership as a means of leveraging financing. Furthermore, some firms may be concerned with not being able to use the fact of ownership as a barrier against their competition. To quote the Interim Report, "Further, their fear is that the universities, the actual owners, will not be able to afford the litigation that may ensue. Additionally, even if the universities can afford such litigation, the universities may not have the same goals as the private company that sponsored the research and paid for the license of the IP." The use of litigation as a means of defending patent position is especially commonplace in biotechnology.

Required Actions and Follow-up: Since VRTAC is recommending a change to the Virginia Code, appropriate preparation must be made prior to the upcoming 2001 legislative session. Accordingly, representatives from VRTAC should introduce this recommendation to JCOTS as soon as possible, but in no event later than November 1st, 2000.

If the governor so wishes, he can issue an executive order covering the interim period before any legislative action might take effect.

Recommendations 3-5 below deal with enhanced and easier to access Commonwealth IP resources.

Recommendation #3: CIT should complete and fully implement an user-friendly, website based, statewide comprehensive Intellectual Property database, including the Commonwealth's research universities and federal laboratories.

Background and Rationale: Several years ago the Center for Innovative Technology encouraged the Virginia universities to adopt a common database system for tracking inventions and issued patents and offered to subsidize the purchase of the necessary software. At that time, the plan was to eventually use this platform to provide a central database of patents held by the Commonwealth's universities. In addition to acting as a statewide database, the Daily Evaluation and Licensing Software (D.E.A.L.S.) can help individual university patent offices manage their entire patent portfolio. It was determined that D.E.A.L.S. could support both non-confidential and confidential data resources; D.E.A.L.S. is quite flexible, and can be used to create a central, non-confidential database while at the same time allowing universities to maintain confidentiality of other information kept in their local databases.

The rapid rise in the use of the Internet in university and company life has led most technology transfer offices at the Commonwealth universities to have their own websites, and some of these (most notably at Tech and UVA) provide Internet-accessible listings of inventions available for licensing.

Recognizing their joint interests and shared challenges, the technology transfer officers from most of the Virginia universities last year worked together to form a new "user's group" called the Academic Licensing Community of Virginia (ALCOVe). ALCOVe has become an important conduit for communication among technology transfer officers at Virginia institutions and for informing companies interested in licensing opportunities. ALCOVe has a website at www.alcove.org which provides links to the websites of the technology transfer offices at UVA, Virginia Tech, VCU, and Old Dominion; and each of these contain databases of inventions available for licensing. The ALCOVe website also contains a large number of links to other useful intellectual property-related sites. Perhaps most importantly, this site also contains a private, password-protected "resources" section that contains the model licenses, research contracts, material transfer agreements, and other relevant documents from each institution, and this allows sister institutions to learn from one another. In addition, ALCOVe has an e-mail group that allows members to easily ask other ALCOVe members about specific issues and concerns that have arisen in particular transactions. These messages often lead to detailed telephone conversations that provide very significant cross-fertilization of ideas and perspectives.

The Internet today is awash in databases of inventions available for licensing; there are probably several dozen as of this writing and many of them list university inventions for free. However, many of these are so large, or so broad in scope, that they suffer from the difficulty often described as "drinking from the fire hose." Consequently there is logic for and potential benefits from constructing a smaller Internet-accessible database that will permit effective sharing of IP information and expertise among the Commonwealth's universities and national laboratories. First, the easy identification of complementary technologies at different Virginia institutions may help attract Virginia companies that are looking for broad competency in a particular discipline that might not be resident at any one Commonwealth institution. Second, the ability to pinpoint complementary IP and, perhaps more importantly, complementary expertise among faculty at different institutions may make Virginia a particularly attractive site for companies considering doing business here. Third, IP list sharing should encourage collaborations and partnerships among universities. Fourth, such list sharing may also aid in finding a "buyer" for technology; as each IP office has many contacts with industries that are looking for technology, and when a company is looking for technology that may not be within the portfolio of a particular institution, making them aware of appropriate technology at another State institution may lead to overall gains in the Commonwealth's licensing success.

Completing the work started using the D.E.A.L.S. database and integrating that with the website and collaborative work already begun by ALCOVe, would be an excellent next step towards developing a more integrated IP effort throughout the Commonwealth.

Required Action and Follow-up: VRTRAC should recommend to the President of CIT that sufficient resources be made available to allow for the full implementation of the D.E.A.L.S. system and the creation from that of a non-confidential database of technologies available for license. CIT should work with ALCOVe in insuring that the database contains appropriate information that will be most helpful to the IP offices and to companies interesting in licensing IP. The resulting non-confidential database should then be made accessible through CIT's website, InnovationAvenue. InnovationAvenue already contains databases of VA universities' faculty expertise, VA technology companies and NASA Intellectual Property. A link to the ALCOVe website should be added to the CIT website (and to any other websites that might make it easier for companies to find the database.)

Recommendation #4: To improve access to Virginia-developed technologies, especially those at smaller institutions, the Academic Licensing Community of Virginia (ALCOVe) should be provided with Commonwealth resources and institutional support to broaden awareness of its existence and user access to its database and other intellectual property information.

Background and Rationale: The development of ALCOVe, described above, is a promising sign that the several universities believe that they can cooperate voluntarily in this area to their mutual benefit. Such grass roots-initiated organization would seem to be an excellent vehicle to continue to develop into a statewide organization that can play an important role in increasing IP-related activities in the Commonwealth. The unusually cooperative, non-competitive nature of this organization suggests that by providing it with financial resources and institutional support, ALCOVe can become considerably stronger and more valuable to the participating institutions and the Commonwealth more generally, while allowing them to maintain local autonomy which is critical for efficient transfer of IP. ALCOVe can also play an important role in the training and support of fledgling IP offices as they become established at our smaller institutions, which should be an important part of any Commonwealth-wide effort to improve access to Virginia-developed technologies.

Required Action and Follow-up: Insofar as ALCOVe is an unstaffed "users group" it may be important to provide some infrastructure (e.g., webmaster services, secretarial support, funds for inter-institutional travel) to ensure that it will become an effective multi-institutional vehicle. A logical organization to provide such support is CIT. VRTAC should request that CIT seek funds to provide appropriate support for ALCOVe.

Recommendation #5: There should be a Commonwealth-wide Intellectual Property Coordinator, funded by and located at CIT.

Background and Rationale: There is general agreement that existing university IP offices are operating near capacity and it seems unlikely that these offices will have sufficient manpower to spend large amounts of time in developing new mechanisms for inter-institutional cooperation and for maintaining common databases, etc. There is logic in creating a position for an individual who could devote time to creating, maintaining and extending a non-confidential DEALS database of technologies available for license, and who could act as a resource for directing companies to appropriate institutional IP offices.

We believe that there is logic to citing the IP coordinator at CIT. CIT has already started implementing the institution-wide DEALS system. In addition, CIT is expected to be a focal point for industry contact. An individual that was fully knowledgeable about IP activities at the state's institutions could act as an important resource in steering companies to the appropriate institution, or in catalyzing interactions among the company and several institutions with complementary IP and/or research expertise.

Required Action and Follow-up: Although the committee believes that there is logic to creation of the coordinator position, it also recognizes that the exact work description for this position and the necessary time commitment requires further study. It will be important for those most knowledgeable about these issues, our institution's IP office directors, to take an active role in defining this position and determining whether it is part-time or full-time. Consequently we recommend that ALCOVe along with CIT be engaged to help develop the work description for the IP coordinator position, to be submitted to VRTAC by 1 February 2000.

Recommendation #6: VRTAC should organize and sponsor a workshop in the late spring of 2001 to enhance awareness and understanding of intellectual property opportunities and management throughout the Commonwealth.

Background and Rationale: The IP subcommittee has found a widespread view that industry, government officials, university faculty, financial organizations and others are not well-versed in the management of intellectual property assets, in arranging for licensing of patents, and in the array of state, federal and institutional policies and practices that shape the context for more effective commercialization of intellectual property developed in Virginia's universities and federal laboratories.

The workshop should have as a task to identify opportunities for VRTAC to take further action to improve intellectual property commercialization in the Commonwealth. The nature of our recommendations and the rationales for them should be widely shared among the interested sectors, and the results of their consideration should be made available to the general public.

Finally, it is our view that the general lack of awareness and understanding, coupled with certain aspects of state and institutional policy and practice, have led to substantial misunderstandings of the nature of past efforts--successful and unsuccessful--to commercialize university-based technology in Virginia.

We believe that a carefully planned and targeted statewide workshop would provide an important means by which to enhance this awareness and understanding.

Primary Objectives of the Workshop

1. To present and discuss the findings and recommendations of VRTAC on intellectual property management among universities, government laboratories and industry in the Commonwealth

2. To increase knowledge and awareness of methods, procedures and organizations that are available to industry and other interested parties to obtain effective access to new ideas and technologies developed in the universities and government laboratories in Virginia.

3. To provide a forum in which interested parties can air issues and problems, as well as successes, that have arise in seeking to strike "deals" between universities, companies and laboratories in Virginia.

Participants

We envision a "leadership" workshop with a target attendance of perhaps 100 persons from industry, universities, laboratories, government agencies, financial institutions, the legal profession, and other interested parties.

Style

The style of the workshop would be participatory and interactive. Speeches "to" the attendees would be limited in number and duration, and intended to stimulate discussion. Information transfer regarding state and federal programs and procedures would be presented in a complementary Web site and/or in hard copy and would not be the subject of detailed presentations.

Logistics

The workshop would be held in a central location in the Commonwealth, most likely in Richmond. A one-day event is envisioned. A modest registration fee would be charged to defray out of pocket expenses such as meals and conference room rentals.

Complementary Case Studies

In order to deepen the dialogue at the workshop, VRTAC, with the assistance of CIT, would commission a well-established, objective researcher to prepare a set of three to six case studies of documented difficulties with technology commercialization in Virginia as a basis for informed discussion of the issues that the cases uncovered. The researcher would interview the principals on various sides of the cases in an effort to get beneath simplistic formulations of the issues. VRTAC members and others knowledgeable about experiences with intellectual property commercialization in Virginia would provide guidance to the research effort. The outputs of this effort would consist of a set of analytical case studies in printed form (posted to the Web site), along with a presentation by the author at the workshop.

Budget

Unique among the Intellectual Property Committee's recommendations, the workshop would require a commitment of funds on behalf of VRTAC from DIT, CIT, or elsewhere. Rough estimates of costs suggest that the workshop could be executed for approximately $10,000. The preparation of a set of working papers would cost about $30,000.

Recommended Actions and Follow-up: The existing VRTAC IP subcommittee could organize and conduct the workshop and plan and oversee the case study project. The direct assistance of staff at CIT or DIT would be needed as well. A meeting-planning firm could be contracted to handle all of the workshop arrangements.