Assessing The Technology Industry Potential Of The Commonwealth Of Virginia

November 9, 2007

P18176

Task 1:
Virginia's Current Technology Clusters

SRI International

Prepared for the Virginia Economic Development Partnership

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Notes On Cluster Data

- Data Sources:
  - **Private Sector Data:** *County Business Patterns*, U.S. Census Bureau (2003 and 2005)
  - **Public Sector Data:** *Quarterly Census of Employment and Wages*, Bureau of Labor Statistics (2003 and 2005)
- All tables and charts depict aggregated data for both the private sector and the public sector.
- Due to data suppression, employment numbers may be underestimated and underreported for many clusters and sub-clusters. This is particularly true for regional-level data and for public sector data.
- Employment ranges were estimated by SRI where data was suppressed. Ranges for employment numbers and employment concentration ratios are depicted in gold in the charts.

State-Level Analysis Of Virginia's Industry Clusters

Section I

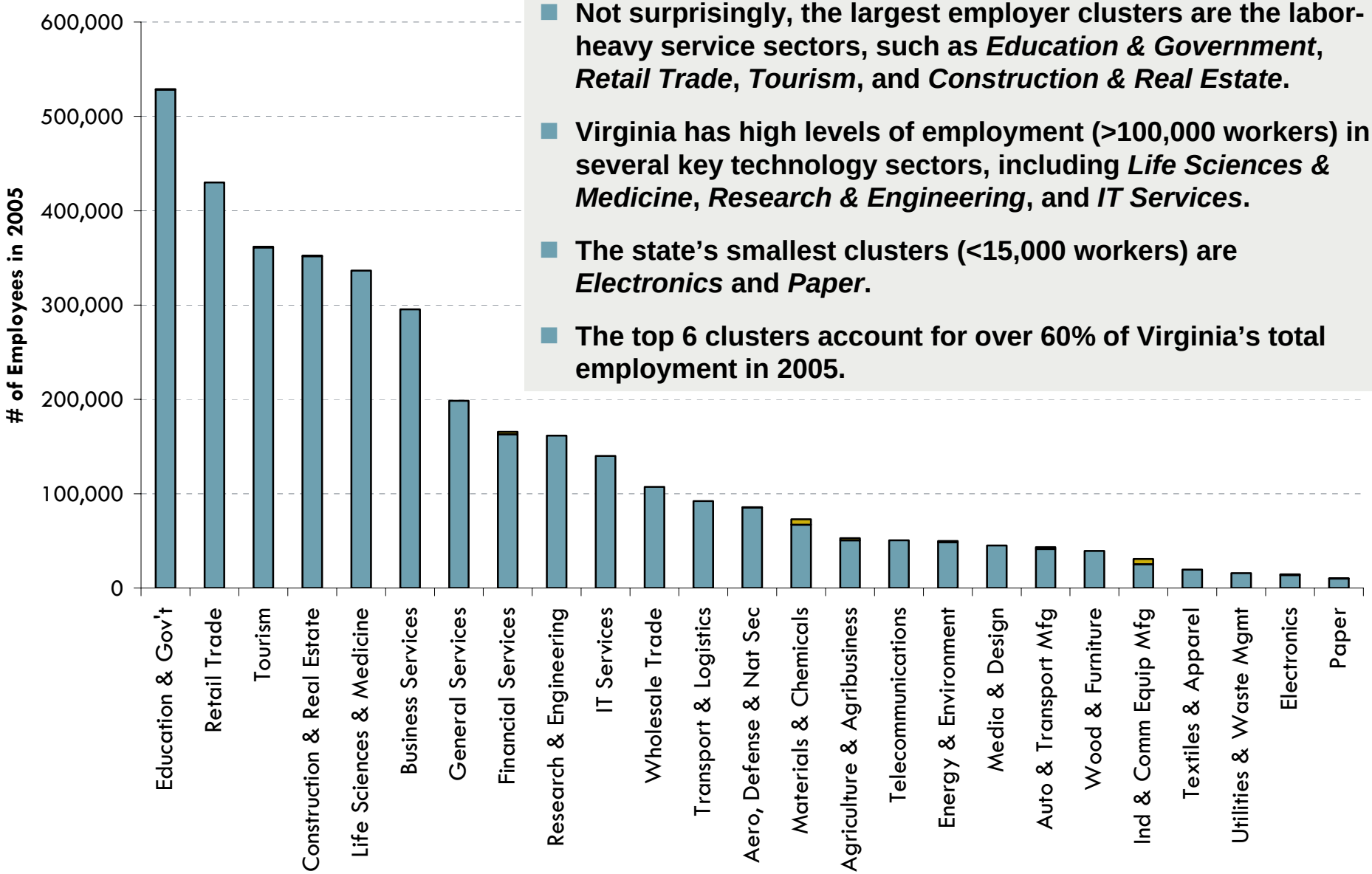
Virginia Cluster Analysis Overview

State-Level Analysis

- **Like most states, in terms of the number of workers and firms, Virginia's economy is dominated by service industries such as *Education & Government*, *Retail Trade*, *Construction & Real Estate*, *Tourism*, and *General & Business Services*.**
- **Several technology and knowledge-based sectors stand out in Virginia for their high levels of employment:**
  - *Life Sciences & Medicine* (336,535 workers)
  - *Research & Engineering Services* (161,633 workers)
  - *IT Services* (140,016 workers)
- **Several technology and knowledge-based sectors also have very high levels of employment concentration in Virginia, as compared to the national average:**
  - *IT Services* (2.69)
  - *Research & Engineering Services* (1.96)
  - *Aerospace, Defense, & National Security* (1.76)
  - *Telecommunications* (1.32)
- **Clusters that have experienced very high employment growth rates in Virginia in recent years (2003-2005) include:**
  - *Research & Engineering Services* (26.6%)
  - *Construction & Real Estate* (12.4%)
  - *Transportation & Logistics* (8.1%)
  - *Tourism* (6.7%)
  - *Business Services* (6.5%)

Employment By Cluster

State-Level Analysis

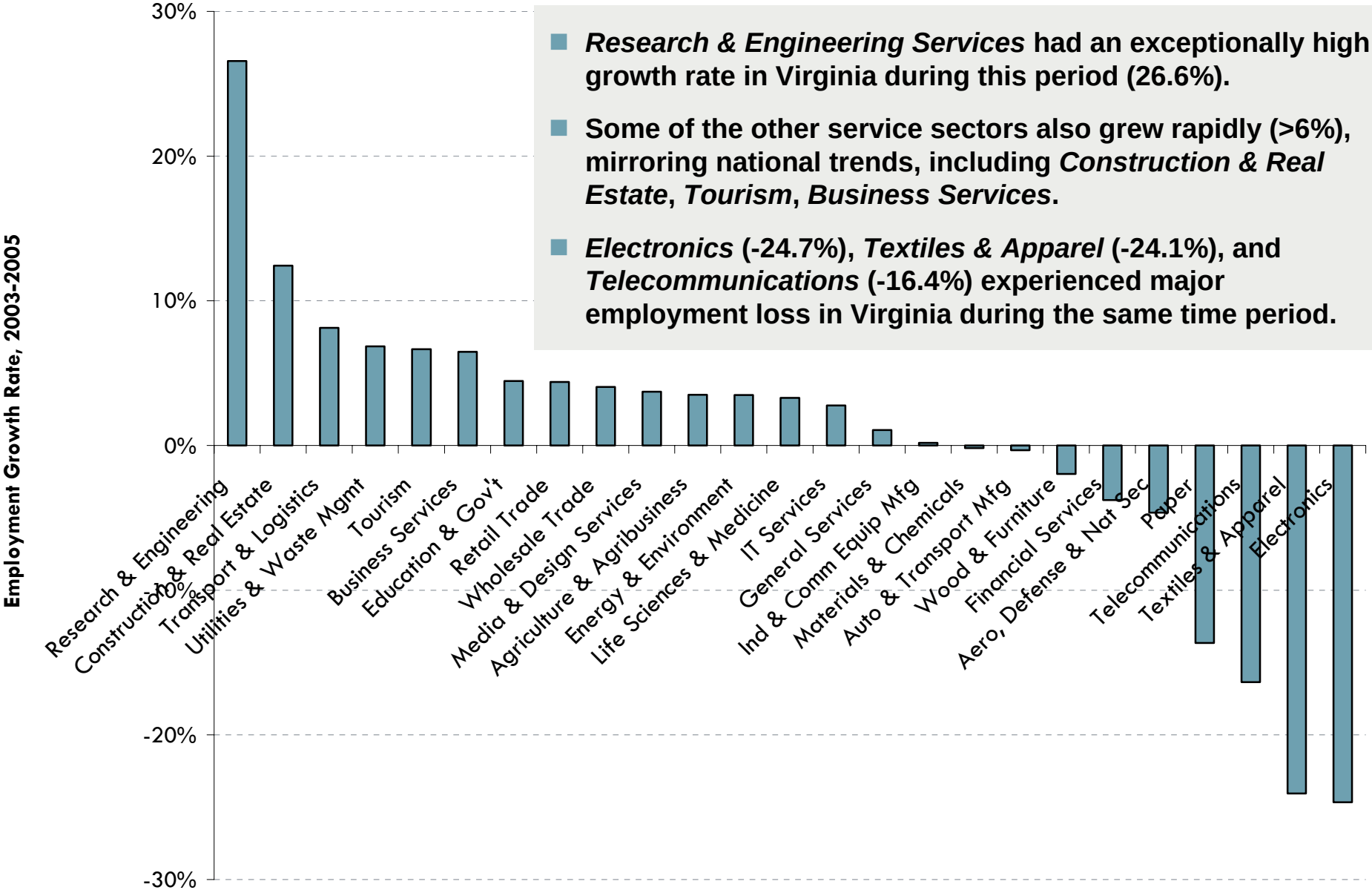


- **Not surprisingly, the largest employer clusters are the labor-heavy service sectors, such as *Education & Government*, *Retail Trade*, *Tourism*, and *Construction & Real Estate*.**
- **Virginia has high levels of employment (>100,000 workers) in several key technology sectors, including *Life Sciences & Medicine*, *Research & Engineering*, and *IT Services*.**
- **The state's smallest clusters (<15,000 workers) are *Electronics* and *Paper*.**
- **The top 6 clusters account for over 60% of Virginia's total employment in 2005.**

Employment Growth Rate By Cluster 2003-2005

State-Level Analysis

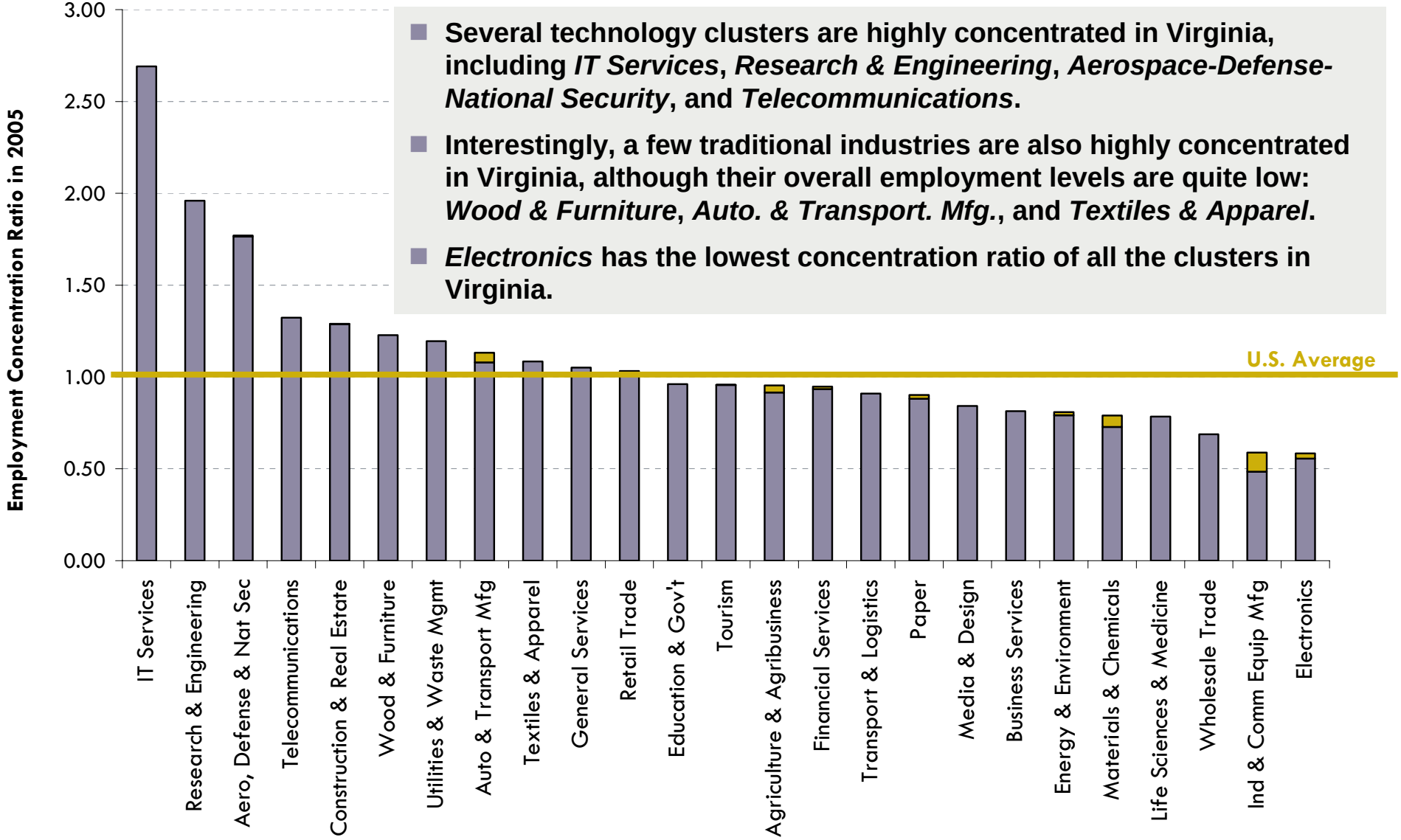
- ***Research & Engineering Services*** **had an exceptionally high growth rate in Virginia during this period (26.6%).**
- **Some of the other service sectors also grew rapidly (>6%), mirroring national trends, including *Construction & Real Estate*, *Tourism*, *Business Services*.**
- ***Electronics*** **(-24.7%),** ***Textiles & Apparel*** **(-24.1%), and** ***Telecommunications*** **(-16.4%) experienced major employment loss in Virginia during the same time period.**



Employment Concentration Ratio By Cluster

State-Level Analysis

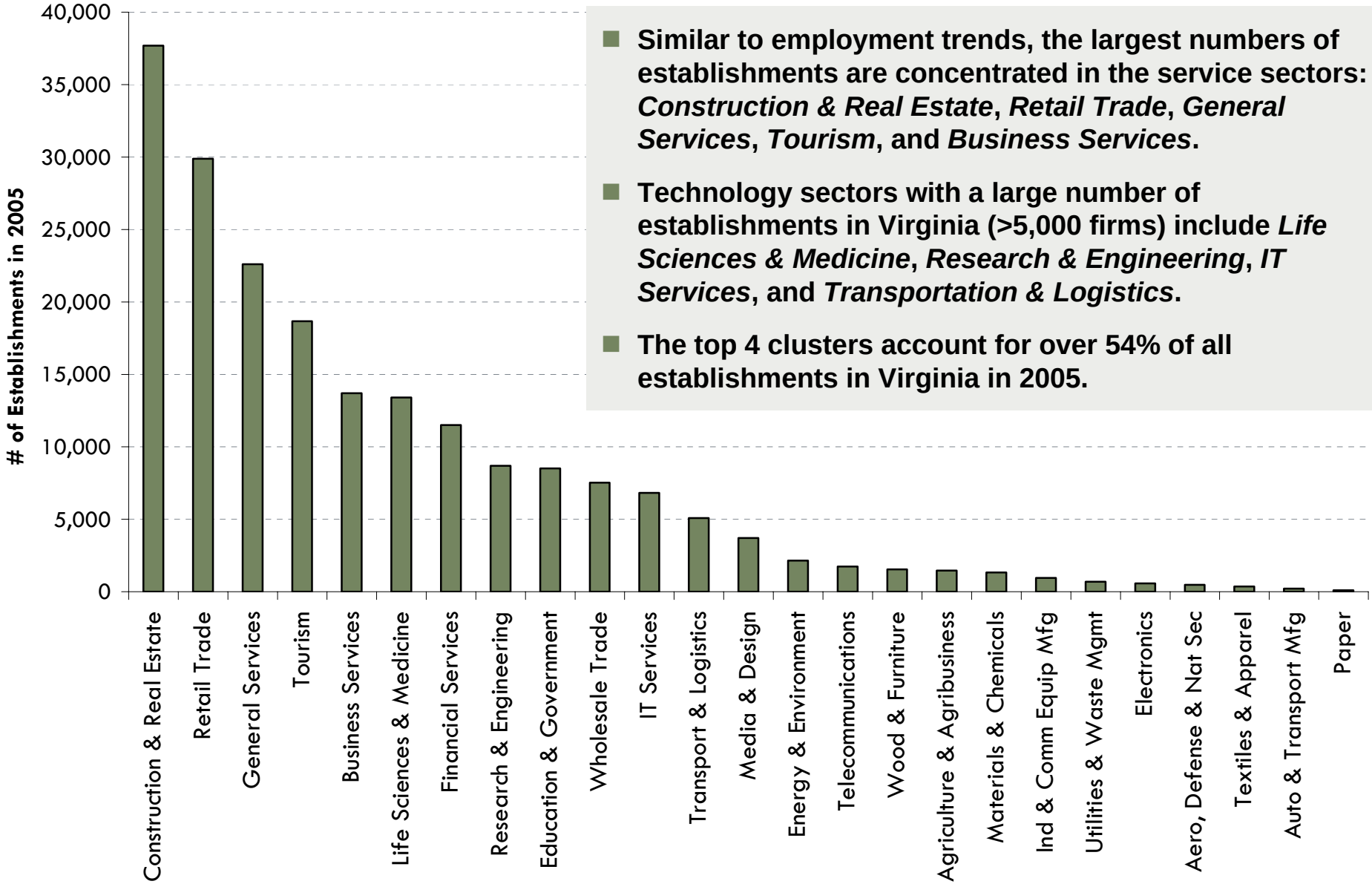
- **Several technology clusters are highly concentrated in Virginia, including *IT Services*, *Research & Engineering*, *Aerospace-Defense-National Security*, and *Telecommunications*.**
- **Interestingly, a few traditional industries are also highly concentrated in Virginia, although their overall employment levels are quite low: *Wood & Furniture*, *Auto. & Transport. Mfg.*, and *Textiles & Apparel*.**
- ***Electronics* has the lowest concentration ratio of all the clusters in Virginia.**



The Employment Concentration Ratio is the industry cluster's share of total employment in the state versus its share in the country. Clusters with a ratio greater than 1.0 are more concentrated in Virginia than in the United States.

Number Of Establishments By Cluster

State-Level Analysis

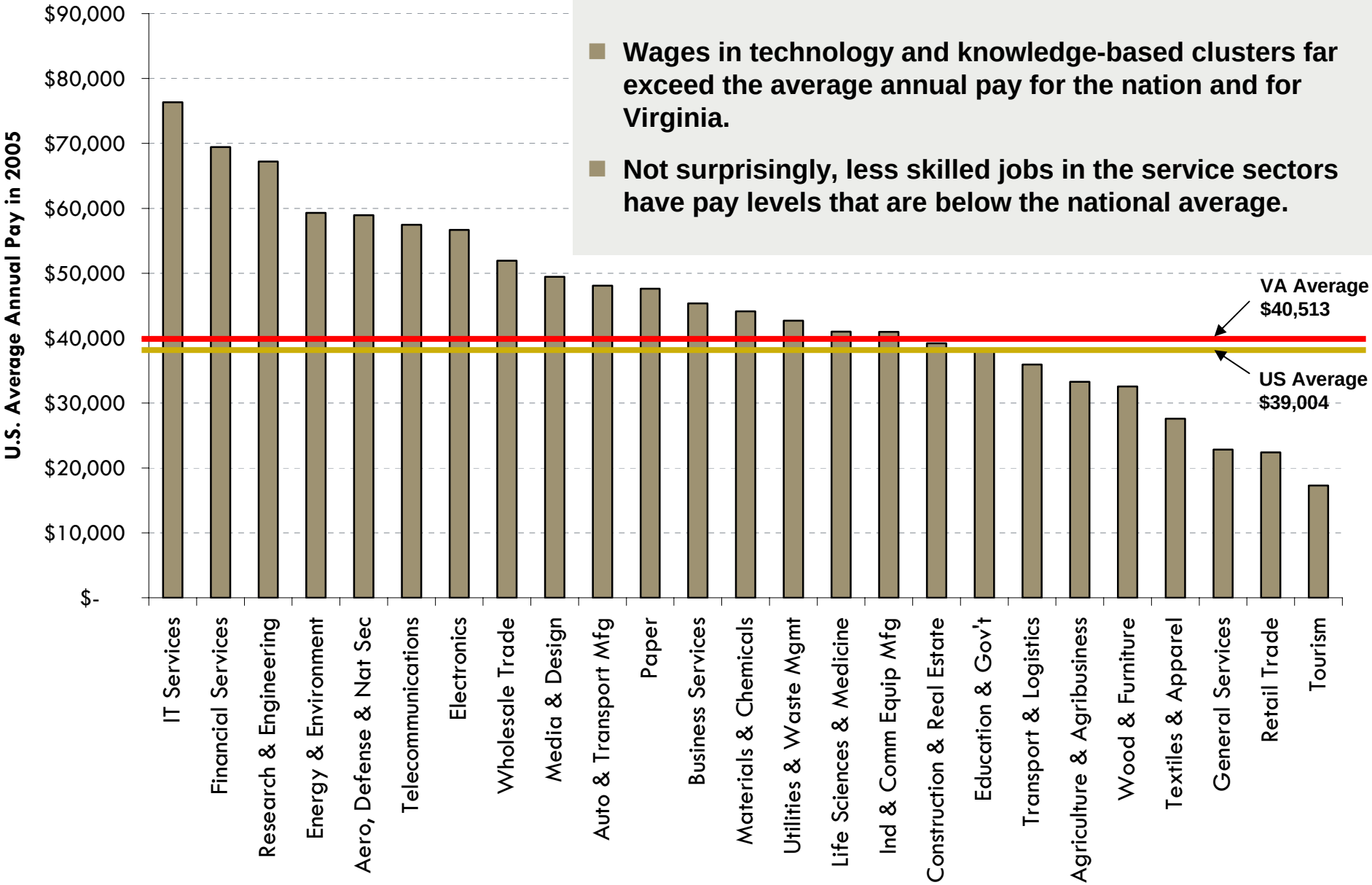


- **Similar to employment trends, the largest numbers of establishments are concentrated in the service sectors: *Construction & Real Estate*, *Retail Trade*, *General Services*, *Tourism*, and *Business Services*.**
- **Technology sectors with a large number of establishments in Virginia (>5,000 firms) include *Life Sciences & Medicine*, *Research & Engineering*, *IT Services*, and *Transportation & Logistics*.**
- **The top 4 clusters account for over 54% of all establishments in Virginia in 2005.**

U.S. Average Annual Pay By Cluster

State-Level Analysis

- **Wages in technology and knowledge-based clusters far exceed the average annual pay for the nation and for Virginia.**
- **Not surprisingly, less skilled jobs in the service sectors have pay levels that are below the national average.**



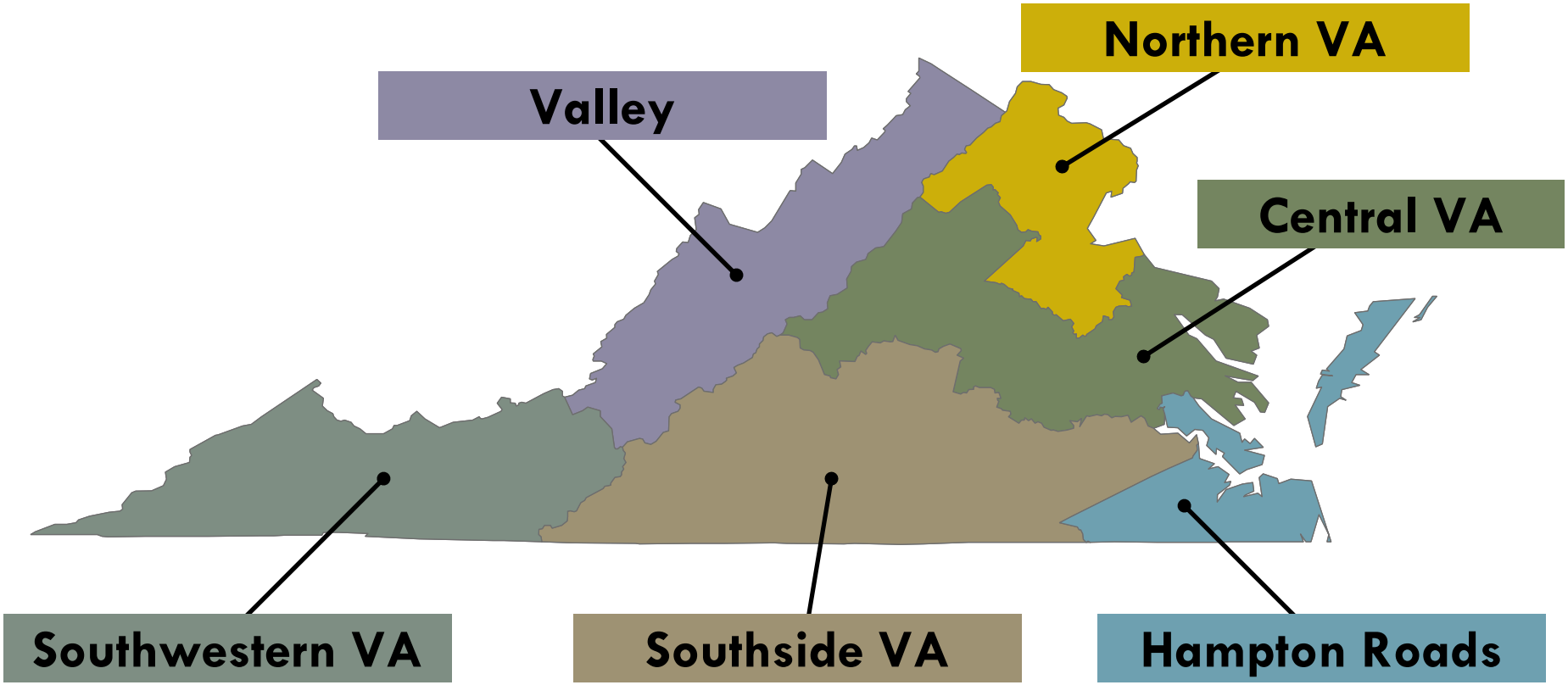
Regional Cluster Trends In Virginia

Section II

Definition Of Virginia's Regions

Regional Analysis

The SRI team conducted analysis of industry cluster data and trends across six regions in Virginia:



Regional Cluster Analysis Overview

- **Several employment trends are common across all regions in the state:**
  - *Retail Trade*, *Tourism*, and *Construction & Real Estate* are major employment-generating sectors across every region. This is typical throughout the United States, but also reflects the recent housing boom and population trends in Virginia, as well as the importance of tourism in the state.
  - *Life Sciences & Medicine* also tends to dominate in employment, ranking in the top 3 clusters for every region except Northern Virginia. This cluster's dominance is driven by its service component (the *Health & Medical Services* sub-cluster).
  - *Business Services* and *General Services* rank in the top tier of clusters for employment across every region, but do not have especially high employment concentrations. This reflects a national trend of the increasing importance of service sectors throughout the economy.
- **There are also significant variations in industry strengths across state's regions:**
  - The Northern Virginia and Hampton Roads regions are dominant for technology and knowledge-based clusters – such as *Research & Engineering*, *IT Services*, *Aerospace/Defense/National Security* – due to the concentration of government, military, and research facilities in these regions.
  - There are high concentrations of employment in natural resource-based clusters – such as *Materials & Chemicals* and *Energy & Environment* – in the Southwestern and Southside regions.
  - Several of the more rural regions in Virginia have very strong employment concentrations for traditional industries such as *Wood & Furniture* (Southwestern, Southside, Valley), *Paper* (Southside, Valley), and *Textiles & Apparel* (Southwestern, Southside, Valley). However, overall employment levels for these clusters are relatively low compared to other industries.
  - With its location in between major metropolitan areas and more rural areas of the state, the Central Virginia region has fairly strong employment trends across a wide cross-section of industries, but no sectors stand out as being especially dominant.

Regional Cluster Employment Concentrations

Regional Analysis

Cluster Name	Central VA	Hampton Roads	Northern VA	Southside VA	South-western VA	Valley
Aerospace, Defense, & National Security	0.66	1.95	3.17	0.57	1.23	0.34
Agriculture & Agribusiness	1.06	1.43	0.34	1.17	0.53	2.48
Automotive & Transportation Manufacturing	0.20	2.57	0.03	0.38	3.27	0.86
Business Services	0.81	0.86	0.90	0.59	0.51	0.78
Construction & Real Estate	1.32	1.23	1.44	1.07	0.73	1.22
Energy & Environment	0.84	0.51	0.57	1.01	3.21	0.84
Education & Government	0.47	0.35	0.45	0.49	0.39	0.38
Electronics	0.86	0.60	0.68	0.30	0.51	0.64
Financial Services	1.75	0.82	0.85	0.61	0.57	0.85
Industrial & Commercial Equipment Manufacturing	0.64	0.35	0.14	1.11	1.93	1.29
IT Services	0.60	1.17	6.38	0.31	0.42	0.22
Life Sciences & Medicine	0.89	0.84	0.51	0.98	0.95	1.01
Materials & Chemicals	0.60	0.49	0.17	2.62	1.90	1.93

Very Low — Regional Mean Employment Concentration Ratio - 2005 — Very High

Regional Cluster Employment Concentrations (cont'd.)

Regional Analysis

Cluster Name	Central VA	Hampton Roads	Northern VA	Southside VA	South-western VA	Valley
Media & Design Services	0.91	0.96	1.08	0.50	0.50	0.73
Paper	1.08	1.00	0.02	3.31	0.23	2.28
Research & Engineering Services	0.75	1.57	3.81	0.54	0.51	0.69
Retail Trade	1.05	1.09	0.96	1.18	1.36	1.12
General Services	1.17	0.95	1.02	1.00	0.93	1.02
Textiles & Apparel	1.10	0.28	0.09	5.25	3.29	2.28
Telecommunications	1.02	0.95	1.94	1.00	1.93	1.03
Transportation & Logistics Services	0.79	1.10	0.66	1.44	1.05	1.47
Tourism	0.95	1.11	0.91	0.83	0.91	0.92
Utilities & Waste Management	0.70	0.69	0.66	0.77	0.42	0.59
Wholesale Trade	1.02	0.71	0.57	0.65	0.63	0.84
Wood & Furniture	1.37	0.38	0.29	5.62	4.32	2.16

Very Low — **Regional Mean Employment Concentration Ratio - 2005** — **Very High**

Central Virginia

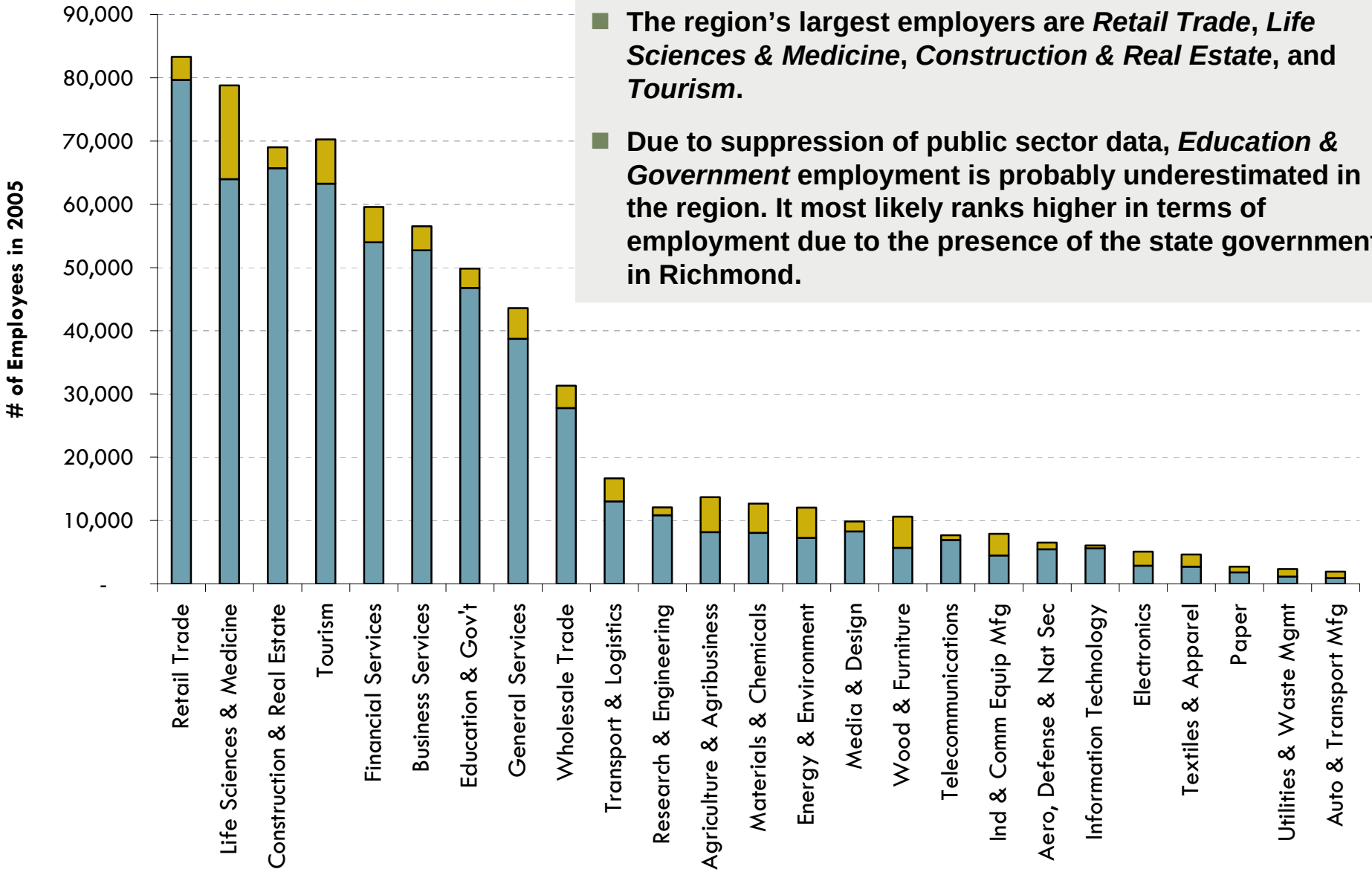
Regional Profile

- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Central VA region include:**
  - *Financial Services* – likely related to the concentration of regional/national banking headquarters in the Richmond area.
  - *Construction* – due to the national housing boom during this period, as well as strong growth trends in the region as people and businesses migrate outward from the DC metro area.
  - *Wholesale Trade*
- **Other clusters with very high concentration ratios but low overall employment include *Agriculture & Agribusiness*, *Paper*, *Textiles & Apparel*, *Telecommunications*, and *Wood & Furniture*.**
- **Interestingly, many technology and knowledge-based clusters are not particularly strong in this region, in spite of the presence of major universities such as UVA and VCU and the proximity to the DC area. For example, *Research & Engineering* and *IT Services* both have relatively low employment and concentration ratios in Central VA.**

Central Virginia

Employment Trends

- **The region's largest employers are *Retail Trade*, *Life Sciences & Medicine*, *Construction & Real Estate*, and *Tourism*.**
- **Due to suppression of public sector data, *Education & Government* employment is probably underestimated in the region. It most likely ranks higher in terms of employment due to the presence of the state government in Richmond.**



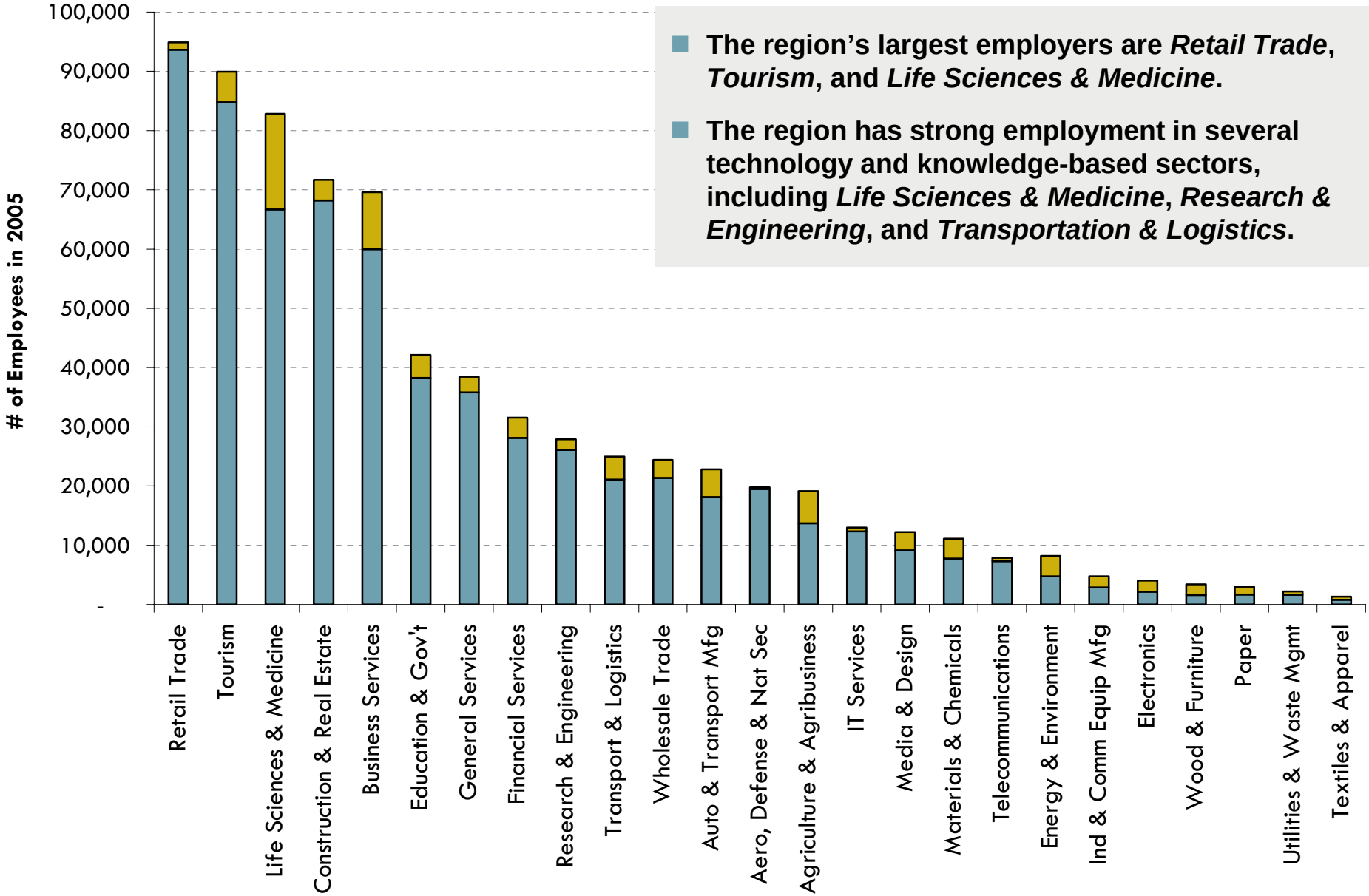
Hampton Roads

Regional Profile

- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Hampton Roads region include:**
  - *Aerospace, Defense, & National Security* – due to the presence of major navy and other military facilities in this area, as well as the Langley Research Center.
  - *Research & Engineering* – likely to be serving the military installations in the region.
  - *Construction* – due to the national housing boom, increased federal government spending, and strong growth trends in the region.
  - *Transportation & Logistics Services* – related to the major port, shipyard, and water commerce facilities in the region.
  - *Tourism* – because the area attracts many visitors to its beaches and the attractions in and around Williamsburg.
  - *Automotive & Transportation Manufacturing*
- **Other clusters with very high concentration ratios but low overall employment include *Agriculture & Agribusiness*, *IT Services*, and *Paper*.**
- **The Hampton Roads region is second to the Northern Virginia region as a major hub in the state for high technology and knowledge-based sectors such as *Research & Engineering*, *Aerospace/Defense/National Security*, and *IT Services*.**

Hampton Roads

Employment Trends



- **The region's largest employers are *Retail Trade*, *Tourism*, and *Life Sciences & Medicine*.**
- **The region has strong employment in several technology and knowledge-based sectors, including *Life Sciences & Medicine*, *Research & Engineering*, and *Transportation & Logistics*.**

Northern Virginia

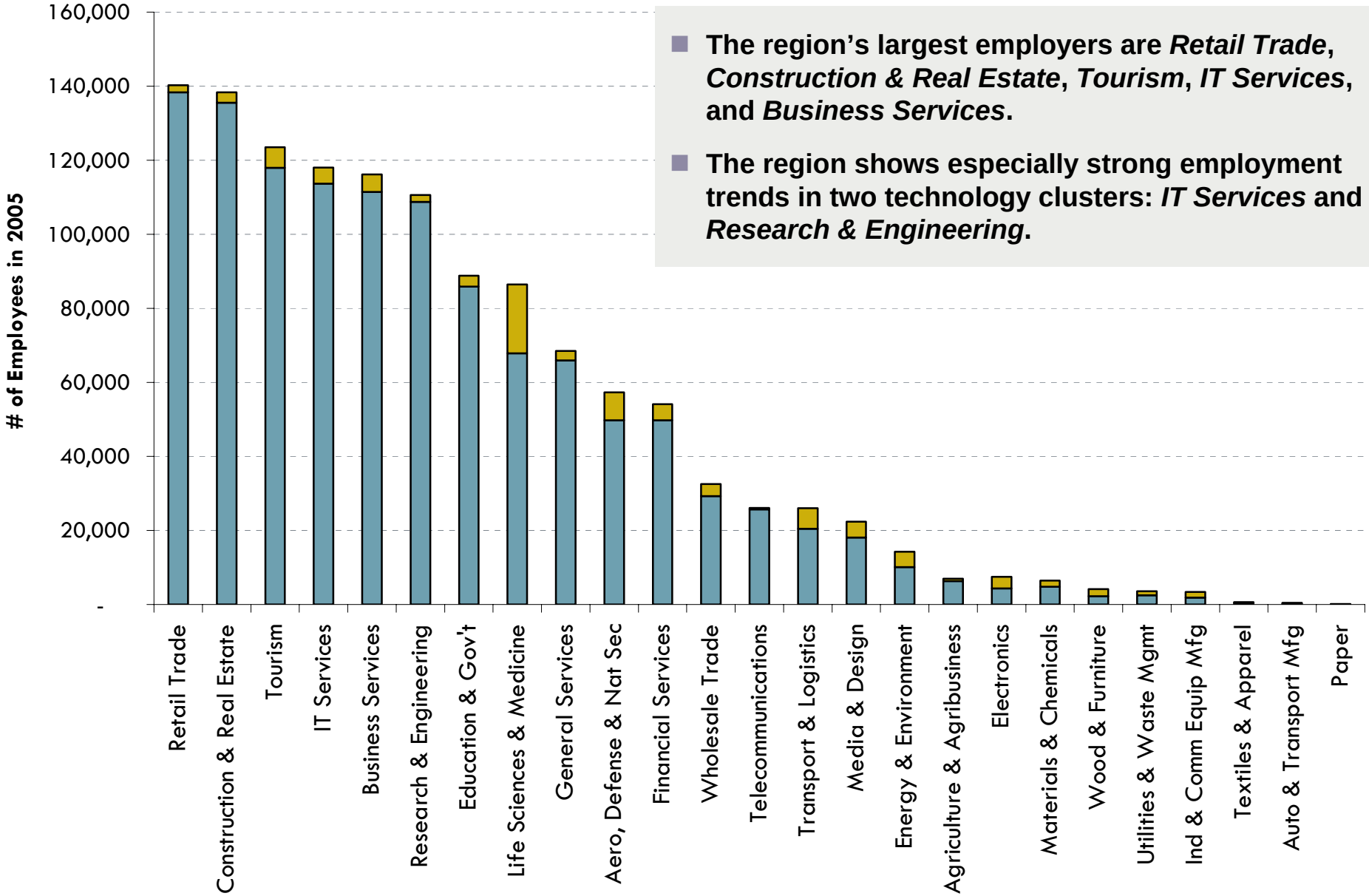
Regional Profile

- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Northern VA region include:**
  - *Aerospace, Defense, & National Security* – due to the region's proximity to major federal government and military facilities and research centers.
  - *Research & Engineering* – serving the federal government and military in the DC area.
  - *IT Services* – serving the federal government and military, and reflecting the presence of a major IT corridor in the region.
  - *Construction & Real Estate* – due to the national housing boom and the region's consistently strong population and business growth rates.
- **Other clusters with very high concentration ratios but low overall employment include *Media & Design Services* and *Telecommunications*.**
- **Overall, Northern Virginia's cluster trends reflect its position as a major hub for research and development, knowledge-based services, and contracting and consulting serving the federal government, military, and major universities concentrated in the greater DC metropolitan area.**

Northern Virginia

Employment Trends

- **The region's largest employers are *Retail Trade*, *Construction & Real Estate*, *Tourism*, *IT Services*, and *Business Services*.**
- **The region shows especially strong employment trends in two technology clusters: *IT Services* and *Research & Engineering*.**



Southside Virginia

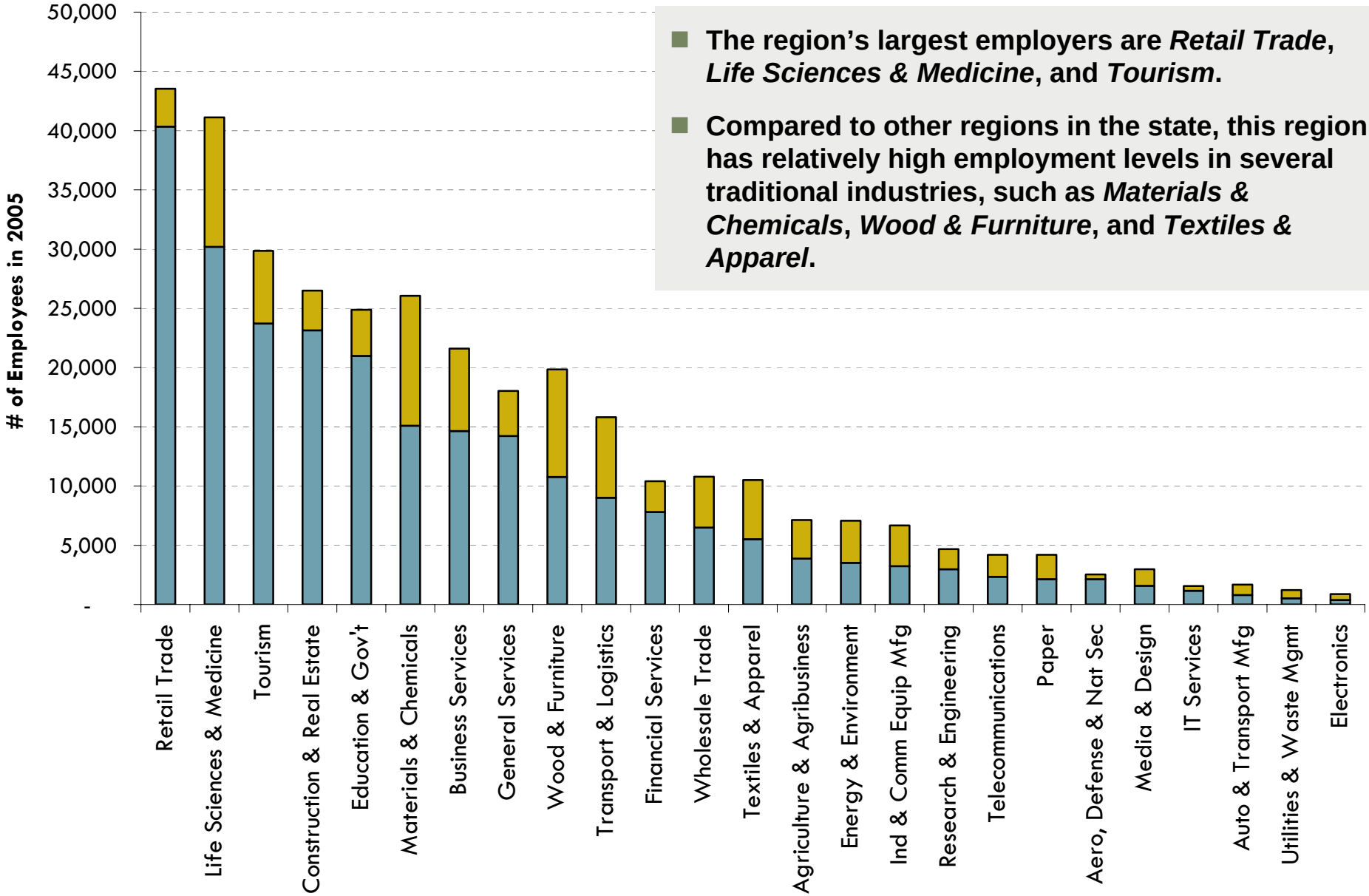
Regional Profile

- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Southside VA region include:**
  - *Materials & Chemicals* – probably related to the presence of key natural resources and manufacturing facilities in this region.
  - *Transportation & Logistics* – due to the region's proximity to key interstate transportation routes connecting the southeastern United States with the DC area and northeast.
  - *Wood & Furniture and Textiles & Apparel* – most likely due a legacy of strength in these traditional industries in the southeastern United States.
  - *Construction & Real Estate*
- **Other clusters with very high concentration ratios but low overall employment include *Agriculture & Agribusiness*, *Paper*, *Telecommunications*, *Energy & Environment*, and *Industrial & Commercial Equipment Manufacturing*.**
- **Although the region does not benefit from the presence of major government and research facilities, it shows particularly strong concentrations of several traditional industries where potential new directions in advanced technologies could be explored (*Textiles & Apparel*, *Wood & Furniture*, *Paper*, and *Materials & Chemicals*).**

Southside Virginia

Employment Trends

- **The region's largest employers are *Retail Trade*, *Life Sciences & Medicine*, and *Tourism*.**
- **Compared to other regions in the state, this region has relatively high employment levels in several traditional industries, such as *Materials & Chemicals*, *Wood & Furniture*, and *Textiles & Apparel*.**



Southwestern Virginia

Regional Profile

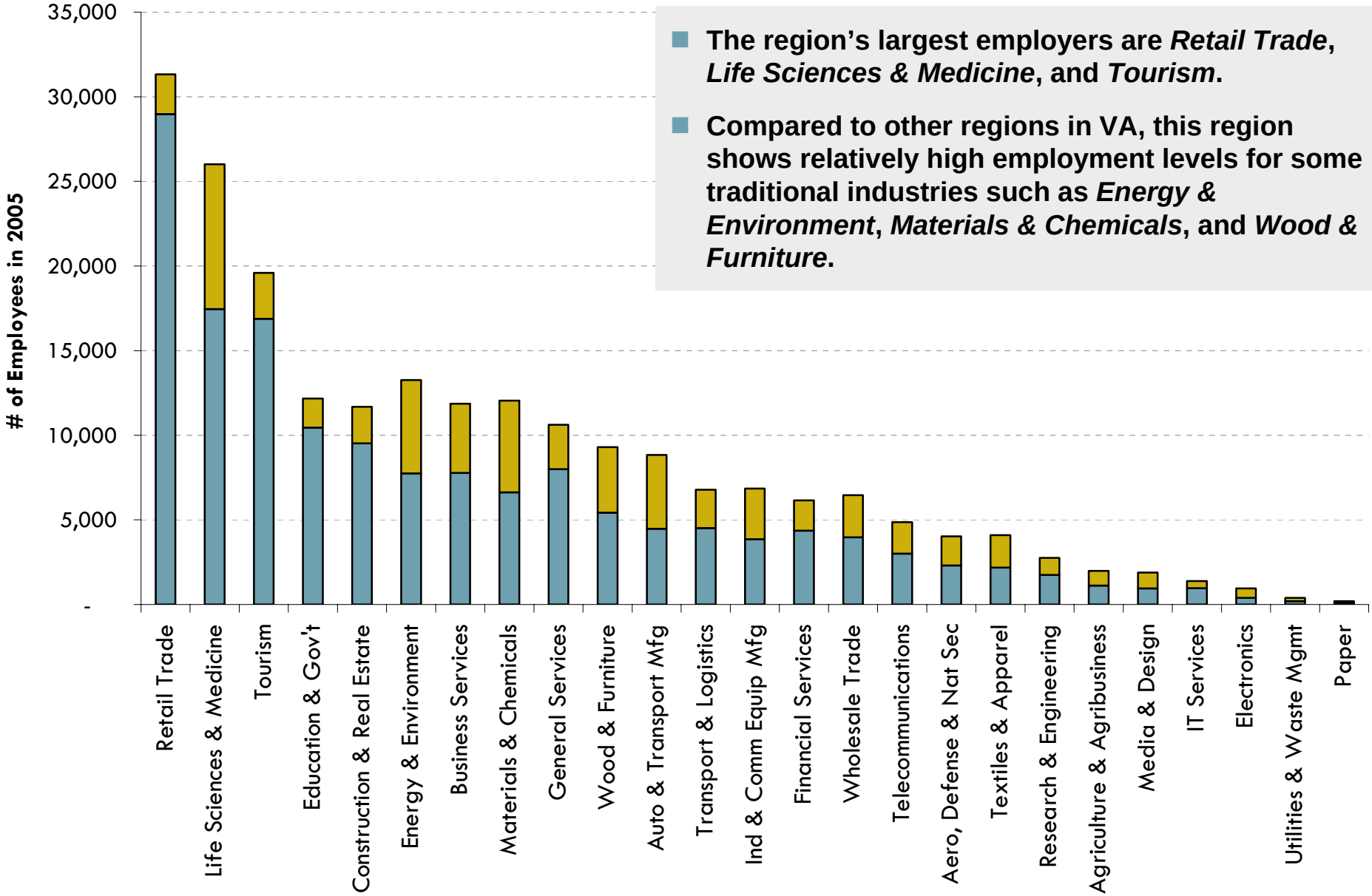
- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Southwestern VA region include:**
  - *Materials & Chemicals*
  - *Energy & Environment*
  - *Wood & Furniture*

  – probably related to the presence of key natural resources and related manufacturing facilities for these industries in this mountainous region.
  - *Transportation & Logistics* – due to the region's location along a major interstate transportation corridor between the northeastern and southeastern United States.
  - *Automotive & Transportation Equipment Manufacturing*
  - *Industrial & Commercial Equipment Manufacturing*
- **Other clusters with very high concentration ratios but low overall employment include *Textiles & Apparel*, *Telecommunications*, *Aerospace/Defense/National Security*.**
- **Similar to the Southside and Valley regions, the Southwestern region shows particularly strong concentrations of several traditional industries where potential new directions in advanced technologies could be explored (*Textiles & Apparel*, *Wood & Furniture*, *Automotive & Transportation Equipment Manufacturing*, and *Energy & Environment*).**

Southwestern Virginia

Employment Trends

- **The region's largest employers are *Retail Trade*, *Life Sciences & Medicine*, and *Tourism*.**
- **Compared to other regions in VA, this region shows relatively high employment levels for some traditional industries such as *Energy & Environment*, *Materials & Chemicals*, and *Wood & Furniture*.**



Valley Region

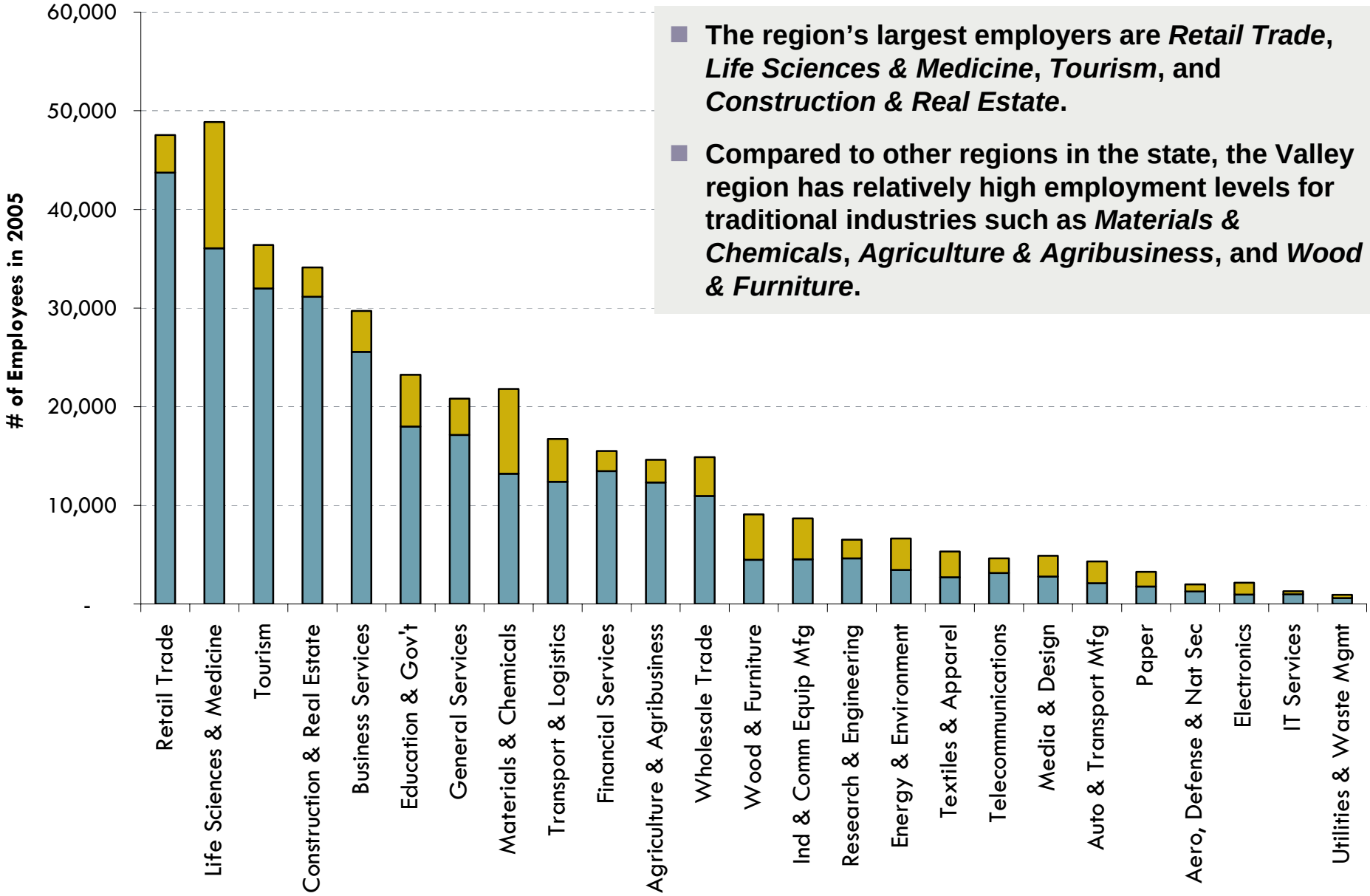
Regional Profile

- **Clusters with both high employment levels and high employment concentrations (above the national average) in the Valley region include:**
  - *Materials & Chemicals*
  - *Agriculture & Agribusiness*

  – probably related to the presence of key natural resources and related manufacturing facilities for these industries in the region.
  - *Construction & Real Estate* – most likely related to the national housing boom, as well as migration of population outward from the DC metropolitan area.
  - *Transportation & Logistics* – due to the region's location along a major interstate transportation corridor between the northeastern and southeastern United States.
- **Other clusters with very high concentration ratios but low overall employment include *Industrial & Commercial Equipment Manufacturing*, *Paper*, *Textiles & Apparel*, *Telecommunications*, and *Wood & Furniture*.**
- **Similar to the Southside and Southwestern regions, the Valley region shows particularly strong concentrations of several traditional industries where potential new directions in advanced technologies could be explored (*Textiles & Apparel*, *Wood & Furniture*, *Materials & Chemicals*, and *Agriculture & Agribusiness*).**

Valley Region

Employment Trends



- **The region's largest employers are *Retail Trade*, *Life Sciences & Medicine*, *Tourism*, and *Construction & Real Estate*.**
- **Compared to other regions in the state, the Valley region has relatively high employment levels for traditional industries such as *Materials & Chemicals*, *Agriculture & Agribusiness*, and *Wood & Furniture*.**

Detailed Analysis Of Potential Target Technology Clusters

Section III

Selection Of Clusters For Detailed Analysis

- The SRI team selected 8 technology clusters for detailed analysis in this section of the report.
- These 8 clusters represent potential target technology clusters for Virginia. A short-list of recommended target technology clusters for Virginia will be made at a later stage of the project.
- The 8 clusters were selected according to one or more of the following criteria:
  - They encompass strategic technologies and research areas that are expected to have high potential and high growth over the short-, medium-, or long-term.
  - They currently have high levels of employment, and/or high rates of growth in Virginia.
  - They show strong growth rates on the national or global level.
  - They offer strong salaries and wages for "knowledge workers."

The following clusters were selected and are analyzed in greater detail in this section:

Electronics	**Materials & Chemicals**
Energy & Environment	**Media & Design Services**
Information Technology Services	**Research & Engineering Services**
Life Sciences & Medicine	**Transportation & Logistics Services**

Electronics Cluster

Cluster Definition

The *Electronics* cluster includes manufacturing of consumer electronics (such as computers, photography, and audio-visual equipment), as well as industrial and laboratory-related controls and instruments, and electronic components (such as semiconductors).

Electronics Sub-Clusters

- **IT Hardware:** Manufacturing of computers and peripherals, semiconductors, and other electronic components; Repair of computers
- **Measuring & Controlling Device Manufacturing:** Manufacturing of industrial and environmental controls, meters, measuring devices, testing instruments, laboratory instruments, and other electronics-related equipment
- **Other Electronics:** Manufacturing of optical instruments and lenses, photographic and photocopying equipment, audio-visual equipment, magnetic media, and machinery related to semiconductors

Electronics Cluster

Cluster Profile

	2005	Trend
Virginia Employment	13,799-14,526	↓↓↓
U.S. Employment	920,357	↓↓
Virginia Employment Growth Rate (2003-2005)	-24.7%	↓↓↓
U.S. Employment Growth Rate (2003-2005)	-10.4%	↓↓
Virginia Employment Concentration Ratio	0.56-0.58	↓↓↓
U.S. Average Annual Pay	$56,677	↑↑
Virginia Establishments	581	↓
Virginia Average Private Sector Firm Size	24 employees	

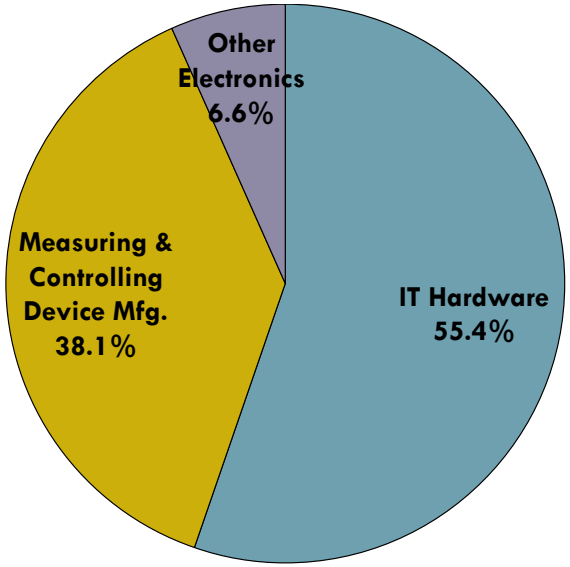
no change ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Electronics Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 13,799–14,526**
- **Ranks 24th out of 25 clusters in VA for employment size**
- **Accounts for 0.4% of total VA employment**
- **Over 75% of VA's cluster employment is concentrated in:**
  - Semiconductor & electronic component mfg. (NAICS 3344)
  - Other electronic equipment repair (NAICS 811219)
  - Computer & office machine repair (NAICS 811212)
  - Relay & industrial control mfg. (NAICS 335314)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
IT Hardware	7,842	0.55	276	$56,491
Measuring & Controlling Device Manufacturing	5,266–5,517	0.72–0.75	171	$58,817
Other Electronics	691–1,167	0.21–0.36	134	$52,703
Electronics TOTAL	**13,799–14,526**	**0.56–0.58**	**581**	**$56,677**

Electronics Cluster

Growth Trends

- The *Electronics* cluster, and all its sub-clusters, have experienced negative employment growth in recent years, both in Virginia and at the national level.
- From 2003-2005, *Electronics* cluster employment in VA fell by -24.7%, and the number of establishments declined by -3.3%.
- Only a few NAICS codes in the cluster experienced employment growth in VA from 2003-2005:
  - Semiconductor & electronic component manufacturing (NAICS 3344): 8% growth
  - Industrial process variable instruments (NAICS 334513): 15% growth
  - Other electronic equipment repair (NAICS 811219): 10% growth

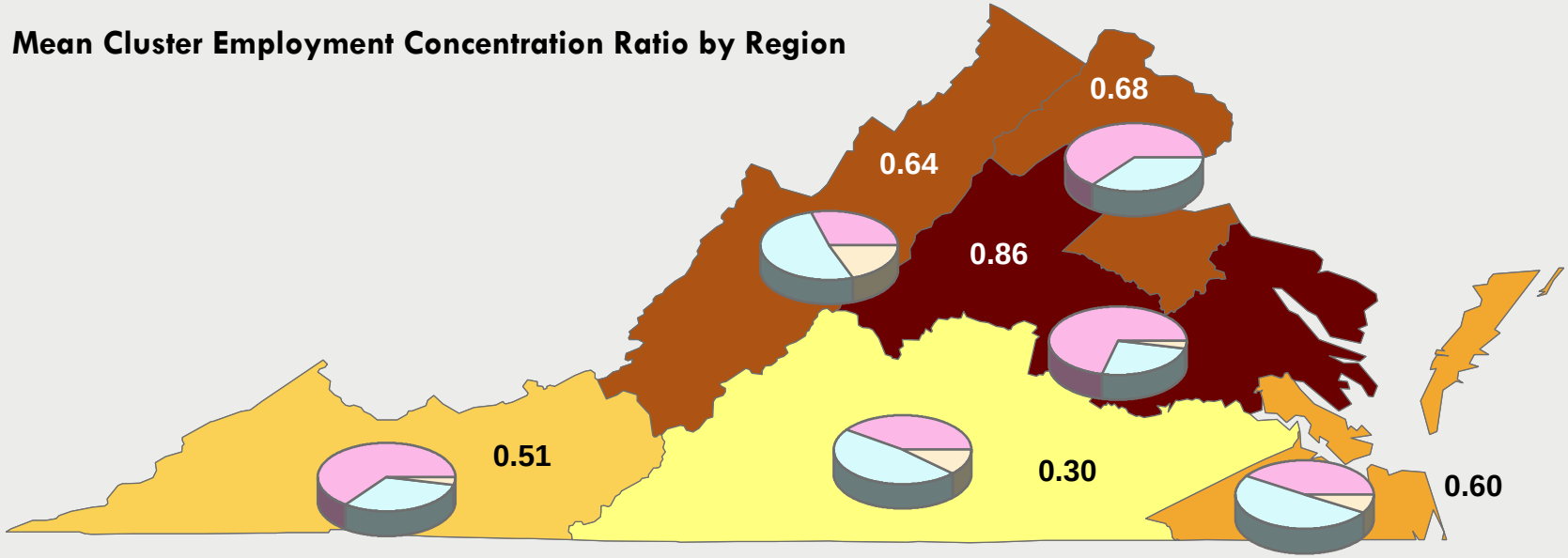
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
IT Hardware	-16.8%	-14.2%
Measuring & Controlling Device Manufacturing	-11.5%	-0.6%
Other Electronics	-71.7%	-12.6%
Electronics TOTAL	**-24.7%**	**-10.4%**

Electronics Cluster

Regional Trends

- The *Electronics* cluster is most concentrated in the Central Virginia region; however, none of the regions have a concentration ratio that is above the national average.
- *IT Hardware* is the largest sub-cluster in the Central, Northern, and Southwestern regions. *Measuring & Controlling Device Mfg.* is largest in the Hampton Roads, Southside, and Valley regions.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- IT Hardware
- Measuring & Controlling Device Manufacturing
- Other Electronics

Energy & Environment Cluster

Cluster Definition

Energy & Environment covers a wide variety of energy-related activities, including the production and distribution of fuel and electric power, and the manufacturing of power and transmission equipment. It also includes environmental activities, such as recycling, and public and private organizations specializing in environmental consulting and research.

Energy & Environment Sub-Clusters

- **Fuel Production & Distribution:** Extraction, processing, distribution, and sales of oil, gas, coal; Related machinery and support activities; Mfg. of ethyl alcohol
- **Power Generation & Technology:** Generation, transmission, distribution of electric power; Mfg. of turbine and power transmission, power boiler and heat exchanger, electric power and specialty transformer equipment; Mfg. of storage batteries
- **Recycling & Waste Remediation:** Materials recovery (sorting recyclables); Wholesaling recyclable materials; Remediation services
- **Environmental Research & Management:** Government environmental programs; Environmental consulting; Environment/conservation organizations; Geophysical surveying & mapping; Forestry support & management

Energy & Environment Cluster

Cluster Profile

	2005	Trend
Virginia Employment	48,677–49,738	↑
U.S. Employment	2,276,281	↑
Virginia Employment Growth Rate (2003-2005)	3.5%	↑
U.S. Employment Growth Rate (2003-2005)	1.0%	↑
Virginia Employment Concentration Ratio	0.79–0.81	○
U.S. Average Annual Pay	$59,316	↑↑
Virginia Establishments	2,149	↑↑
Virginia Average Private Sector Firm Size	24 employees	

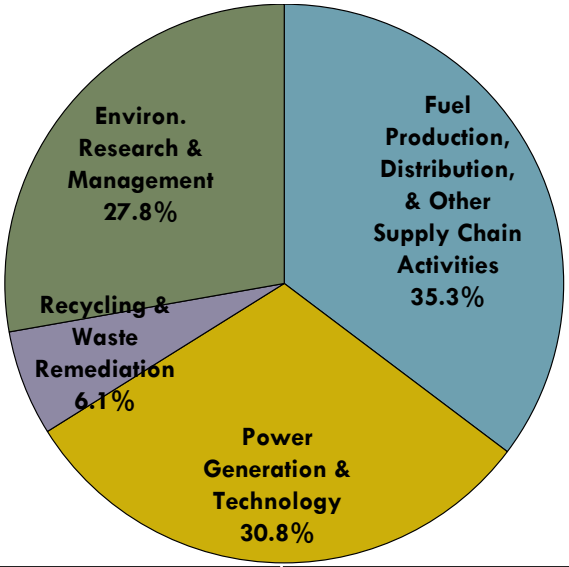
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Energy & Environment Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 48,677–49,738**
- **Ranks 17th out of 25 clusters in VA for employment size**
- **Accounts for 1.3% of total VA employment**
- **Over 60% of VA's cluster employment is concentrated in:**
  - Power generation & supply (NAICS 2211)
  - Coal mining (NAICS 2121)
  - Fuel dealers (NAICS 45431)
  - Environmental consulting services (NAICS 54162)
  - Administration of environmental programs (government) (NAICS 9241)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Fuel Production, Distribution, & Other Supply Chain Activities	17,006–17,720	0.71–0.74	795	$61,242
Power Generation & Technology	15,037–15,270	0.74–0.75	250	$69,056
Recycling & Waste Remediation	3,006	0.66	213	$41,395
Environmental Research & Management	13,628–13,742	1.09–1.10	891	$46,323
Energy & Environment TOTAL	**48,677–49,738**	**0.79–0.81**	**2,149**	**$59,316**

Energy & Environment Cluster

Growth Trends

- ***Environmental Research & Management*** **is the only sub-cluster with an employment concentration ratio in VA that is above the national average.**
- ***Environmental Research & Management*** **also experienced a very high growth rate (+12.1%) in VA from 2003-2005 – this is significantly higher than the national rate.**
- **At the national level, *Recycling & Waste Remediation* had a high growth rate (+8.0%) from 2003-2005, but VA did not share this growth.**
- **The following NAICS codes had especially high growth in VA from 2003-2005:**
  - Turbine & power transmission equipment mfg. (NAICS 3336): 12% growth
  - Materials recovery facilities (NAICS 56292): 89% growth
  - Geophysical surveying & mapping services (NAICS 54136): 23% growth
  - Environmental consulting services (NAICS 54162): 12% growth
  - Environment & conservation organizations (NAICS 813312): 80% growth

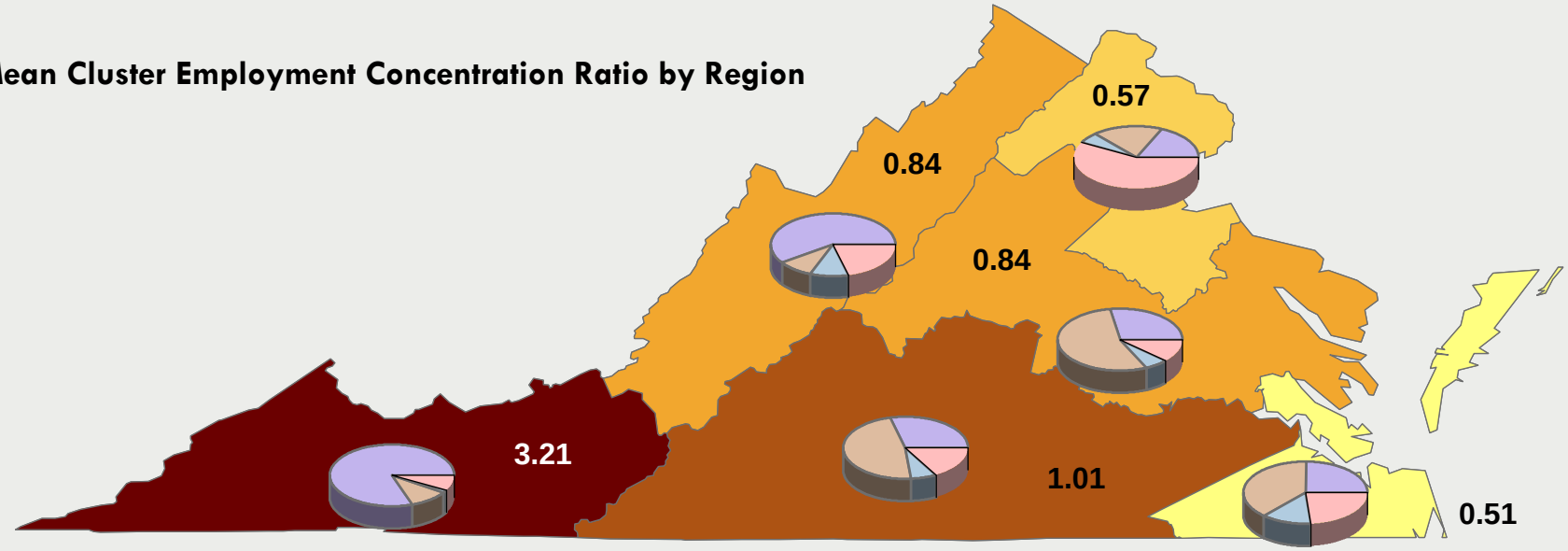
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Fuel Production, Distribution, & Other Supply Chain Activities	4.2%	3.3%
Power Generation & Technology	-2.3%	-3.8%
Recycling & Waste Remediation	-5.5%	8.0%
Environmental Research & Management	12.1%	2.8%
Energy & Environment TOTAL	**3.5%**	**1.0%**

Energy & Environment Cluster

Regional Trends

- The *Energy & Environment* cluster is most concentrated in the Southwestern Virginia region, probably due to fuel extraction and processing activities in that mountainous area.
- *Fuel Prod./Distrib./Supply Chain* is the largest sub-cluster in the Southwestern and Valley regions. Hampton Roads, Southside, and Central regions have large *Power Generation & Technology* sub-clusters. Northern Virginia is dominated by *Environ. Research & Mgmt*, probably due to proximity to the Federal Government.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

	Highest Employment Concentration Ratio
	↕
	Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

	Fuel Prod., Distrib., & Other Supply Chain Activities
	Power Generation & Technology
	Recycling & Waste Remediation
	Environmental Research & Management

Information Technology Services Cluster

Cluster Definition

The *Information Technology Services* cluster includes IT activities outside of manufacturing, such as software, computer systems design and programming, and Internet-related services.

Information Technology Services Sub-Clusters

- **Programming, Systems Design, & Data Services:** Planning, designing, and managing computer systems and networks; Customized computer programming; Computer facilities management; Computer disaster recovery and installation services; Data processing services; Hosting services (for data, applications, Internet)
- **Internet Services:** Internet service providers; Development and operation of web search portals and business-to-business electronic markets
- **Software Development:** Producing, publishing, and reproducing software products and computer applications

Information Technology Services Cluster

Cluster Profile

	2005	Trend
Virginia Employment	140,016	↑
U.S. Employment	1,925,984	↑
Virginia Employment Growth Rate (2003-2005)	2.8%	↑
U.S. Employment Growth Rate (2003-2005)	2.2%	↑
Virginia Employment Concentration Ratio	2.69	↓
U.S. Average Annual Pay	$76,328	↑↑
Virginia Establishments	6,816	↑↑↑
Virginia Average Private Sector Firm Size	21 employees	

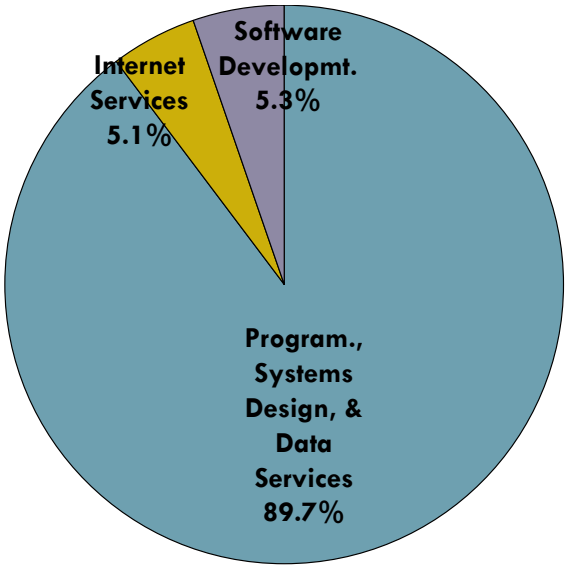
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Information Technology Services Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 140,016**
- **Ranks 10th out of 25 clusters in VA for employment size**
- **Accounts for 3.8% of total VA employment**
- **Over 80% of VA's cluster employment is concentrated in:**
  - Computer systems design & related services (NAICS 5415)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Programming, Systems Design, & Data Services	125,559	3.06	6,329	$69,215
Internet Services	7,088	3.33	214	$99,595
Software Development	7,369	0.83	273	$103,719
IT Services TOTAL	**140,016**	**2.69**	**6,816**	**$76,328**

Information Technology Services Cluster

Growth Trends

- This cluster has a very high employment concentration in VA. In particular, *Programming/Sys. Design/Data Services* and *Internet Services* are very highly concentrated in VA (concentration ratios greater than 3.0).
- This cluster's establishment growth rate was also very high in VA (+16.4% from 2003-2005) indicating significant start-up and small-firm activity.
- *Programming/Sys. Design/Data Services* dominates the cluster, both in terms of employment size and employment growth (+11.1% from 2003-2005).
- Both *Internet Services* and *Software Development* experienced declining employment in VA in recent years, parallel to national-level declines.
- Most of the cluster's employment growth in VA has occurred in two NAICS codes:
  - Computer systems design & related services (NAICS 5415): 17% growth
  - Business-to-business (B2B) electronic markets (NAICS 42511): 140% growth

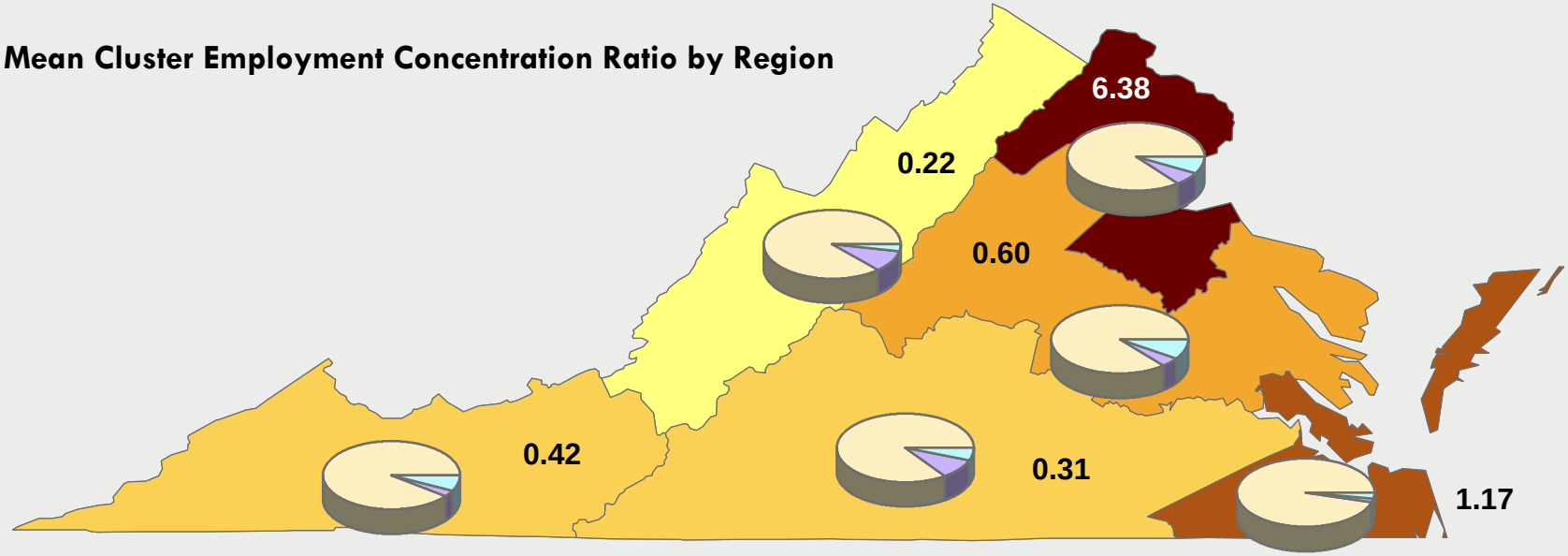
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Programming, Systems Design, & Data Services	11.1%	3.6%
Internet Services	-49.7%	7.0%
Software Development	-18.8%	-4.8%
IT Services TOTAL	**2.8%**	**2.2%**

Information Technology Services Cluster

Regional Trends

- The *IT Services* cluster is most concentrated in the Northern Virginia region, which is not surprising given the rapid growth of technology services to support government and business in the DC area. In addition, the Hampton Roads region, which also has many government and military installations, has a high employment concentration ratio.
- *Programming, Systems Design, & Data Services* is by far the largest sub-cluster across all of the regions in Virginia.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

	Highest Employment Concentration Ratio
	↕
	Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

	Programming, Systems Design, & Data Services
	Internet Services
	Software Development

Life Sciences & Medicine Cluster

Cluster Definition

Life Sciences & Medicine incorporates all health-related services (doctors, dentists, hospitals, nursing homes, etc.), as well as the development and manufacture of pharmaceuticals and medical devices.

Life Sciences & Medicine Sub-Clusters

- **Pharmaceuticals:** Manufacturing of medicines and botanicals, pharmaceutical preparations, in-vitro diagnostic substances, and biological products
- **Medical Equipment:** Manufacturing of electromedical and electrotherapeutic apparatus, laboratory apparatus and furniture, surgical and medical instruments, surgical appliances and supplies, dental equipment and supplies, and ophthalmic goods; Rental of home health equipment
- **Health & Medical Services:** Health care services (physicians, dentists, mental health, outpatient and home health care, etc.); Hospitals; Residential and nursing care; Medical and diagnostic laboratories

Life Sciences & Medicine Cluster

Cluster Profile

	2005	Trend
Virginia Employment	336,535	↑
U.S. Employment	15,896,225	↑
Virginia Employment Growth Rate (2003-2005)	3.3%	↑
U.S. Employment Growth Rate (2003-2005)	3.0%	↑
Virginia Employment Concentration Ratio	0.78	↓
U.S. Average Annual Pay	$40,995	↑↑
Virginia Establishments	13,409	↑
Virginia Average Private Sector Firm Size	23 employees	

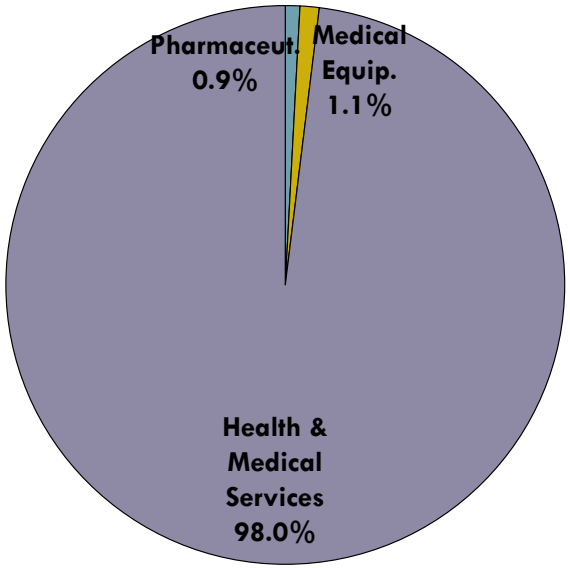
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Life Sciences & Medicine Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 336,535**
- **Ranks 5th out of 25 clusters in VA for employment size**
- **Accounts for 9.1% of total VA employment**
- **Over 97% of VA's cluster employment is concentrated in:**
  - Ambulatory health care services (NAICS 621)
  - Hospitals (NAICS 622)
  - Nursing & residential care facilities (NAICS 623)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Pharmaceuticals	3,191	0.48	15	$72,995
Medical Equipment	3,617	0.36	258	$52,511
Health & Medical Services	329,727	0.80	13,136	$40,198
Life Sciences & Medicine TOTAL	**336,535**	**0.78**	**13,409**	**$40,995**

Life Sciences & Medicine Cluster

Growth Trends

- Employment in this cluster is heavily dominated by *Health & Medical Services*. This is also the only Life Sciences & Medicine sub-cluster to experience positive employment growth in VA in the last few years (+3.6% from 2003-2005).
- VA does not show strong trends in *Pharmaceuticals* or *Medical Equipment*. Both sub-clusters have low employment concentration ratios and have shown declining employment in VA in 2003-2005.

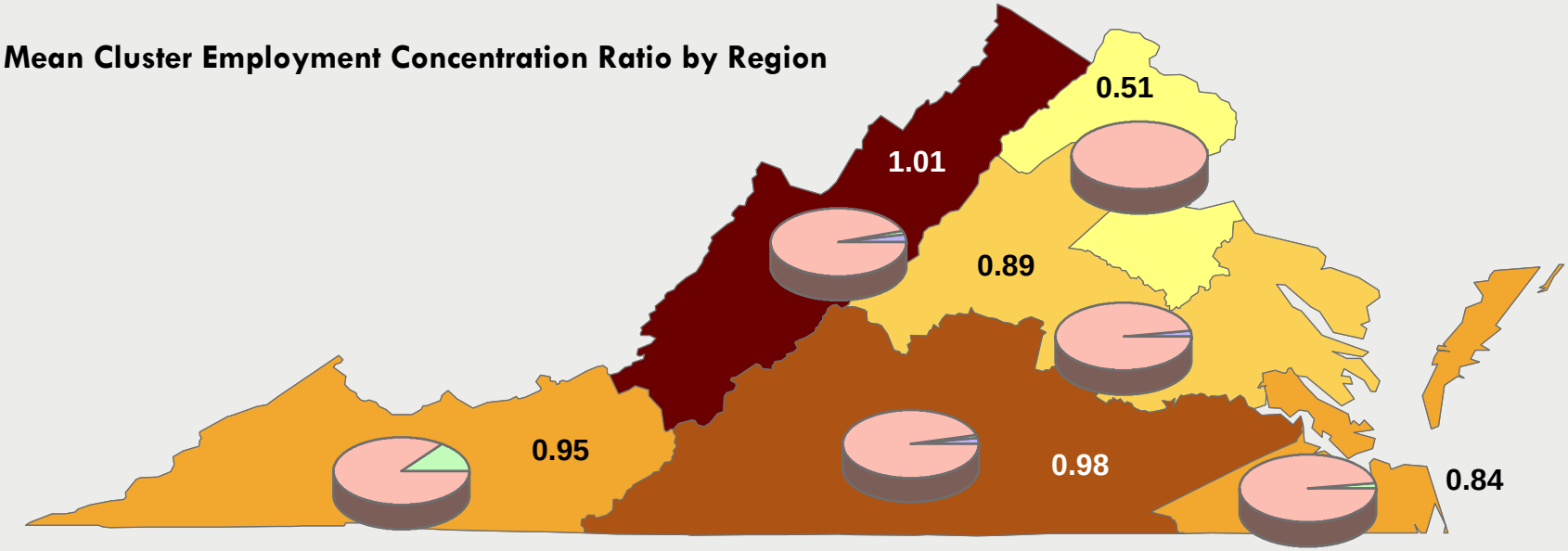
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Pharmaceuticals	-7.7%	-1.6%
Medical Equipment	-14.0%	1.3%
Health & Medical Services	3.6%	3.2%
Life Sciences & Medicine TOTAL	**3.3%**	**3.0%**

Life Sciences & Medicine Cluster

Regional Trends

- The *Life Sciences & Medicine* cluster is most concentrated in the Valley region, but none of the regions in the state have especially high concentration ratios.
- *Health & Medical Services* is the predominant sub-cluster throughout the state.
- The Southwestern region has a slightly larger share of *Medical Equipment* employment.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- Pharmaceuticals
- Medical Equipment
- Health & Medical Services

Materials & Chemicals Cluster

Cluster Definition

The *Materials & Chemicals* cluster covers a variety of mining, manufacturing, and support activities for metals, minerals, chemicals, plastics, resins, rubber, and other related materials.

Materials & Chemicals Sub-Clusters

- **Chemicals:** Manufacturing of petrochemicals, industrial gases, synthetic dyes and pigments, basic inorganic and organic chemicals, agricultural chemicals, paints/coatings/adhesives, soaps and cleaning compounds, printing inks, and other chemical preparations
- **Metals:** Mining and support activities for metal ores and primary metals; Forging and stamping; Metal coating, engraving, and heat treating; Manufacturing of architectural and structural metals and metalworking machinery
- **Plastics, Resin, & Rubber:** Manufacturing of resins, rubbers, and artificial fibers; Manufacturing plastics and rubber products; Machinery related to plastics and rubber
- **Other Materials:** Mining and support activities for nonmetallic minerals; Manufacturing of asphalt materials, petroleum and coal products
- **Packaging Materials:** Manufacturing of packaging materials and bags made from coated and laminated paper, foil, plastics, and related materials.

Materials & Chemicals Cluster

Cluster Profile

	2005	Trend
Virginia Employment	67,199-72,929	○
U.S. Employment	3,417,935	↓
Virginia Employment Growth Rate (2003-2005)	-0.2%	○
U.S. Employment Growth Rate (2003-2005)	-1.9%	↓
Virginia Employment Concentration Ratio	0.73-0.79	○
U.S. Average Annual Pay	$44,125	↑↑
Virginia Establishments	1,328	○
Virginia Average Private Sector Firm Size	53 employees	

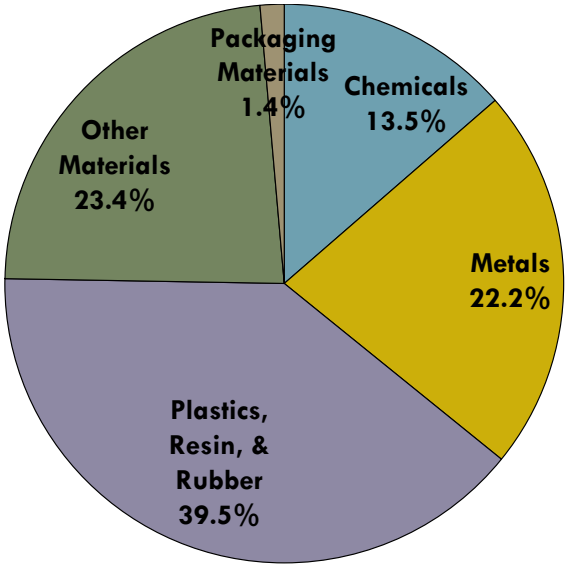
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Materials & Chemicals Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 67,199–72,929**
- **Ranks 14th out of 25 clusters in VA for employment size**
- **Accounts for 1.8% of total VA employment**
- **About 70% of VA's cluster employment is concentrated in:**
  - Plastics & rubber products mfg. (NAICS 326)
  - Nonmetallic mineral product mfg. (NAICS 327)
  - Primary metal mfg. (NAICS 331)
  - Architectural & structural metals mfg. (NAICS 3323)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Chemicals	8,501–10,402	0.68–0.84	148	$54,917
Metals	15,482–15,646	0.44–0.45	443	$44,174
Plastics, Resin, & Rubber	27,498–27,806	1.01–1.02	204	$39,080
Other Materials	14,951–17,878	0.91–1.08	522	$43,949
Packaging Materials	767–1,197	0.59–0.92	11	$47,710
Materials & Chemicals TOTAL	**67,199–72,929**	**0.73–0.79**	**1,328**	**$44,125**

Materials & Chemicals Cluster

Growth Trends

- In this cluster, only *Plastics/Resin/Rubber* and *Other Materials* have employment concentrations in VA that approach or exceed the national average.
- VA's employment growth in *Chemicals* was exceptionally strong in recent years (+23.5%), during a time when the national employment trend was declining.
- In the *Chemicals* sub-cluster, VA's 2003-2005 employment growth was especially strong for:
  - Other basic inorganic chemical mfg. (NAICS 32518): 126% growth
  - Printing ink mfg. (NAICS 32591): 196% growth

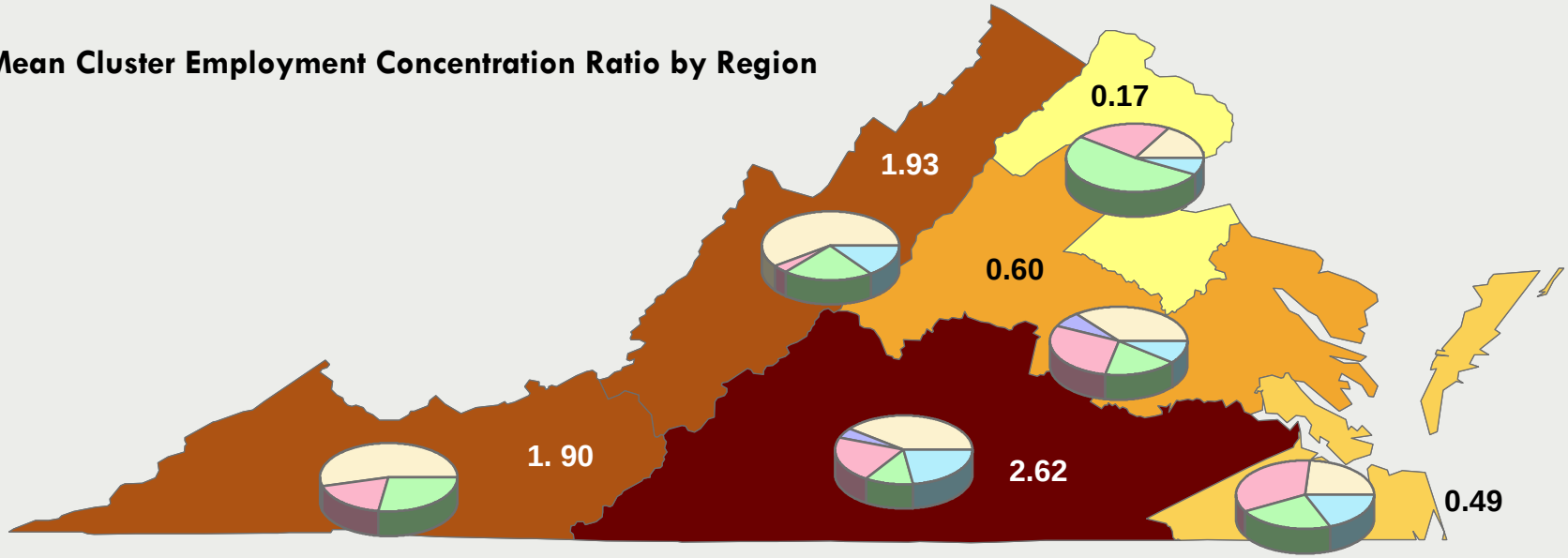
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Chemicals	23.5%	-4.5%
Metals	-8.3%	-1.8%
Plastics, Resin, & Rubber	-4.9%	-2.7%
Other Materials	6.6%	1.5%
Packaging Materials	-10.8%	-5.6%
Materials & Chemicals TOTAL	**-0.2%**	**-1.9%**

Materials & Chemicals Cluster

Regional Trends

- The *Materials & Chemicals* cluster is most concentrated in the Southside Virginia region.
- *Plastics/Resin/Rubber* is the largest sub-cluster in the Southwestern, Valley, and Southside regions. Northern Virginia's largest sub-cluster is *Other Materials*. Central Virginia and Hampton Roads have a relatively even distribution of employment across the sub-clusters.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- Chemicals
- Metals
- Plastics, Resin, & Rubber
- Other Materials
- Packaging Materials

Media & Design Services Cluster

Cluster Definition

Media & Design Services covers a wide variety of “creative” fields, including broadcasting and publishing across a variety of media (newspapers, books, Internet, etc.); motion pictures; news; advertising and public relations; and design-related sectors.

Media & Design Services Sub-Clusters

- **Media & Broadcasting:** Motion picture and sound recording; Broadcasting; Internet publishing and broadcasting; News syndicates and other information services
- **Advertising:** Agencies conducting advertising, public relations, media buying, display and direct mail advertising, and other related activities
- **Publishing:** Publishing of newspapers, books, periodicals, directories and mailing lists, greeting cards, and other related items
- **Design Services:** Graphic design; Interior design; Other specialized design services (fashion, jewelry, etc.); Photography services

Media & Design Services Cluster

Cluster Profile

	2005	Trend
Virginia Employment	44,985	↑
U.S. Employment	1,977,098	↑
Virginia Employment Growth Rate (2003-2005)	3.7%	↑
U.S. Employment Growth Rate (2003-2005)	1.9%	↑
Virginia Employment Concentration Ratio	0.84	○
U.S. Average Annual Pay	$49,454	↑
Virginia Establishments	3,713	↑↑
Virginia Average Private Sector Firm Size	12 employees	

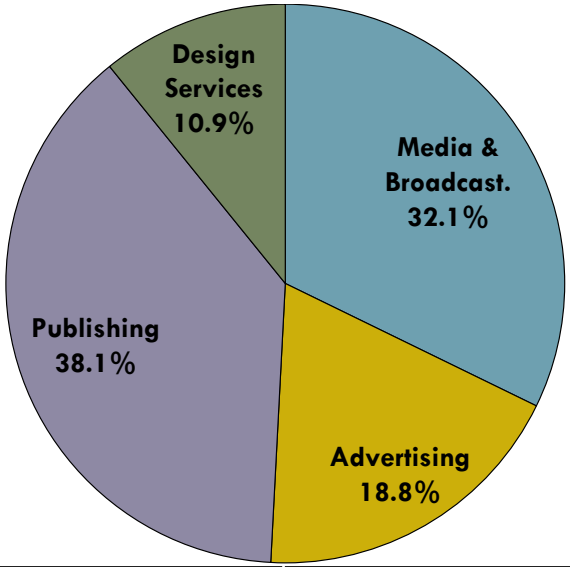
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Media & Design Services Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 44,985**
- **Ranks 18th out of 25 clusters in VA for employment size**
- **Accounts for 1.2% of total VA employment**
- **Over 56% of VA's cluster employment is concentrated in:**
  - Newspaper, book, & directory publishers (NAICS 5111)
  - Advertising & related services (NAICS 5418)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Media & Broadcasting	14,461	0.81	806	$53,427
Advertising	8,459	0.76	1,059	$54,348
Publishing	17,143	0.90	669	$46,991
Design Services	4,922	0.94	1,179	$34,450
Media & Design Services TOTAL	**44,985**	**0.84**	**3,713**	**$49,454**

Media & Design Services Cluster

Growth Trends

- While none of the *Media & Design Services* sub-clusters have employment concentration ratios above the national average, almost all of the sub-clusters have experienced positive employment growth in recent years.
- *Design Services* is smallest in terms of employment size, but has shown very strong employment growth (+15.3%) from 2003-2005, well above the U.S. trend.
- From 2003-2005, a few NAICS codes showed very strong growth rates in VA:
  - Internet publishing & broadcasting (NAICS 516): 16% growth
  - Graphic design services (NAICS 54143): 32% growth
  - Other specialized design services (NAICS 54149): 38% growth
  - Photographic services (NAICS 54192): 12% growth

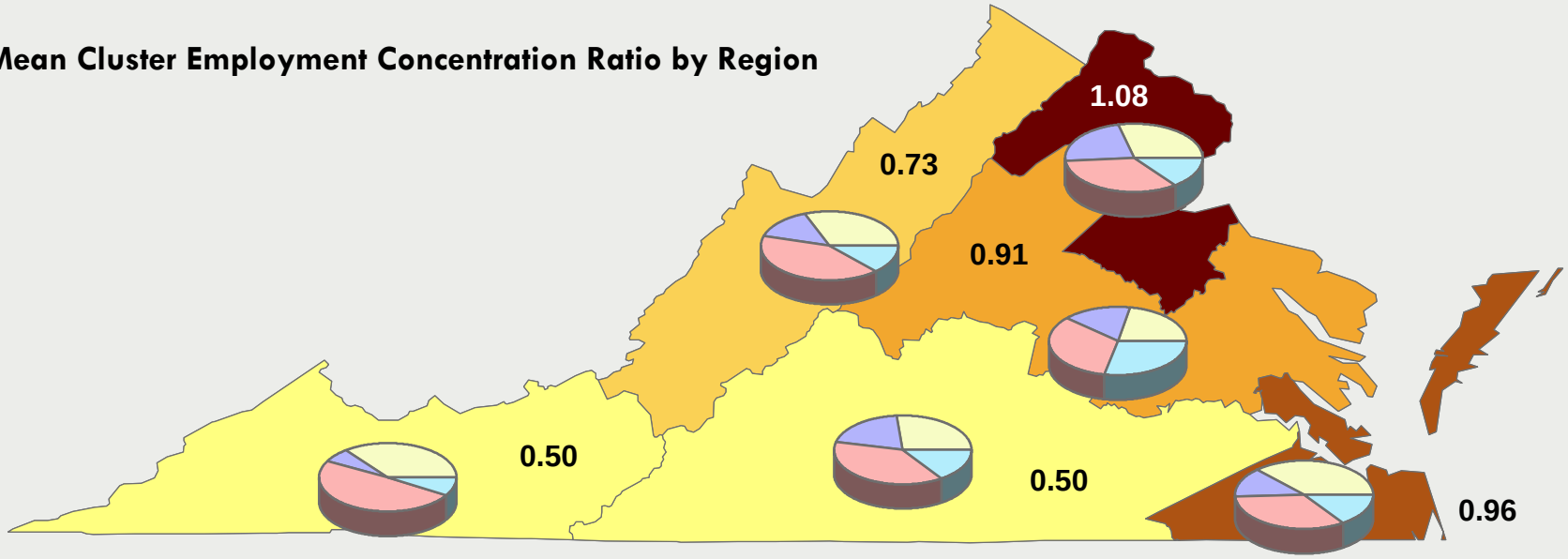
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Media & Broadcasting	-0.5%	5.1%
Advertising	1.8%	-1.4%
Publishing	5.4%	-0.1%
Design Services	15.3%	5.9%
Media & Design Services TOTAL	**3.7%**	**1.9%**

Media & Design Services Cluster

Regional Trends

- The *Media & Design Services* cluster is most concentrated in the Northern Virginia region, followed by the Hampton Roads region, most likely due to proximity to government and large businesses and corporations.
- The distribution of employment across the sub-clusters is fairly consistent across all regions in the state.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- Media & Broadcasting
- Advertising
- Publishing
- Design Services

Research & Engineering Services Cluster

Cluster Definition

The *Research & Engineering Services* cluster includes many knowledge-based fields such as architecture and engineering, as well as a wide range of consulting services and scientific R&D.

Research & Engineering Services Sub-Clusters

- **Engineering, Testing, & Architecture:** Architectural services; Engineering and drafting services; Surveying and mapping services; Testing laboratories; Industrial design services
- **Consulting & Research:** Management consulting services; Technical consulting services; Scientific research and development services; Marketing research and public opinion polling

Research & Engineering Services Cluster

Cluster Profile

	2005	Trend
Virginia Employment	161,633	↑↑↑
U.S. Employment	3,053,384	↑↑
Virginia Employment Growth Rate (2003-2005)	26.6%	↑↑↑
U.S. Employment Growth Rate (2003-2005)	7.9%	↑↑
Virginia Employment Concentration Ratio	1.96	↑↑↑
U.S. Average Annual Pay	$67,203	↑↑
Virginia Establishments	8,694	↑↑
Virginia Average Private Sector Firm Size	18 employees	

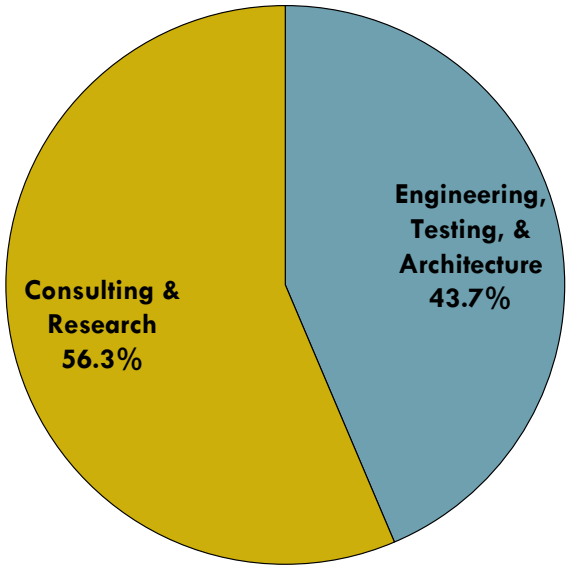
○ **no change** ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Research & Engineering Services Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 161,633**
- **Ranks 9th out of 25 clusters in VA for employment size**
- **Accounts for 4.4% of total VA employment**
- **Over 88% of VA's cluster employment is concentrated in:**
  - Engineering services (NAICS 54133)
  - Management consulting services (NAICS 54161)
  - Scientific research & development services (NAICS 5417)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Engineering, Testing, & Architecture	70,626	1.95	3,299	$63,175
Consulting & Research	91,007	1.97	5,395	$70,362
Research & Engineering Services TOTAL	**161,633**	**1.96**	**8,694**	**$67,203**

Research & Engineering Services Cluster

Growth Trends

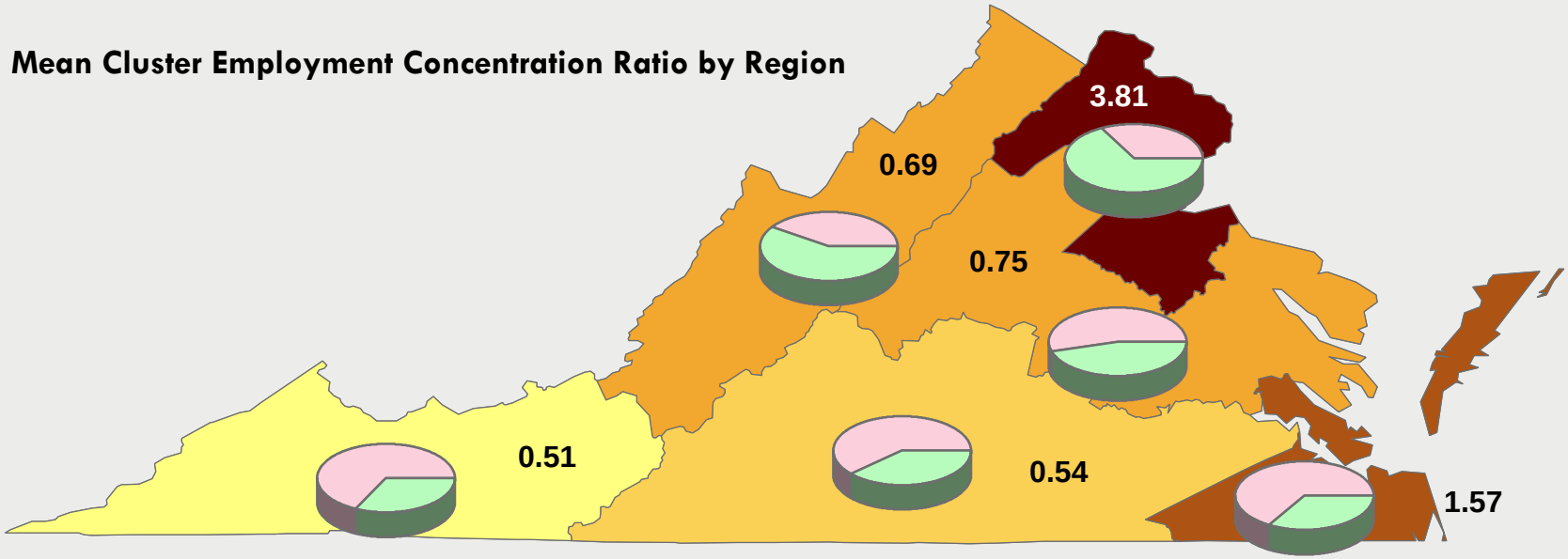
- This is probably VA's strongest cluster, with a very high employment concentration ratio (1.960) and very strong employment growth rates (+26.6% from 2003-2005).
- The national trend shows growth in both sub-clusters, and VA's growth rates have far exceeded the national average.
- Many NAICS codes show very strong employment growth in VA from 2003-2005:
  - Engineering services (NAICS 54133): 32% growth
  - Other surveying & mapping services (NAICS 54137): 12% growth
  - Testing laboratories (NAICS 54138): 18% growth
  - Management consulting services (NAICS 54161): 26% growth
  - Other technical consulting services (NAICS 54169): 97% growth
  - Scientific research & development services (NAICS 5417): 21% growth

	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Engineering, Testing, & Architecture	27.6%	5.4%
Consulting & Research	25.8%	10.0%
Research & Engineering Services TOTAL	**26.6%**	**7.9%**

Research & Engineering Services Cluster

Regional Trends

- The *Research & Engineering Services* cluster is most concentrated in the Northern Virginia region, followed by the Hampton Roads region, most likely due to the high concentration of government and military facilities in these regions.
- *Consulting & Research* is the largest sub-cluster in the Northern and Valley regions, while *Engineering/Testing/Architecture* is largest in the other regions.



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- Engineering, Testing, & Architecture
- Consulting & Research

Transportation & Logistics Services Cluster

Cluster Definition

Transportation & Logistics Services covers the provision of transportation services by water, rail, and ground for both freight and passengers. It also incorporates services related to transportation logistics, packing, warehousing, and storage.

Transportation & Logistic Services Sub-Clusters

- **Water Transportation:** Deep sea, coastal, and inland water transportation services and related support activities
- **Rail Transportation:** Rail transportation services and related support activities
- **Ground Freight Transportation:** Freight trucking services and related support activities; Courier and messenger services
- **Logistics & Warehousing:** Freight transportation arrangement; Packing and crating services; Warehousing and storage; Rental and leasing of transportation equipment; Other transportation support activities
- **Ground Passenger Transit:** Urban transit systems; Bus and school bus transport; Taxi and limousine services; Other passenger transportation services

Transportation & Logistics Services Cluster

Cluster Profile

	2005	Trend
Virginia Employment	92,052	↑↑
U.S. Employment	3,745,545	↑
Virginia Employment Growth Rate (2003-2005)	8.1%	↑↑
U.S. Employment Growth Rate (2003-2005)	4.1%	↑
Virginia Employment Concentration Ratio	0.91	↑
U.S. Average Annual Pay	$35,945	↑↑
Virginia Establishments	5,090	↑
Virginia Average Private Sector Firm Size	17 employees	

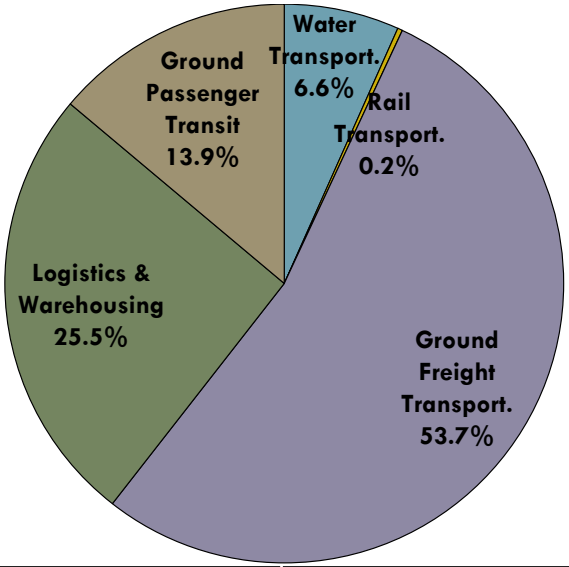
no change ↕ **0-5% change** ↕↕ **5-10% change** ↕↕↕ **>10% change**

Transportation & Logistics Services Cluster

Employment Trends

- **Estimated 2005 VA cluster employment is 92,052**
- **Ranks 12th out of 25 clusters in VA for employment size**
- **Accounts for 2.5% of total VA employment**
- **Over 72% of VA's cluster employment is concentrated in:**
  - Truck transportation (NAICS 484)
  - Warehousing & storage (NAICS 493)
  - Couriers & messengers (NAICS 492)

Distribution of Cluster Employment - 2005



	Employment	Employment Concentration	Establishments	U.S. Average Annual Pay
Water Transportation	6,056	1.39	120	$53,040
Rail Transportation	229	0.31	12	$37,690
Ground Freight Transportation	49,417	0.86	3,895	$35,579
Logistics & Warehousing	23,511	1.09	693	$37,837
Ground Passenger Transit	12,839	0.75	370	$30,370
Transportation & Logistics Services TOTAL	**92,052**	**0.91**	**5,090**	**$35,945**

Transportation & Logistics Services Cluster

Growth Trends

- Both *Water Transportation* and *Logistics & Warehousing* are more concentrated in VA than the national average (concentration ratios greater than 1.0).
- However, *Logistics & Warehousing* was the only sub-cluster to experience declining employment in VA from 2003-2005.
- The cluster and all its sub-clusters strong positive employment trends at the national level.
- Both *Rail Transportation* and *Ground Passenger Transit* experienced exceptionally high employment growth in VA from 2003-2005.

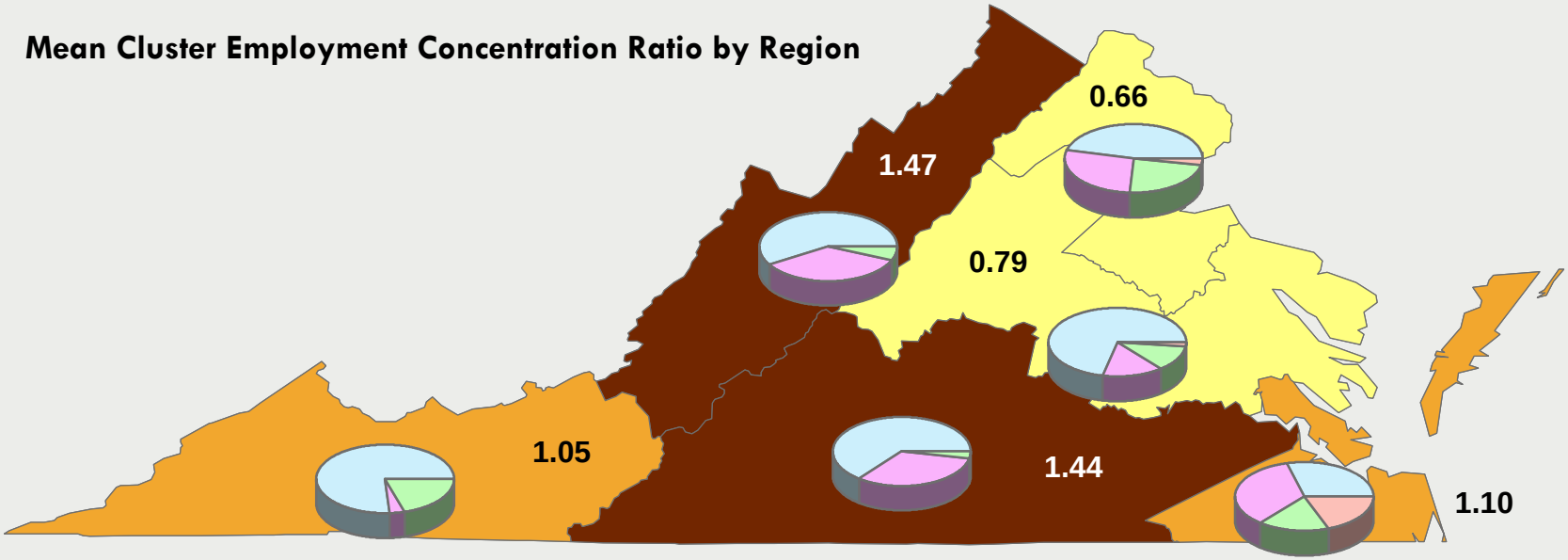
	Virginia Employment Growth Rate 2003-2005	U.S. Employment Growth Rate 2003-2005
Water Transportation	13.3%	3.0%
Rail Transportation	42.2%	7.0%
Ground Freight Transportation	7.8%	3.8%
Logistics & Warehousing	-3.9%	6.8%
Ground Passenger Transit	37.7%	2.0%
Transportation & Logistics Services TOTAL	**8.1%**	**4.1%**

Transportation & Logistics Services Cluster

Regional Trends

- The *Transportation & Logistics Services* cluster is most concentrated in the Valley and Southside regions, probably due to proximity to major interstate highways running through these regions.
- *Water Transportation* is a relatively large sub-cluster in the Hampton Roads region, due to the port facilities in the area. In other regions, *Ground Freight Transportation* is the predominant sub-cluster.

Mean Cluster Employment Concentration Ratio by Region



Regional Employment Concentration Ratio - 2005

- Highest Employment Concentration Ratio
- ↕
- Lowest Employment Concentration Ratio

Distribution of Regional Cluster Employment - 2005

- Water Transportation
- Rail Transportation
- Ground Freight Transportation
- Logistics & Warehousing
- Ground Passenger Transit

Summary Conclusions: Potential Target Tech. Clusters

In terms of size, critical mass, and growth trends, the following sectors may offer especially strong prospects for development and investment in Virginia:

- **Environmental Research & Management**
- **Computer Programming, Systems Design, & Data Services**
- **Healthcare / Medical Research**
- **Chemicals & Related Advanced Materials**
- **Graphic & Advanced Design Services**
- **Internet Services Related to Publishing, Broadcasting, Electronic Markets**
- **Engineering, Testing, & Architecture**
- **Scientific Consulting & Research**
- **Advanced Transportation Logistics**

These sectors will be matched against global and national industry trends, as well as Virginia's technology foundations and competencies, in order to develop a short-list of recommended target technology sectors.

Cluster Data Sources And Research Methodology

Section IV

Data Sources And Research Methodology

- Data for the cluster analysis were drawn from two sources:
  - **Private Sector Data:** *County Business Patterns*, U.S. Census Bureau (2003 and 2005), http://www.census.gov/epcd/cbp/view/cbpview.html
  - **Public Sector Data:** *Quarterly Census of Employment and Wages*, Bureau of Labor Statistics (2003 and 2005), http://www.bls.gov/cew/
- All industry clusters, and the NAICS codes that comprise each cluster, were selected and defined by SRI International, in consultation with the Virginia Economic Development Partnership. Clusters were defined according to the 2002 North American Industry Classification System.
- Due to changes in the NAICS codes in 2002, it impossible to conduct accurate time series analysis prior to this period. For this reason, growth rates were calculated over the 2003-2005 time period.

Due to federal government data suppression policies, industry data for employment, payroll, and wages are not available for many NAICS codes at the state and county level. This prevents calculating accurate employment figures for many industry clusters and sub-clusters.

SRI has developed a methodology to calculate employment estimates for industries with suppressed data by utilizing the "establishments by employment size class" data from the Census Bureau's *County Business Patterns*. Because *County Business Patterns* excludes most government employment, this data source is supplemented with public sector industry data from the Bureau of Labor Statistics' *Quarterly Census of Employment and Wages*. Although the data are drawn from two different sources, with slightly different data collection methodologies, this approach allows the SRI team to calculate the most accurate cluster employment estimates possible within the data suppression restrictions.

As a result of the data suppression issues and SRI's calculation methodology:

- Employment data for some clusters are given in ranges, not exact figures.
- Employment data may be underestimated, because data are suppressed for many public sector NAICS codes, and there is no way to develop estimates for these suppressed codes.
- It is not possible to calculate average annual pay at the state or county level. All figures for average annual pay are for the U.S. only.

Cluster Data Tables

Section V

Virginia Cluster Data 2005

State Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number Of Establishments	U.S. Average Annual Pay
Aerospace, Defense, & National Security	85,411 – 85,688	1.76 – 1.77	469	$58,963
Agriculture & Agribusiness	50,699 – 52,856	0.92 – 0.95	1,463	$33,272
Automotive & Transportation Manufacturing	41,317 – 43,344	1.08 – 1.13	207	$48,099
Business Services	295,556	0.81	13,702	$45,352
Construction & Real Estate	351,784 – 352,228	1.29	37,692	$39,214
Energy & Environment	48,677 – 49,738	0.79 – 0.81	2,149	$59,316
Education & Government	528,471 – 528,766	0.96	8,502	$37,961
Electronics	13,799 – 14,526	0.56 – 0.58	581	$56,677
Financial Services	163,099 – 165,440	0.93 – 0.95	11,512	$69,442
Industrial & Commercial Equipment Manufacturing	25,265 – 30,744	0.48 – 0.59	959	$40,964
Information Technology Services	140,016	2.69	6,816	$76,328
Life Sciences & Medicine	336,535	0.78	13,409	$40,995
Materials & Chemicals	67,199 – 72,929	0.73 – 0.79	1,328	$44,125

Virginia Cluster Data 2005 (cont'd.)

State Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number Of Establishments	U.S. Average Annual Pay
Media & Design Services	44,985	0.84	3,713	$49,454
Paper	9,909 – 10,142	0.88 – 0.90	94	$47,606
Research & Engineering Services	161,633	1.96	8,694	$67,203
Retail Trade	430,056	1.03	29,882	$22,403
General Services	198,688	1.05	22,614	$22,833
Textiles & Apparel	19,427 – 19,431	1.08	368	$27,598
Telecommunications	50,652	1.32	1,736	$57,472
Transportation & Logistics Services	92,052	0.91	5,090	$35,945
Tourism	361,164 – 361,820	0.96	18,678	$17,283
Utilities & Waste Management	15,819	1.20	682	$42,705
Wholesale Trade	107,271	0.69	7,521	$51,930
Wood & Furniture	39,262 – 39,276	1.23	1,533	$32,554
TOTAL	**3,707,516**		**199,810**	**$39,004**

Virginia Cluster Growth Rate Data 2003-2005

State Level

Cluster Name	Total Employment Growth Rate	Number Of Establishments Growth Rate	U.S. Average Annual Pay Growth Rate	Employment Concentration Ratio Growth Rate
Aerospace, Defense, & National Security	-4.6%	7.6%	8.3%	-3.2%
Agriculture & Agribusiness	3.5%	0.1%	6.1%	2.4%
Automotive & Transportation Mfg.	-0.3%	6.2%	3.6%	-3.3%
Business Services	6.5%	2.5%	8.5%	-0.7%
Construction & Real Estate	12.4%	12.5%	9.7%	4.0%
Energy & Environment	3.5%	8.5%	10.9%	0.5%
Education & Government	4.5%	6.9%	6.0%	1.1%
Electronics	-24.7%	-3.3%	10.9%	-17.5%
Financial Services	-3.8%	3.7%	14.2%	-5.1%
Industrial & Comm. Equipment Mfg.	0.2%	0.2%	8.9%	2.1%
Information Technology Services	2.8%	16.4%	7.1%	-1.3%
Life Sciences & Medicine	3.3%	4.2%	8.5%	-1.6%
Materials & Chemicals	-0.2%	0.4%	7.7%	-0.1%

Virginia Cluster Growth Rate Data 2003-2005 (cont'd.)

State Level

Cluster Name	Total Employment Growth Rate	Number Of Establishments Growth Rate	U.S. Average Annual Pay Growth Rate	Employment Concentration Ratio Growth Rate
Media & Design Services	3.7%	7.6%	5.8%	-0.1%
Paper	-13.6%	-4.1%	5.3%	-9.9%
Research & Engineering Services	26.6%	8.9%	9.7%	15.1%
Retail Trade	4.4%	0.5%	5.7%	-0.7%
General Services	1.1%	3.1%	6.3%	-2.8%
Textiles & Apparel	-24.1%	-7.8%	5.0%	-10.3%
Telecommunications	-16.4%	8.6%	3.8%	-4.9%
Transportation & Logistics Services	8.1%	5.8%	6.5%	2.0%
Tourism	6.7%	7.2%	6.1%	-0.6%
Utilities & Waste Management	6.8%	6.7%	6.0%	7.0%
Wholesale Trade	4.0%	1.5%	11.4%	0.4%
Wood & Furniture	-2.0%	0.3%	8.0%	-4.4%
TOTAL	**4.3%**	**5.4%**	**7.8%**	

Central VA Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	5,452 – 6,494	0.60 – 0.72	62
Agriculture & Agribusiness	8,152 – 13,695	0.79 – 1.33	315
Automotive & Transportation Manufacturing	912 – 1,906	0.13 – 0.27	39
Business Services	52,729 – 56,513	0.78 – 0.83	2,723
Construction & Real Estate	65,720 – 68,997	1.29 – 1.36	8,396
Energy & Environment	7,277 – 12,051	0.64 – 1.05	433
Education & Government	46,781 – 49,817	0.46 – 0.49	1,632
Electronics	2,844 – 5,090	0.61 – 1.10	126
Financial Services	54,018 – 59,575	1.66 – 1.83	2,672
Industrial & Commercial Equipment Manufacturing	4,461 – 7,898	0.46 – 0.81	236
Information Technology Services	5,597 – 6,047	0.58 – 0.62	729
Life Sciences & Medicine	63,974 – 78,798	0.80 – 0.98	2,496
Materials & Chemicals	8,040 – 12,666	0.47 – 0.74	256

Central VA Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	8,285 – 9,859	0.83 – 0.99	800
Paper	1,813 – 2,697	0.87 – 1.29	33
Research & Engineering Services	10,832 – 12,090	0.70 – 0.79	1,427
Retail Trade	79,651 – 83,312	1.03 – 1.07	5,631
General Services	38,729 – 43,571	1.10 – 1.24	4,465
Textiles & Apparel	2,719 – 4,609	0.81 – 1.38	83
Telecommunications	6,928 – 7,661	0.97 – 1.07	317
Transportation & Logistics Services	13,000 – 16,645	0.69 – 0.88	934
Tourism	63,255 – 70,273	0.90 – 1.00	3,448
Utilities & Waste Management	1,139 – 2,318	0.46 – 0.94	139
Wholesale Trade	27,811 – 31,328	0.96 – 1.08	1,985
Wood & Furniture	5,677 – 10,596	0.95 – 1.78	352
TOTAL	**691,066**		**39,819**

Hampton Roads Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	19,477 – 19,768	1.94 – 1.96	103
Agriculture & Agribusiness	13,718 – 19,120	1.19 – 1.66	289
Automotive & Transportation Manufacturing	18,124 – 22,808	2.28 – 2.87	61
Business Services	59,984 – 69,616	0.79 – 0.92	2,540
Construction & Real Estate	68,197 – 71,685	1.20 – 1.26	7,796
Energy & Environment	4,758 – 8,199	0.37 – 0.64	300
Education & Government	38,245 – 42,119	0.33 – 0.37	1,426
Electronics	2,147 – 4,021	0.42 – 0.78	129
Financial Services	28,108 – 31,533	0.78 – 0.87	2,295
Industrial & Commercial Equipment Manufacturing	2,864 – 4,752	0.26 – 0.44	182
Information Technology Services	12,345 – 12,996	1.14 – 1.20	638
Life Sciences & Medicine	66,682 – 82,814	0.75 – 0.93	2,675
Materials & Chemicals	7,758 – 11,108	0.40 – 0.58	224

Hampton Roads Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	9,148 – 12,230	0.82 – 1.10	645
Paper	1,673 – 3,011	0.72 – 1.29	14
Research & Engineering Services	26,095 – 27,864	1.52 – 1.63	1,234
Retail Trade	93,653 – 94,893	1.08 – 1.10	6,367
General Services	35,826 – 38,464	0.91 – 0.98	4,485
Textiles & Apparel	812 – 1,304	0.22 – 0.35	72
Telecommunications	7,297 – 7,883	0.92 – 0.99	273
Transportation & Logistics Services	21,102 – 24,956	1.00 – 1.19	1,039
Tourism	84,777 – 89,925	1.08 – 1.15	4,242
Utilities & Waste Management	1,631 – 2,182	0.59 – 0.79	98
Wholesale Trade	21,355 – 24,404	0.66 – 0.75	1,509
Wood & Furniture	1,610 – 3,391	0.24 – 0.51	137
TOTAL	**770,651**		**38,841**

Northern VA Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	49,800 – 57,347	2.94 – 3.39	183
Agriculture & Agribusiness	6,333 – 6,975	0.33 – 0.36	398
Automotive & Transportation Manufacturing	201 – 472	0.02 – 0.04	18
Business Services	111,408 – 116,193	0.88 – 0.92	5,443
Construction & Real Estate	135,558 – 138,327	1.42 – 1.45	11,725
Energy & Environment	10,091 – 14,243	0.47 – 0.66	414
Education & Government	85,889 – 88,821	0.45 – 0.46	2,396
Electronics	4,316 – 7,460	0.50 – 0.86	202
Financial Services	49,792 – 54,130	0.82 – 0.89	3,498
Industrial & Commercial Equipment Manufacturing	1,834 – 3,399	0.10 – 0.19	126
Information Technology Services	113,650 – 118,038	6.25 – 6.50	5,004
Life Sciences & Medicine	67,874 – 86,446	0.45 – 0.58	4,476
Materials & Chemicals	4,796 – 6,461	0.15 – 0.20	219

Northern VA Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	18,099 – 22,358	0.97 – 1.20	1,598
Paper	51 – 110	0.01 – 0.03	5
Research & Engineering Services	108,733 – 110,582	3.77 – 3.84	5,011
Retail Trade	138,355 – 140,257	0.95 – 0.96	8,258
General Services	65,926 – 68,503	1.00 – 1.04	6,603
Textiles & Apparel	478 – 624	0.08 – 0.10	79
Telecommunications	25,691 – 26,055	1.92 – 1.95	709
Transportation & Logistics Services	20,454 – 26,026	0.58 – 0.74	1,136
Tourism	117,953 – 123,489	0.89 – 0.94	6,189
Utilities & Waste Management	2,505 – 3,608	0.54 – 0.78	164
Wholesale Trade	29,240 – 32,513	0.54 – 0.60	2,073
Wood & Furniture	2,265 – 4,170	0.20 – 0.37	160
TOTAL	**1,295,111**		**66,242**

Southside VA Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	2,146 – 2,535	0.52 – 0.62	45
Agriculture & Agribusiness	3,874 – 7,127	0.82 – 1.51	168
Automotive & Transportation Manufacturing	796 – 1,677	0.24 – 0.51	28
Business Services	14,639 – 21,605	0.47 – 0.70	1,004
Construction & Real Estate	23,139 – 26,492	1.00 – 1.14	3,885
Energy & Environment	3,519 – 7,071	0.67 – 1.35	297
Education & Government	20,980 – 24,875	0.45 – 0.53	1,139
Electronics	376 – 886	0.18 – 0.42	39
Financial Services	7,803 – 10,403	0.53 – 0.70	1,075
Industrial & Commercial Equipment Manufacturing	3,238 – 6,667	0.73 – 1.50	152
Information Technology Services	1,149 – 1,565	0.26 – 0.35	128
Life Sciences & Medicine	30,188 – 41,116	0.83 – 1.13	1,315
Materials & Chemicals	15,102 – 26,065	1.92 – 3.32	239

Southside VA Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	1,583 – 2,970	0.35 – 0.65	220
Paper	2,141 – 4,192	2.24 – 4.38	21
Research & Engineering Services	2,972 – 4,675	0.42 – 0.67	322
Retail Trade	40,343 – 43,528	1.14 – 1.23	3,572
General Services	14,215 – 18,031	0.88 – 1.12	2,743
Textiles & Apparel	5,506 – 10,498	3.61 – 6.88	52
Telecommunications	2,341 – 4,184	0.72 – 1.28	134
Transportation & Logistics Services	9,003 – 15,811	1.05 – 1.84	728
Tourism	23,725 – 29,862	0.74 – 0.93	1,683
Utilities & Waste Management	514 – 1,217	0.46 – 1.08	101
Wholesale Trade	6,482 – 10,782	0.49 – 0.81	628
Wood & Furniture	10,769 – 19,847	3.96 – 7.29	501
TOTAL	**315,580**		**20,253**

Southwestern VA Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	2,300 – 4,022	0.89 – 1.56	35
Agriculture & Agribusiness	1,116 – 1,991	0.38 – 0.68	93
Automotive & Transportation Manufacturing	4,478 – 8,831	2.20 – 4.33	34
Business Services	7,778 – 11,872	0.40 – 0.61	712
Construction & Real Estate	9,518 – 11,690	0.65 – 0.80	1,786
Energy & Environment	7,737 – 13,258	2.36 – 4.05	450
Education & Government	10,450 – 12,172	0.36 – 0.42	876
Electronics	389 – 953	0.29 – 0.72	27
Financial Services	4,368 – 6,157	0.47 – 0.66	707
Industrial & Commercial Equipment Manufacturing	3,859 – 6,850	1.39 – 2.47	105
Information Technology Services	964 – 1,378	0.35 – 0.50	119
Life Sciences & Medicine	17,457 – 26,012	0.76 – 1.14	1,026
Materials & Chemicals	6,625 – 12,042	1.35 – 2.45	154

Southwestern VA Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	952 – 1,881	0.33 – 0.66	128
Paper	80 – 196	0.13 – 0.33	4
Research & Engineering Services	1,746 – 2,751	0.40 – 0.63	238
Retail Trade	28,982 – 31,326	1.31 – 1.41	2,559
General Services	7,989 – 10,629	0.79 – 1.06	1,570
Textiles & Apparel	2,185 – 4,096	2.29 – 4.29	38
Telecommunications	3,007 – 4,859	1.48 – 2.38	103
Transportation & Logistics Services	4,510 – 6,775	0.84 – 1.26	593
Tourism	16,889 – 19,600	0.84 – 0.97	1,152
Utilities & Waste Management	200 – 386	0.28 – 0.55	71
Wholesale Trade	3,974 – 6,461	0.48 – 0.78	402
Wood & Furniture	5,417 – 9,301	3.18 – 5.46	198
TOTAL	**197,362**		**13,214**

Valley Region Cluster Data 2005

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Aerospace, Defense, & National Security	1,269 – 1,979	0.27 – 0.42	40
Agriculture & Agribusiness	12,324 – 14,624	2.27 – 2.69	200
Automotive & Transportation Manufacturing	2,115 – 4,323	0.56 – 1.15	27
Business Services	25,557 – 29,712	0.72 – 0.83	1,261
Construction & Real Estate	31,151 – 34,110	1.16 – 1.27	4,100
Energy & Environment	3,454 – 6,649	0.57 – 1.10	241
Education & Government	1,7985 – 23,248	0.33 – 0.43	1,043
Electronics	970 – 2,152	0.40 – 0.88	57
Financial Services	13,476 – 15,506	0.79 – 0.91	1,245
Industrial & Commercial Equipment Manufacturing	4,532 – 8,685	0.89 – 1.70	158
Information Technology Services	977 – 1,297	0.19 – 0.25	183
Life Sciences & Medicine	36,069 – 48,847	0.86 – 1.16	1,421
Materials & Chemicals	13,192 – 21,808	1.46 – 2.41	234

Valley Region Cluster Data 2005 (cont'd.)

Regional Level

Cluster Name	Total Employment	Employment Concentration Ratio	Total Number of Establishments
Media & Design Services	2,780 – 4,887	0.53 – 0.93	320
Paper	1,765 – 3,263	1.60 – 2.96	17
Research & Engineering Services	4,628 – 6,525	0.57 – 0.81	459
Retail Trade	43,741 – 47,541	1.07 – 1.16	3,495
General Services	17,124 – 20,831	0.92 – 1.12	2,751
Textiles & Apparel	2,705 – 5,316	1.54 – 3.02	44
Telecommunications	3,144 – 4,616	0.84 – 1.23	197
Transportation & Logistics Services	12,378 – 16,728	1.25 – 1.69	659
Tourism	31,999 – 36,387	0.86 – 0.98	1,957
Utilities & Waste Management	595 – 934	0.46 – 0.72	109
Wholesale Trade	10,947 – 14,875	0.72 – 0.97	914
Wood & Furniture	4,487 – 9,082	1.43 – 2.90	185
TOTAL	**363,634**		**21,340**

Assessing The Technology Industry Potential Of The Commonwealth Of Virginia

December 11, 2007

P18176

Task 2:
Benchmarking Virginia's Innovation Foundations

SRI International

Prepared for the Virginia Economic Development Partnership

Table Of Contents

I. Introduction & Summary Analysis

II. Financial Resources

III. Human Resources

IV. Innovation Resources

V. Innovation Economy Outcomes

VI. List of Benchmark Indicators & Data Sources

Introduction & Summary Analysis

Section I

Benchmarking Virginia's Innovation Foundations

Methodology

- The SRI team selected 4 competitiveness areas for benchmarking:

Financial Resources	**Innovation Resources**
Human Resources	**Innovation Economy Outcomes**

- These 4 competitiveness areas provide a robust, objective, and trackable assessment of Virginia's technology industry potential, based on the state's current strengths and assets and its position for growth relative to other states.
- Virginia is benchmarked against 9 other states selected on the following basis:
  - Similar-sized economy (as measured by GSP);
  - Similar high-tech industry focus or profile; and/or
  - A traditional regional competitor.

Benchmarking Virginia's Innovation Foundations

Summary Results

	Financial Resources	Human Resources	Innovation Resources	Innovation Economy Outcomes
Strength	STTR awards SBIR awards	NAEP Science & Math Scores S&E degrees AP exams Labor force growth	Federal R&D	Tech Fast 500 companies Real GSP growth
Average	Small business loans	Advanced S&E degrees Young adult population growth	R&D productivity	R&D to GSP Business Start-Ups Entrepreneurs
Weakness	Micro loans VC investment		Publications Patents Academic R&D Industrial R&D	Exports

Benchmarking Virginia's Innovation Foundations

Conclusions

- Venture capital funding (at all stages) for industry sectors outside of IT services, software, and telecommunications is very limited in Virginia. For example, biotech, energy, and networking receive a lower-than-average share.
- Micro and small business loans are being utilized at a lower rate in Virginia than in other benchmark states.
- While Virginia performs well in preparing K-12 students and undergraduates for higher-level S&E studies, there is scope for expanding graduate-level research at universities. Academic R&D expenditures per capita are low relative to the benchmark states, as is the number of advanced S&E degrees conferred.
- Looking at Virginia's total R&D enterprise, the Federal government performs a significant share of R&D and is a major source of funding (45%) for industrial R&D in Virginia—much more so than in other benchmark states.

Benchmarking Virginia's Innovation Foundations

Conclusions

- With the Federal government also a major purchaser of services and goods, Virginia's outward orientation has suffered. Exports account for a very small share of GSP relative to other benchmark states and the US average.

- Similarly, Virginia's universities could improve their outreach and collaboration with industry—this would benefit S&E undergraduate and graduate students by enhancing career opportunities and providing more applied research experience.

Benchmarking Virginia's Innovation Foundations

Next Steps

- Data limitations—for example, the fact that technology-based start-up or lending activity cannot be isolated from overall business start-up and micro/small lending indicators—lead to some challenges in benchmarking technology-specific activities.
- Nevertheless, the indicators presented are informative and widely-used benchmarks for assessing how a state stacks up against its peers in particular economic development foundation areas. Data gaps and inconsistencies (e.g., ranking relatively high on one particular indicator and lower on another in the same category) are beneficial to policymakers by pointing out areas for further attention and analysis.
- Moving forward, the SRI team will develop case studies built on best practices in other states that address the innovation foundation weaknesses highlighted in this benchmarking analysis of VA and 9 other states.

Financial Resources

Section II

Financial Resources

Venture Capital

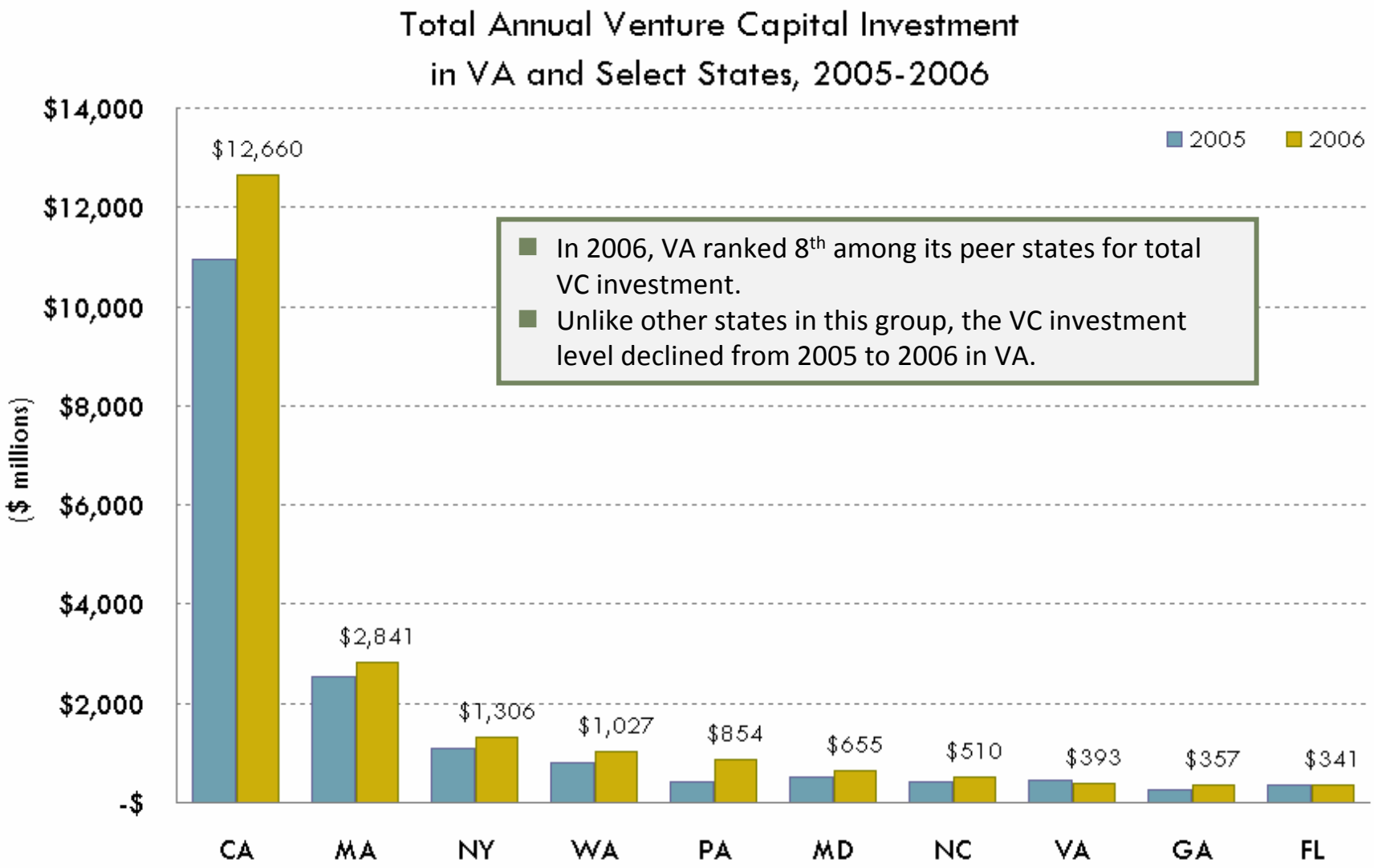
Category Significance: New companies based upon new technologies or business models are risky investments. Nevertheless, the small number of successes do compensate investors with high payoffs. They also generate large economic impacts through the creation of small firms with high growth potential. A dearth of venture and seed capital can be a major constraint on a state's startup environment.

Virginia's Performance

- Overall, VA ranked low among its peer states for total and per capita VC investment. VA ranked highly in government funded SBIR/STTR awards, but these are small compared to total VC investments.
- VA's share of total US VC trended downwards from 1995-2006.
- VA's VC distribution was highly concentrated in software, IT services, and telecom (74%)—much higher than the VC distribution for these industries at the national level. VA had lower-than-average levels of VC investment in biotech, semiconductors, and energy.

Financial Resources

Total VC

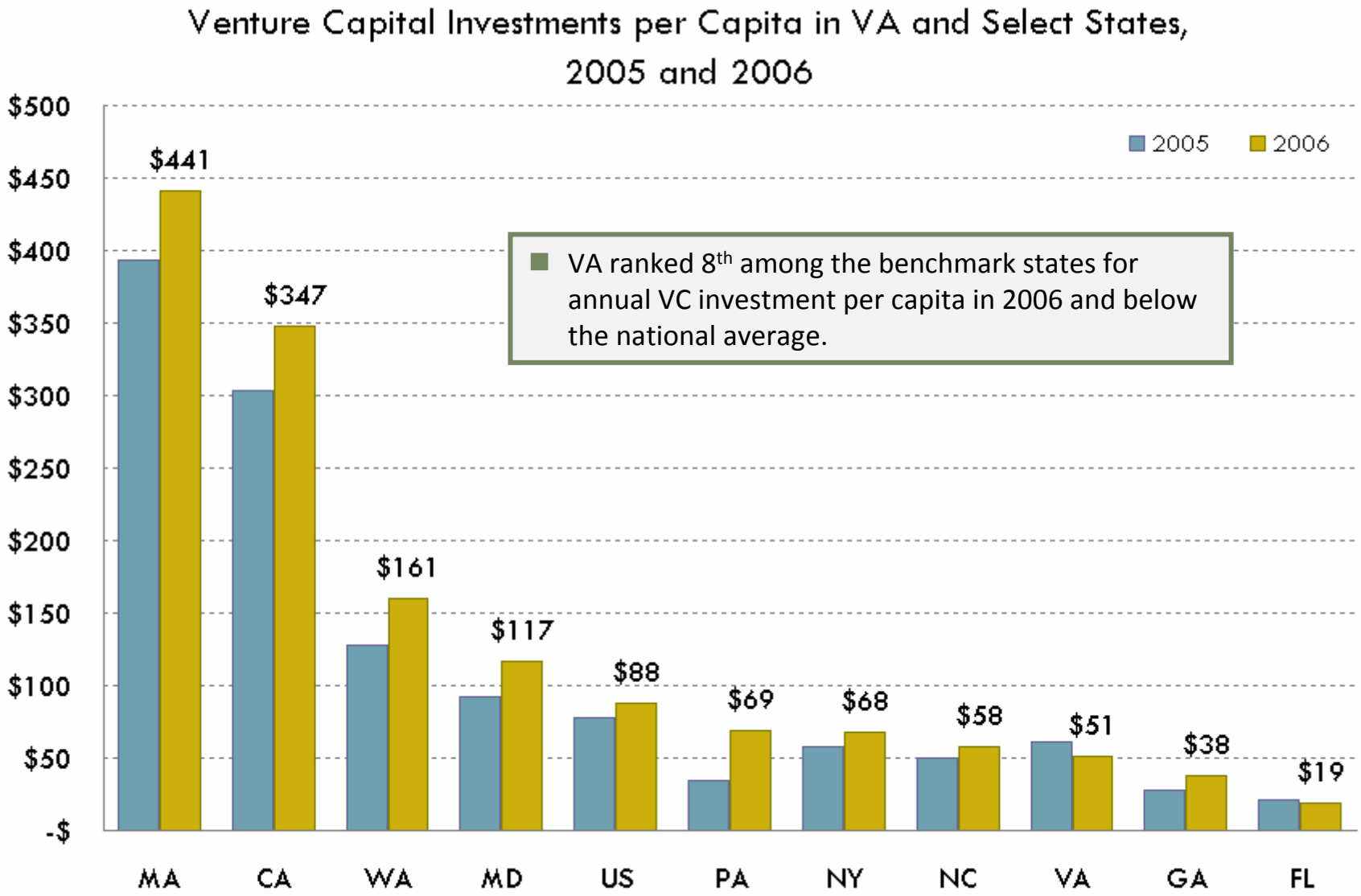


- In 2006, VA ranked 8th among its peer states for total VC investment.
- Unlike other states in this group, the VC investment level declined from 2005 to 2006 in VA.

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VC Per Capita

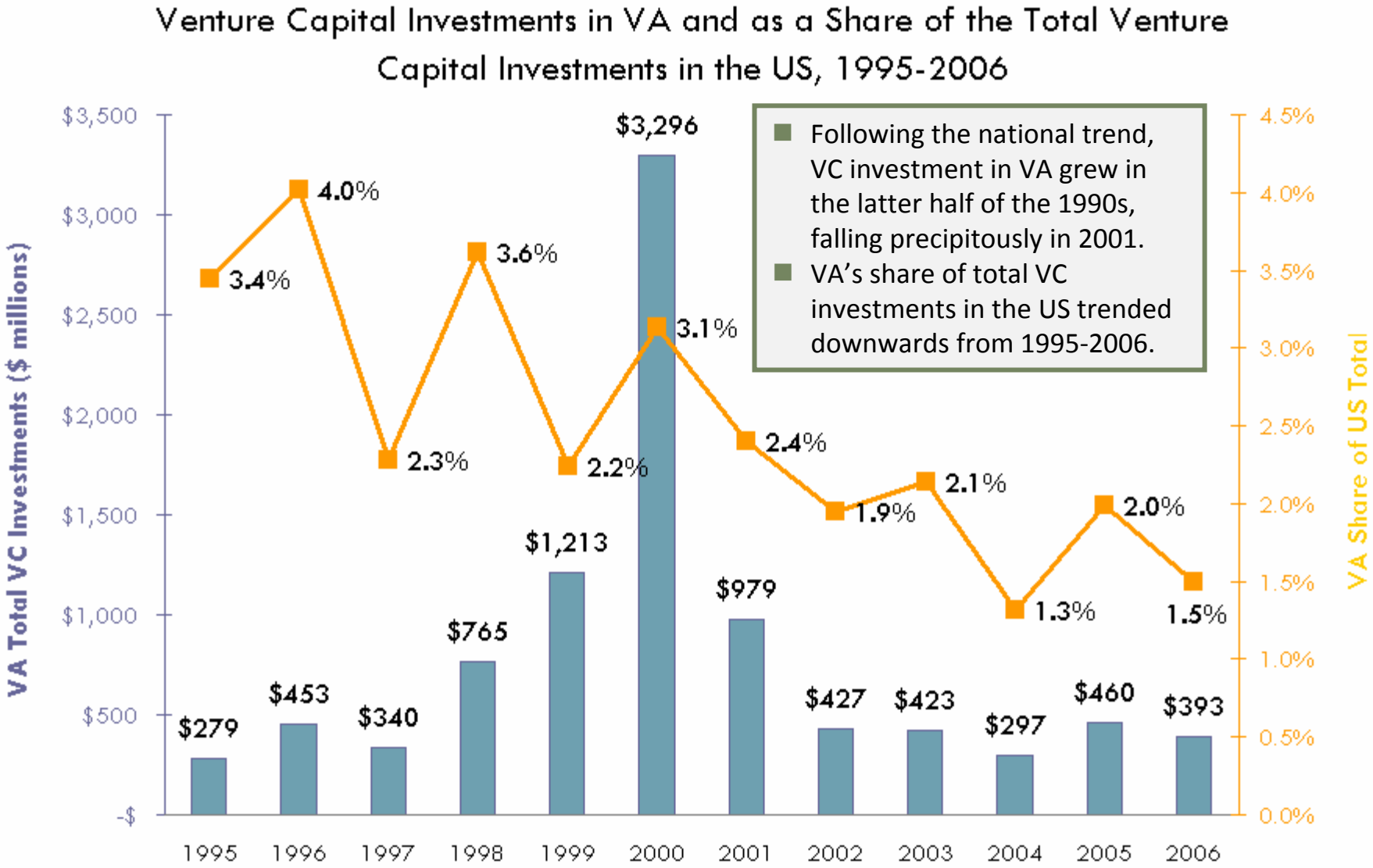


- VA ranked 8th among the benchmark states for annual VC investment per capita in 2006 and below the national average.

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VA's Share of US VC



Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VC by Sector

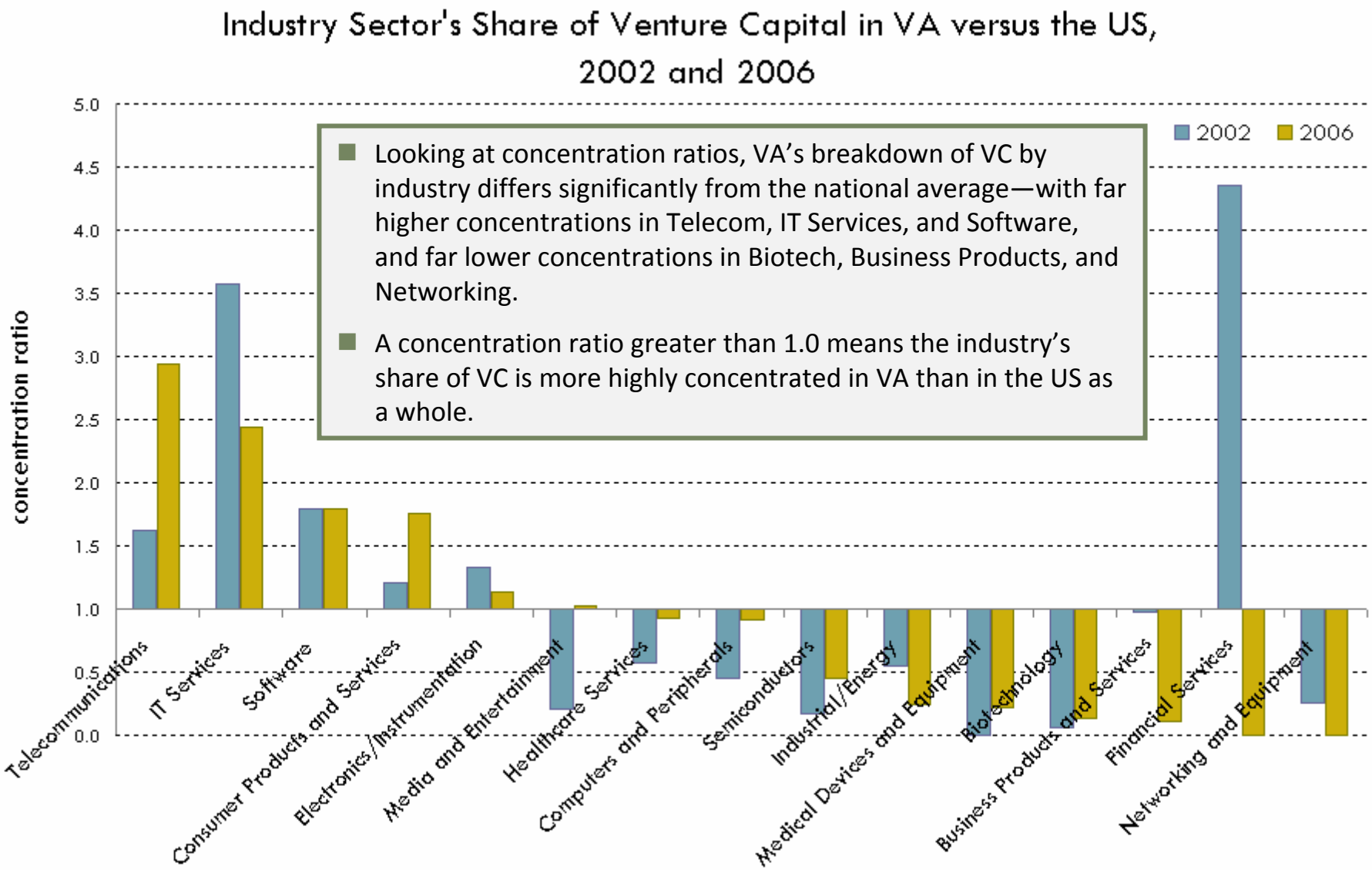
Comparison of VA and US Distribution of Venture Capital, 2006		
Industry	**VA**	**US**
Software	34.8%	19.4%
Telecommunications	28.8%	9.8%
IT Services	9.9%	4.1%
Media and Entertainment	6.6%	6.5%
Semiconductors	3.6%	8.0%
Consumer Products and Services	3.4%	1.9%
Electronics/Instrumentation	3.0%	2.7%
Biotechnology	2.5%	17.7%
Medical Devices and Equipment	2.4%	10.7%
Industrial/Energy	1.7%	7.0%
Computers and Peripherals	1.6%	1.8%
Healthcare Services	1.5%	1.6%
Business Products and Services	0.3%	2.4%
Networking and Equipment	0%	4.0%
Financial Services	0%	1.7%
Retailing/Distribution	0%	0.8%

- VA's venture capital investment is skewed towards Software, Telecom, and IT Services (73.5% vs. 33.3% in the US).
- Biotech, medical devices, and industry/energy are under-represented in VA (6.6% vs. 35.4% in the US).

Source: Pricewaterhouse Coopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VC by Sector

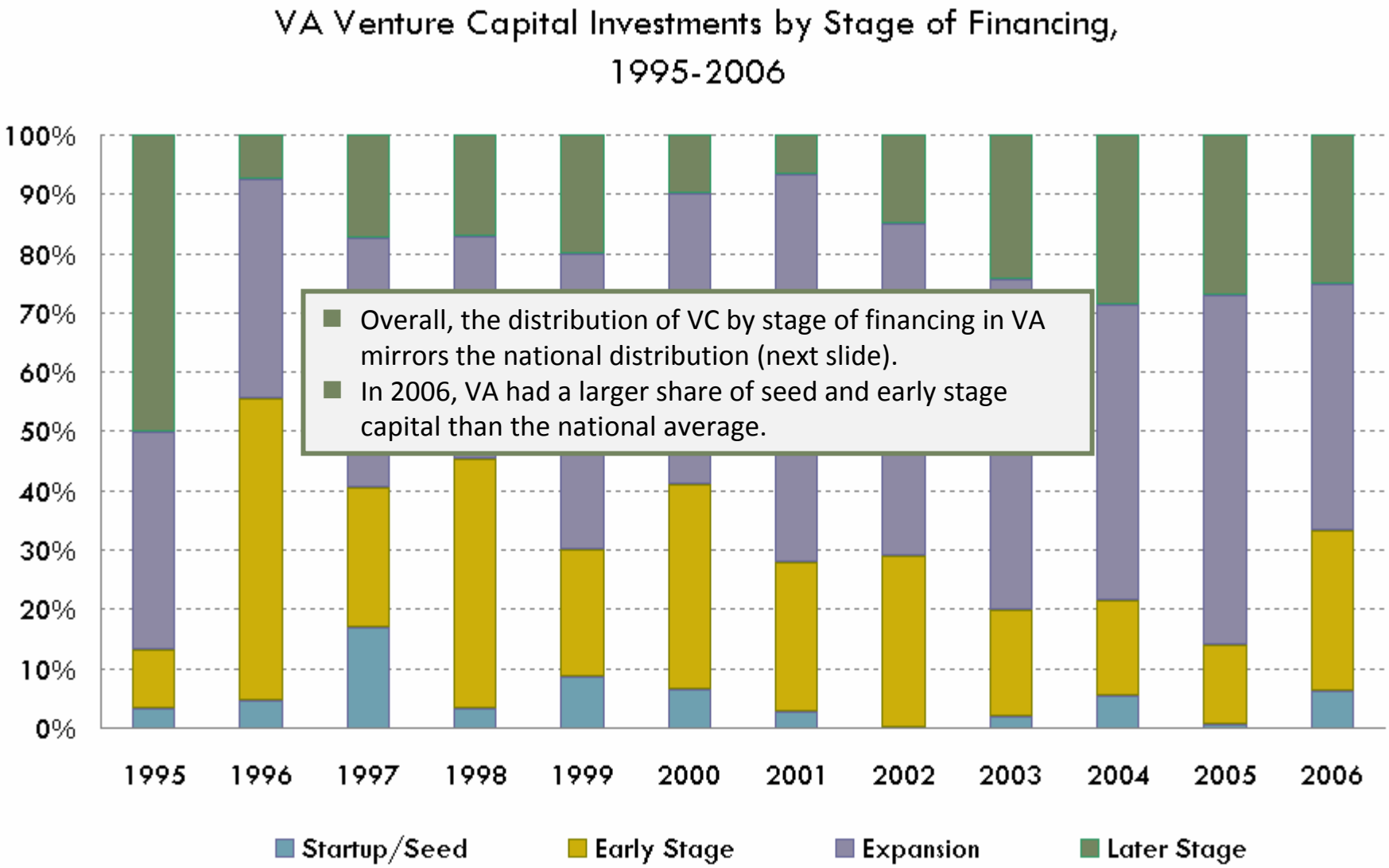


- Looking at concentration ratios, VA's breakdown of VC by industry differs significantly from the national average—with far higher concentrations in Telecom, IT Services, and Software, and far lower concentrations in Biotech, Business Products, and Networking.
- A concentration ratio greater than 1.0 means the industry's share of VC is more highly concentrated in VA than in the US as a whole.

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VC by Stage

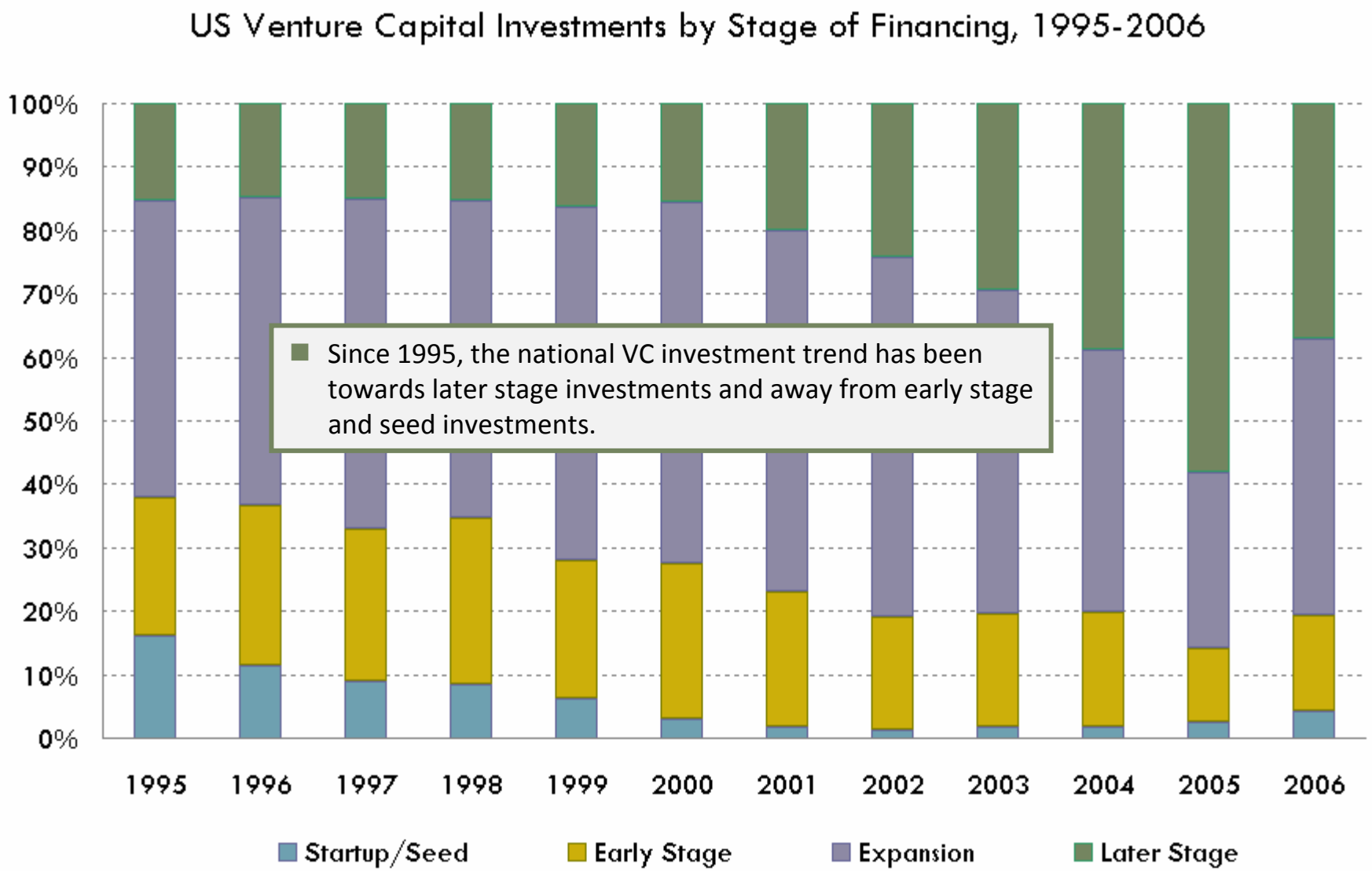


- Overall, the distribution of VC by stage of financing in VA mirrors the national distribution (next slide).
- In 2006, VA had a larger share of seed and early stage capital than the national average.

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

VC by Stage



- Since 1995, the national VC investment trend has been towards later stage investments and away from early stage and seed investments.

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Financial Resources

Micro & Small Business Loans

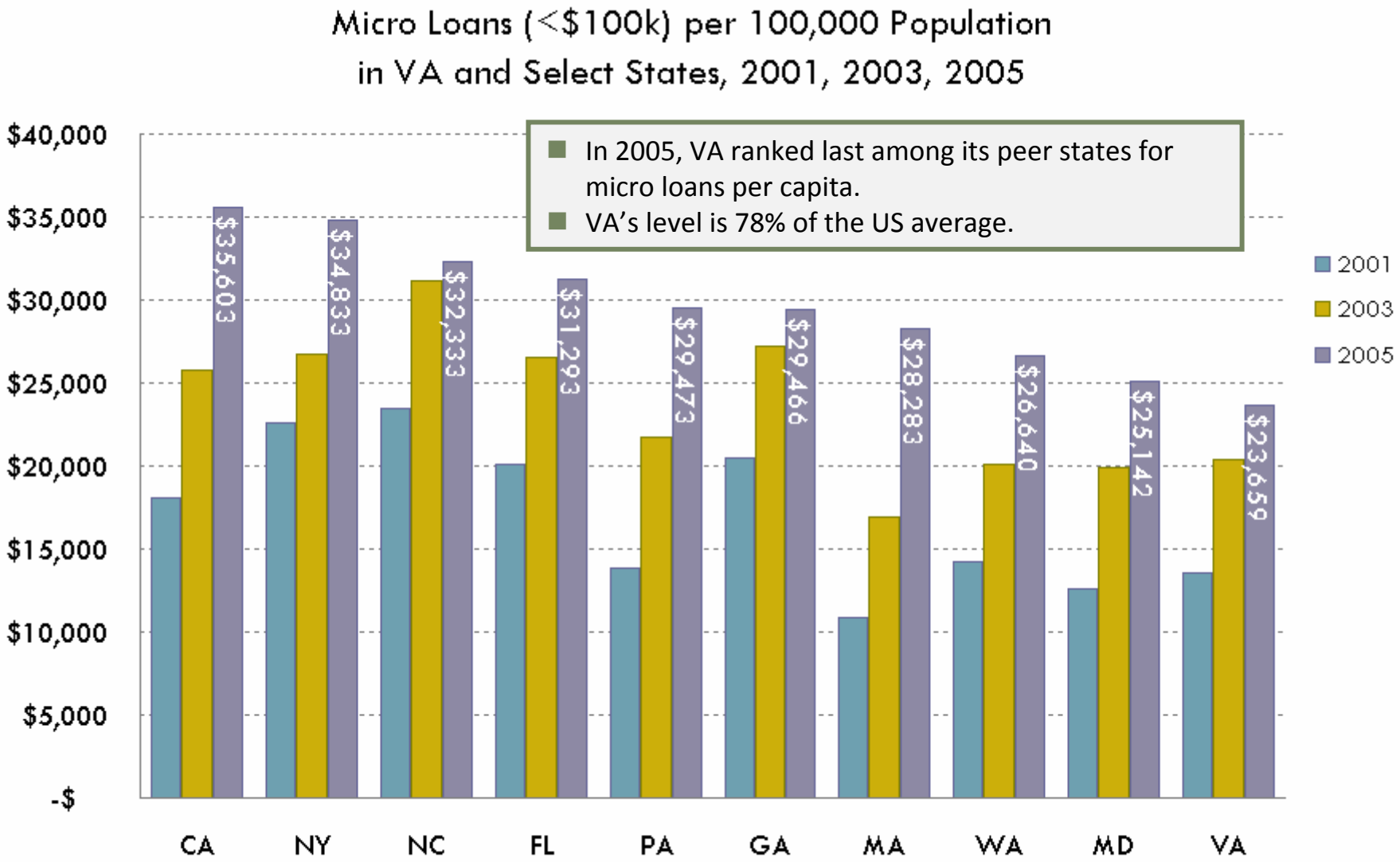
Category Significance: Even in the era of venture capital, traditional bank loans remain the primary source of funds for business start-ups and expansions. In this regard, a low level of per capita micro loans (<$100K) and small business loans (<$1 million) indicates either a limited applicant pool or risk-averse bankers.

Virginia's Performance

- In 2005, VA had the lowest value of per capita micro loans (<$100K) among the benchmark states.
- VA ranked in the middle of the benchmark states for value of per capita small business loans (<$1 million).
- These data are for all business loans, not only loans made to technology-based companies. However, they are good indicators of the overall availability of financing for entrepreneurs in the state.

Financial Resources

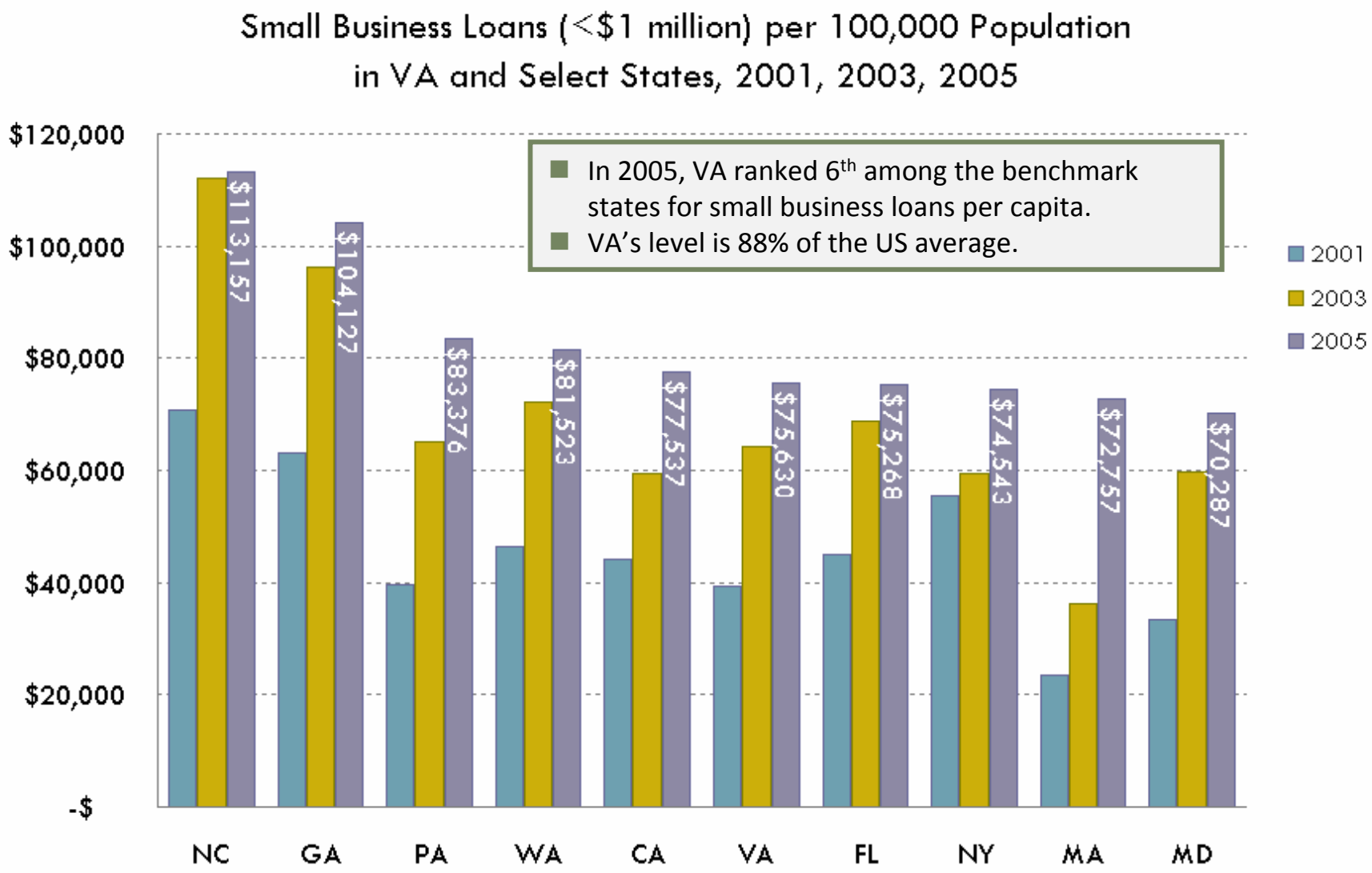
Micro Loans



Source: US Small Business Administration

Financial Resources

Small Loans



Source: US Small Business Administration

Financial Resources

SBIR & STTR Awards

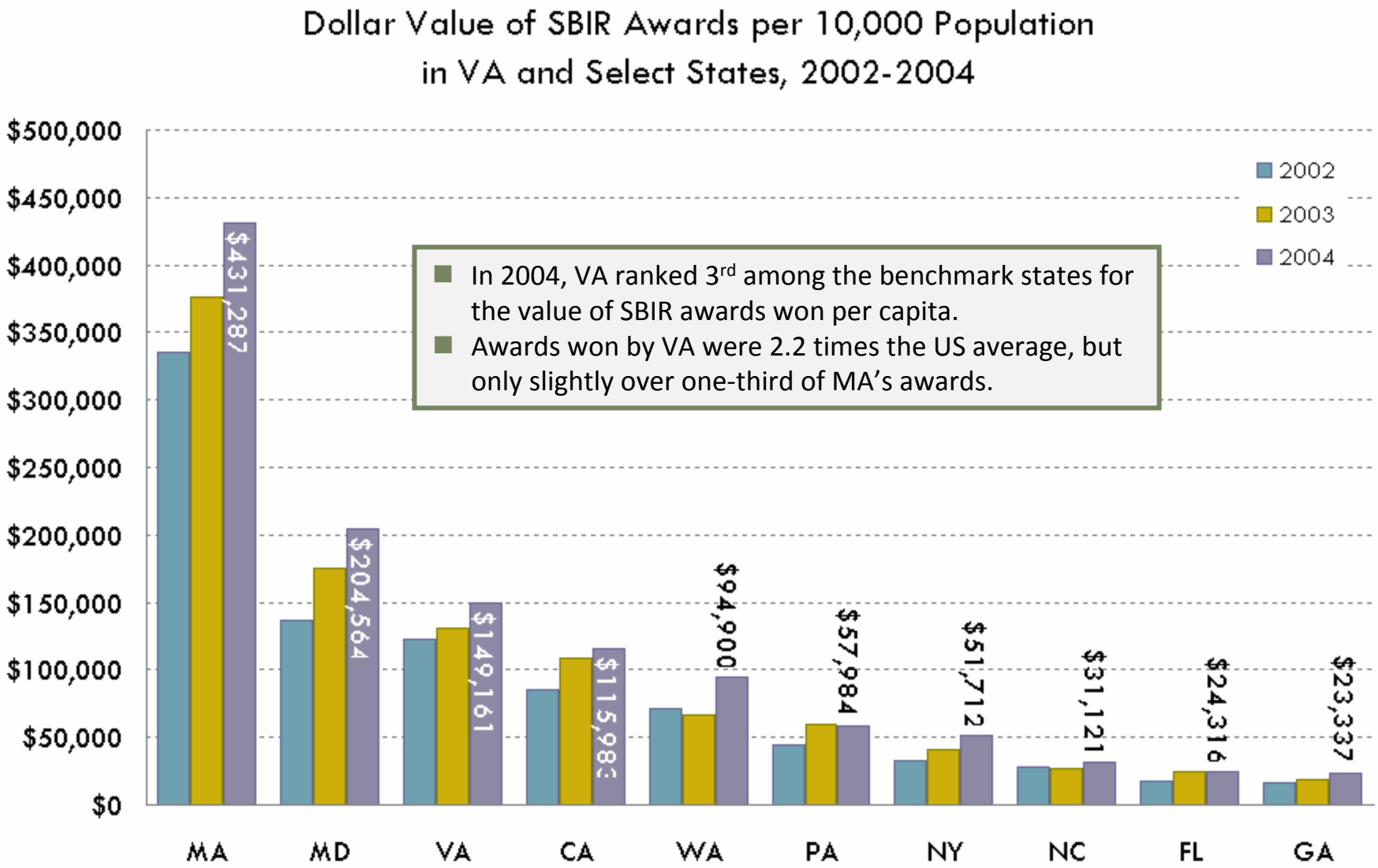
Category Significance: The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs are the Federal government's premier seed capital funds. They are intended to help move innovative ideas and technologies from the lab to the marketplace and to fill the seed capital gap.

Virginia's Performance

- VA ranked 3rd within the benchmark group for value of SBIR awards per capita—ahead of CA. While more than double the national average, the value of VA's SBIR awards per capita was one-third of MA' value in 2004.
- VA ranked 2nd among its peers for the value of STTR awards won per capita, still representing only one-third of MA' value in 2004.
- While VA performed well in these indicators, SBIR and STTR awards represent a small pool of funds relative to total VC investments made in the United States.

Financial Resources

SBIR Awards

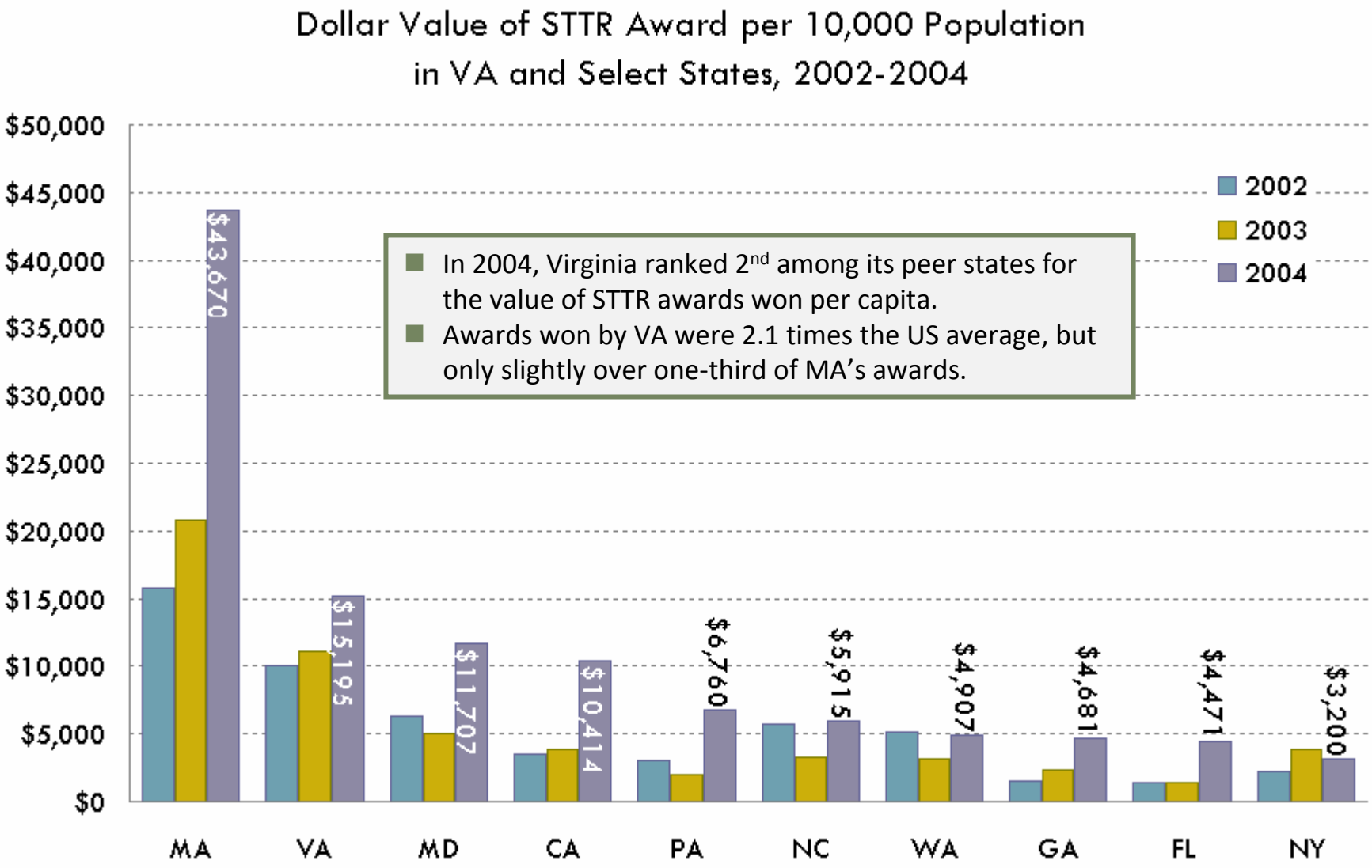


- In 2004, VA ranked 3rd among the benchmark states for the value of SBIR awards won per capita.
- Awards won by VA were 2.2 times the US average, but only slightly over one-third of MA's awards.

Source: US Small Business Administration

Financial Resources

STTR Awards



- In 2004, Virginia ranked 2nd among its peer states for the value of STTR awards won per capita.
- Awards won by VA were 2.1 times the US average, but only slightly over one-third of MA's awards.

Source: US Small Business Administration

Human Resources

Section III

Human Resources

Labor Force

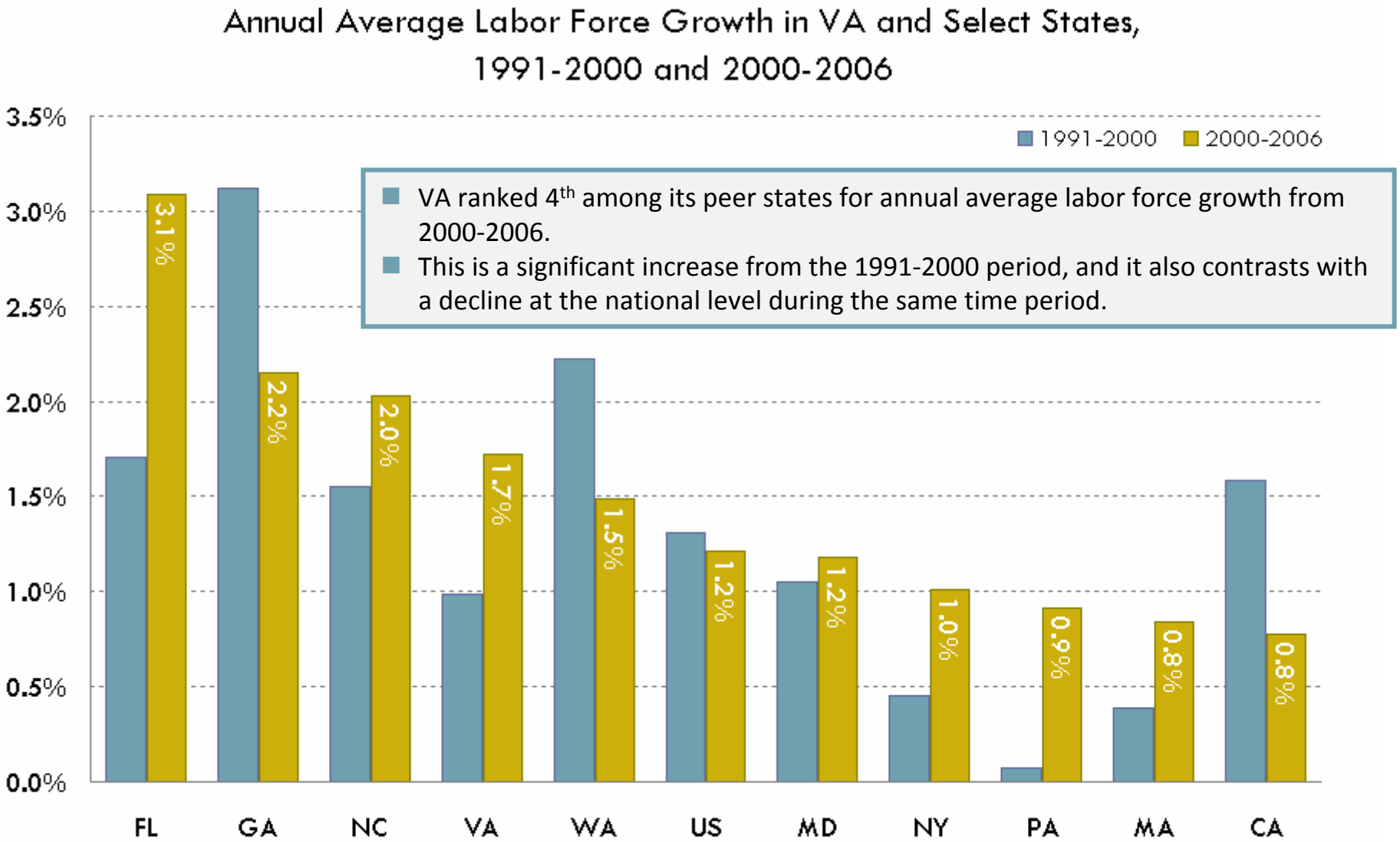
Category Significance: Knowledge-intensive, service sector industries are driving the US economy. With highly skilled labor as the key input in these industries, a state's competitiveness hinges first and foremost upon sufficient labor force growth—a function of both population growth and in-state migration. The educational level and skill set of the state's workforce is critical.

Virginia's Performance

- VA experienced solid labor force growth from 2000-2006.
- VA resembled the national average for population growth over this period.
- VA slightly lagged the national average for young adult population growth from 2004-2006.
- Since 2004, the largest contributor to labor force growth in Virginia has been international migration into the state.

Human Resources

Labor Force Growth

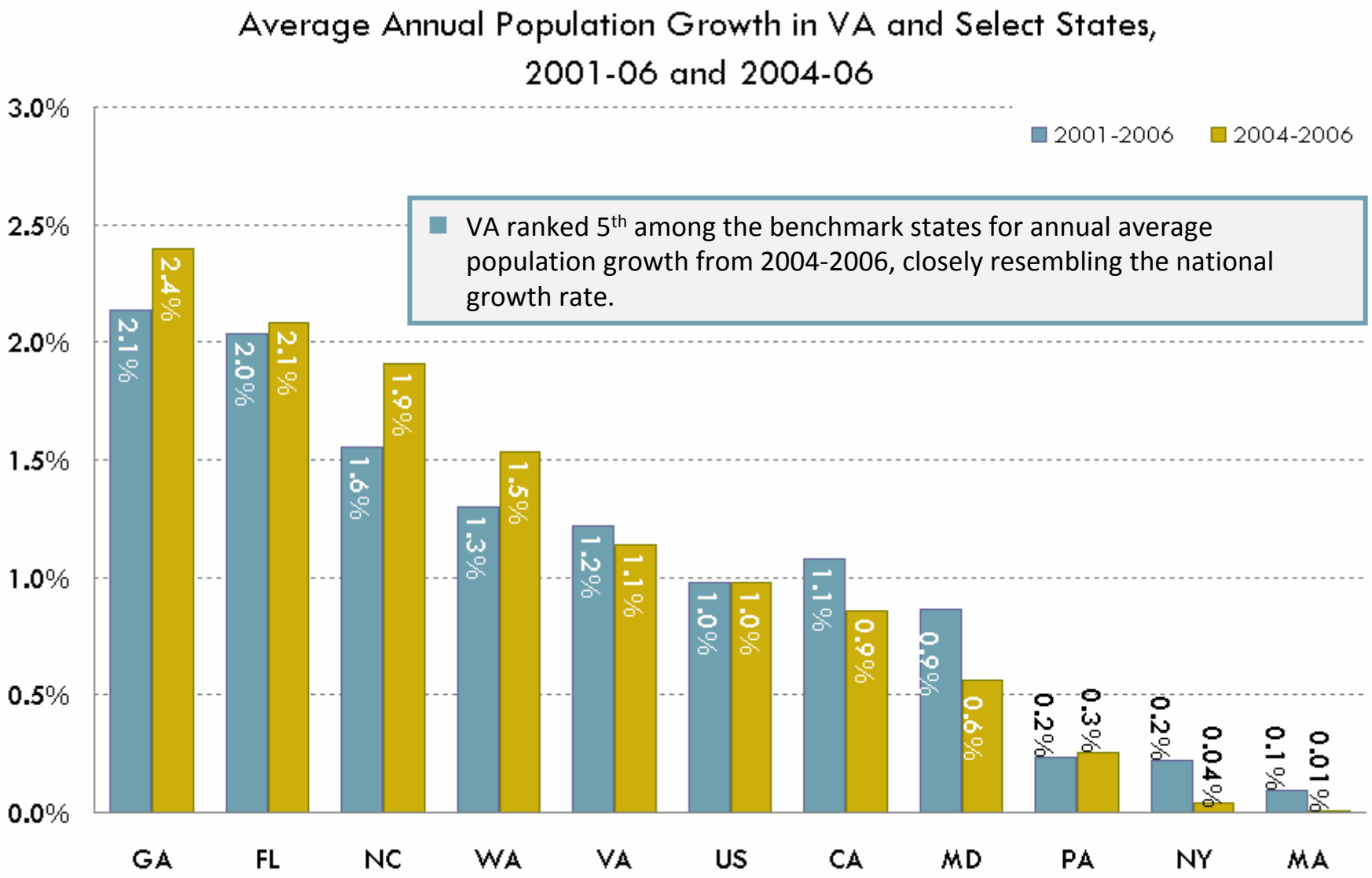


- VA ranked 4th among its peer states for annual average labor force growth from 2000-2006.
- This is a significant increase from the 1991-2000 period, and it also contrasts with a decline at the national level during the same time period.

Source: US Bureau of Labor Statistics

Human Resources

Population Growth



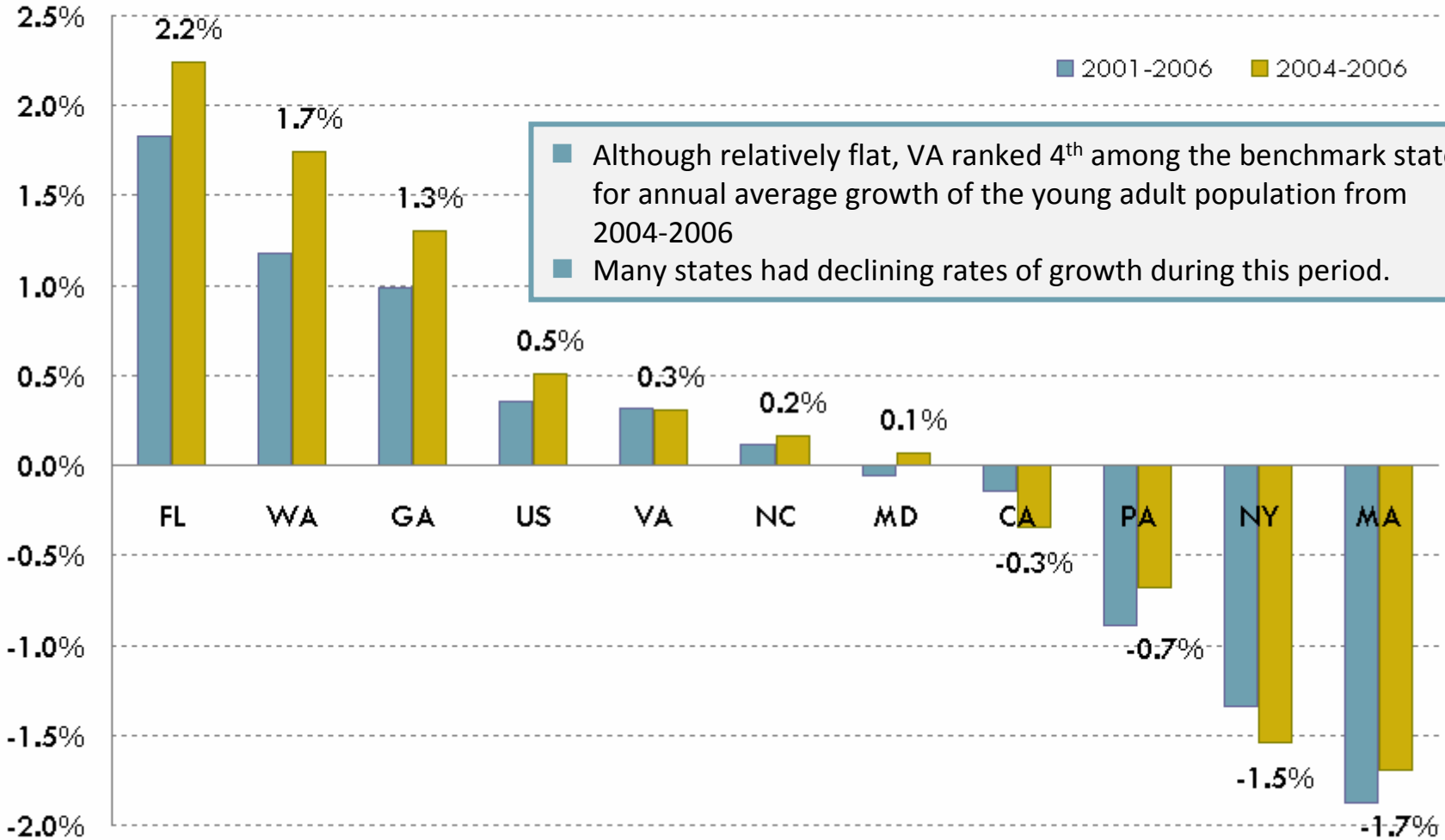
- VA ranked 5th among the benchmark states for annual average population growth from 2004-2006, closely resembling the national growth rate.

Source: US Census Bureau

Human Resources

Young Adults Growth

Annual Average Growth of Age 25-34 Population in VA and Select States, 2001-06 and 2004-06

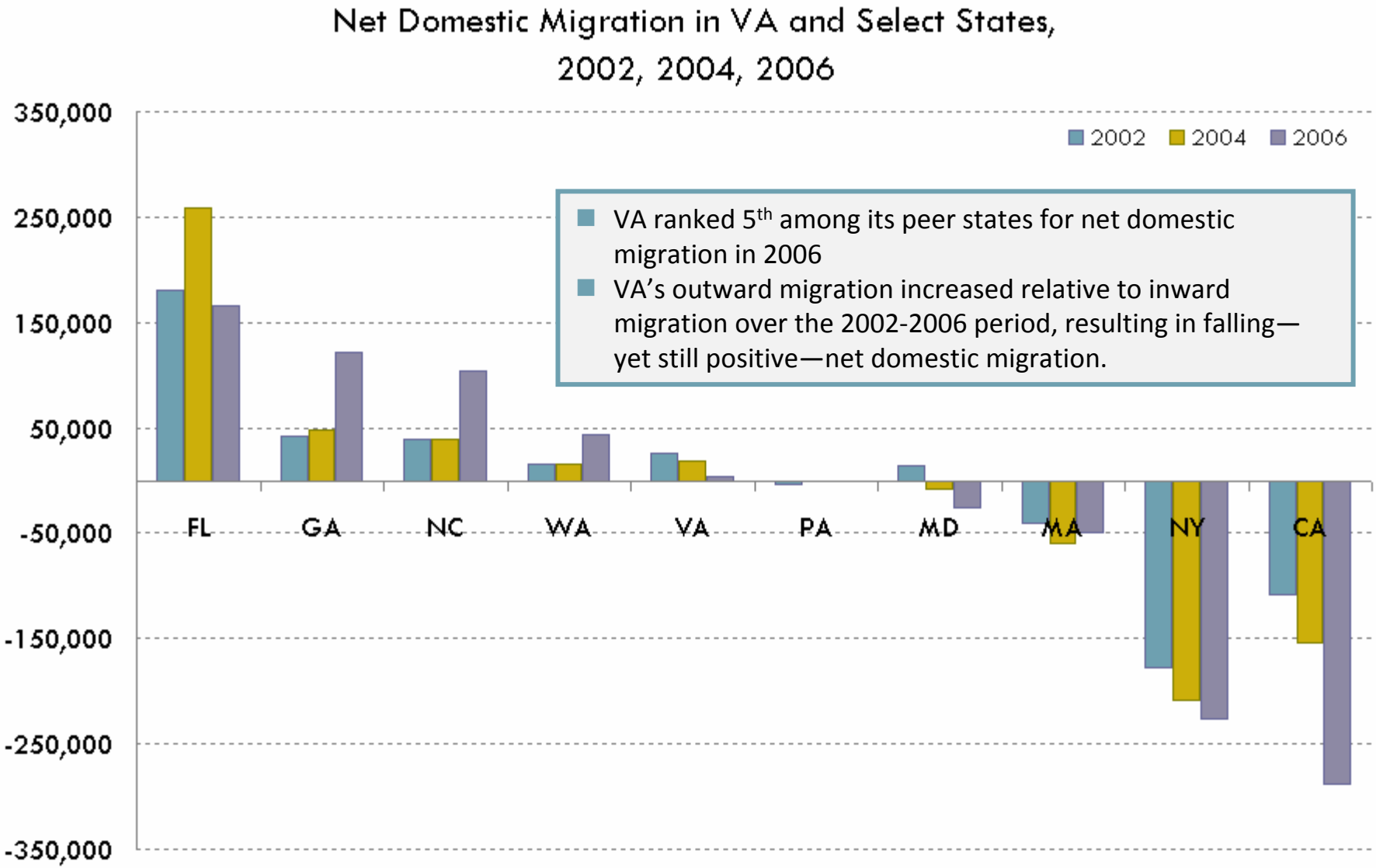


- Although relatively flat, VA ranked 4th among the benchmark states for annual average growth of the young adult population from 2004-2006
- Many states had declining rates of growth during this period.

Source: US Census Bureau

Human Resources

Domestic Migration

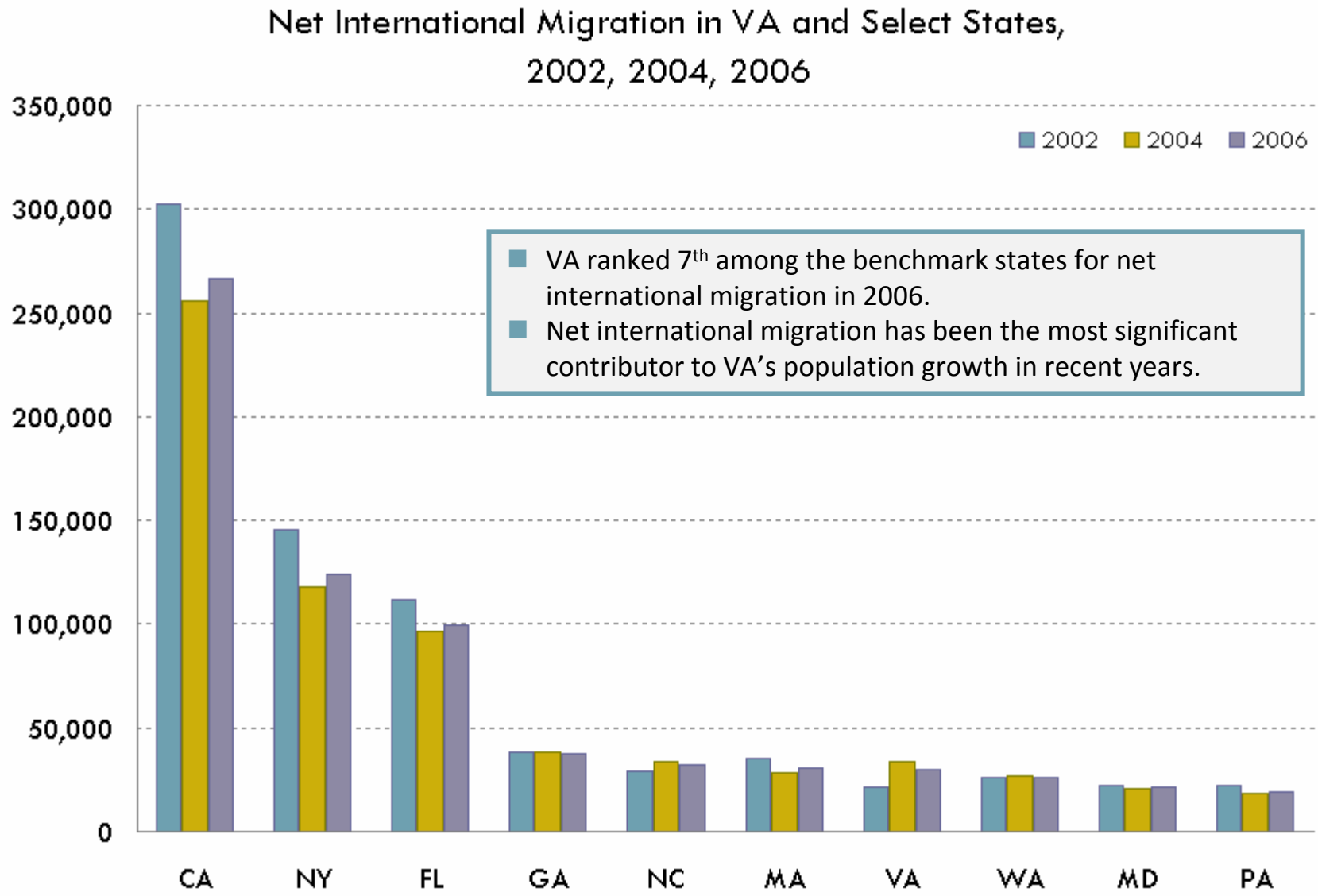


- VA ranked 5th among its peer states for net domestic migration in 2006
- VA's outward migration increased relative to inward migration over the 2002-2006 period, resulting in falling—yet still positive—net domestic migration.

Source: US Census Bureau

Human Resources

International Migration

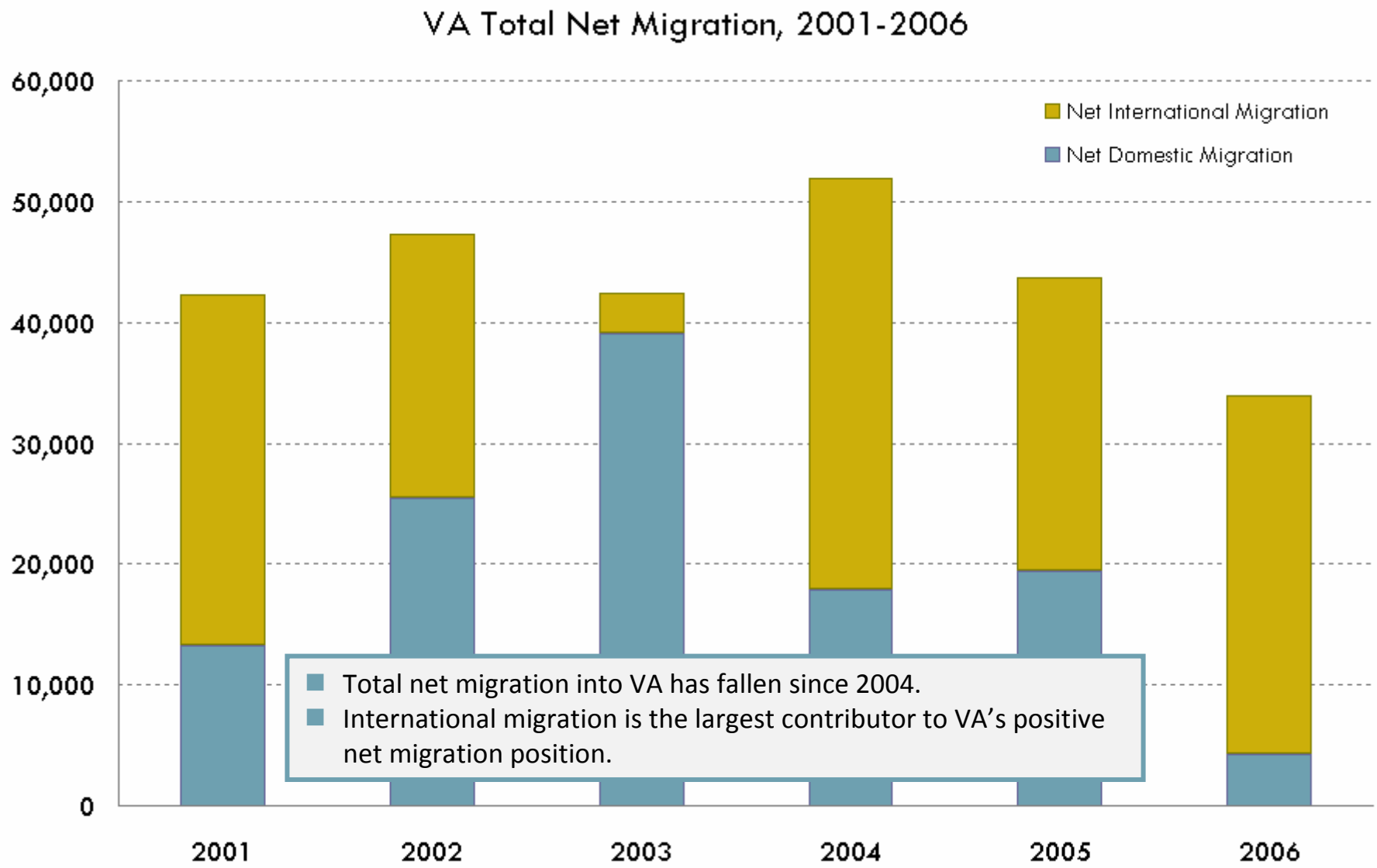


- VA ranked 7th among the benchmark states for net international migration in 2006.
- Net international migration has been the most significant contributor to VA's population growth in recent years.

Source: US Census Bureau

Human Resources

Total Migration



- Total net migration into VA has fallen since 2004.
- International migration is the largest contributor to VA's positive net migration position.

Source: US Census Bureau

Human Resources

Education

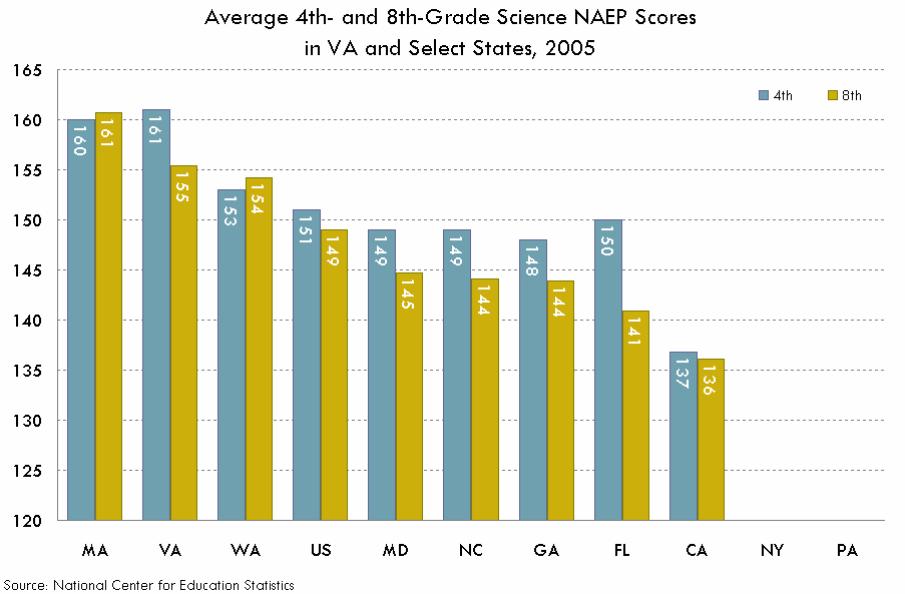
Category Significance: Several recent reports have highlighted the critical importance of the science, technology, engineering, and mathematics (STEM) workforce to maintaining industrial competitiveness in the United States. The STEM pipeline begins at pre-K and continues through the postgraduate level.

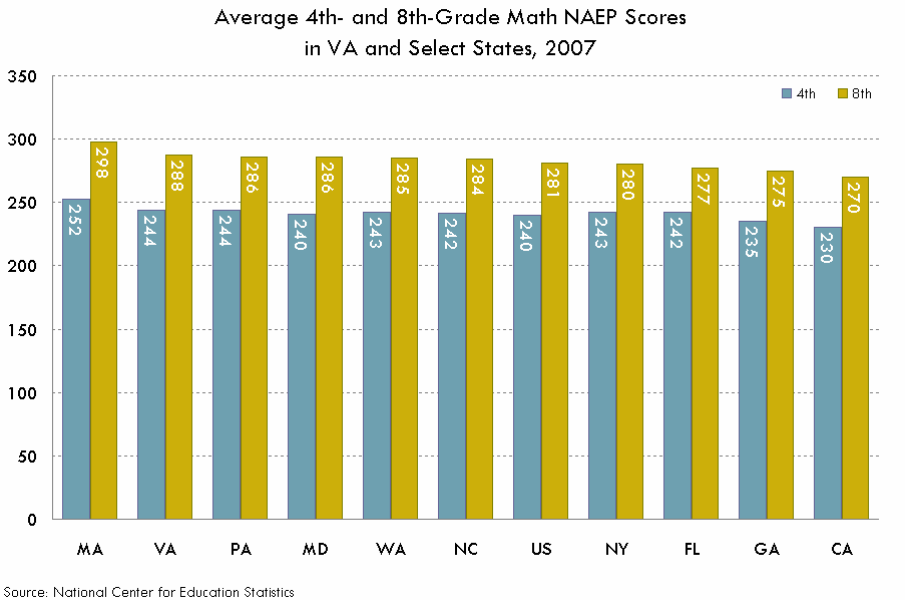
Virginia's Performance

- In 2005, VA ranked very highly for 4th and 8th grade NAEP science scores among the benchmark states. VA also ranked near the top for 4th and 8th grade NAEP math scores.
- VA students also ranked well against the national average and among peer states for the share of students taking and scoring highly on AP exams.
- In 2003, VA ranked highly for S&E degrees conferred as a share of all degrees conferred, but ranked closer to the national average in terms of advanced S&E degrees conferred.

Human Resources

NAEP Scores



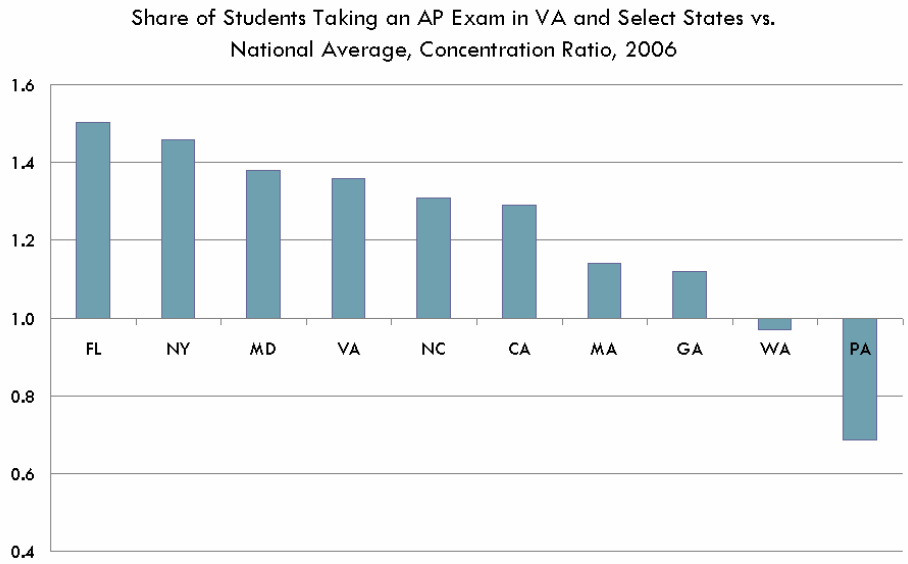


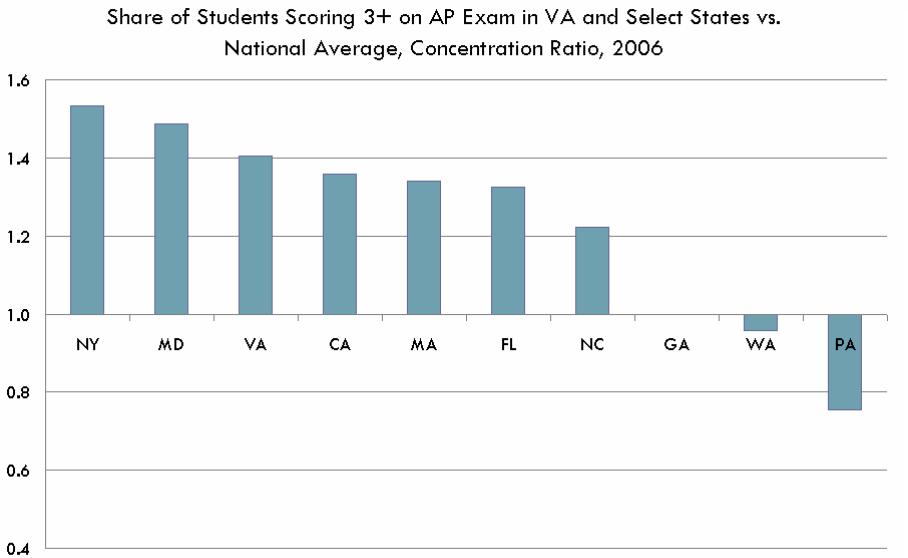
- The National Assessment of Education Progress (NAEP) measures student achievement in various subject areas over time and across the country. The test has been conducted for over 30 years.
- In 2005, VA ranked 1st for its 4th grade science scores and 2nd for its 8th grade science scores among this group of states.
- In 2007, VA's ranked 2nd for both 4th grade and 8th grade math scores among this group of states.

Human Resources

AP Scores

- Advanced Placement (AP) exams measure college-level learning in 37 subject areas. A score of 3 or higher (out of a possible grade of 1-5) typically earns students college credit and is a strong predictor of college success and graduation.
- Concentration ratios for VA and select states are presented. A concentration ratio greater than 1 indicates a higher share of students in VA taking AP tests and scoring well on these tests relative to the national average.
- Nearly all the benchmark states exceeded the national average. VA high school students ranked highly among the peer states for both the percentage of students taking these tests (4th) and for the percentage of VA students scoring 3 or higher on these tests (3rd).

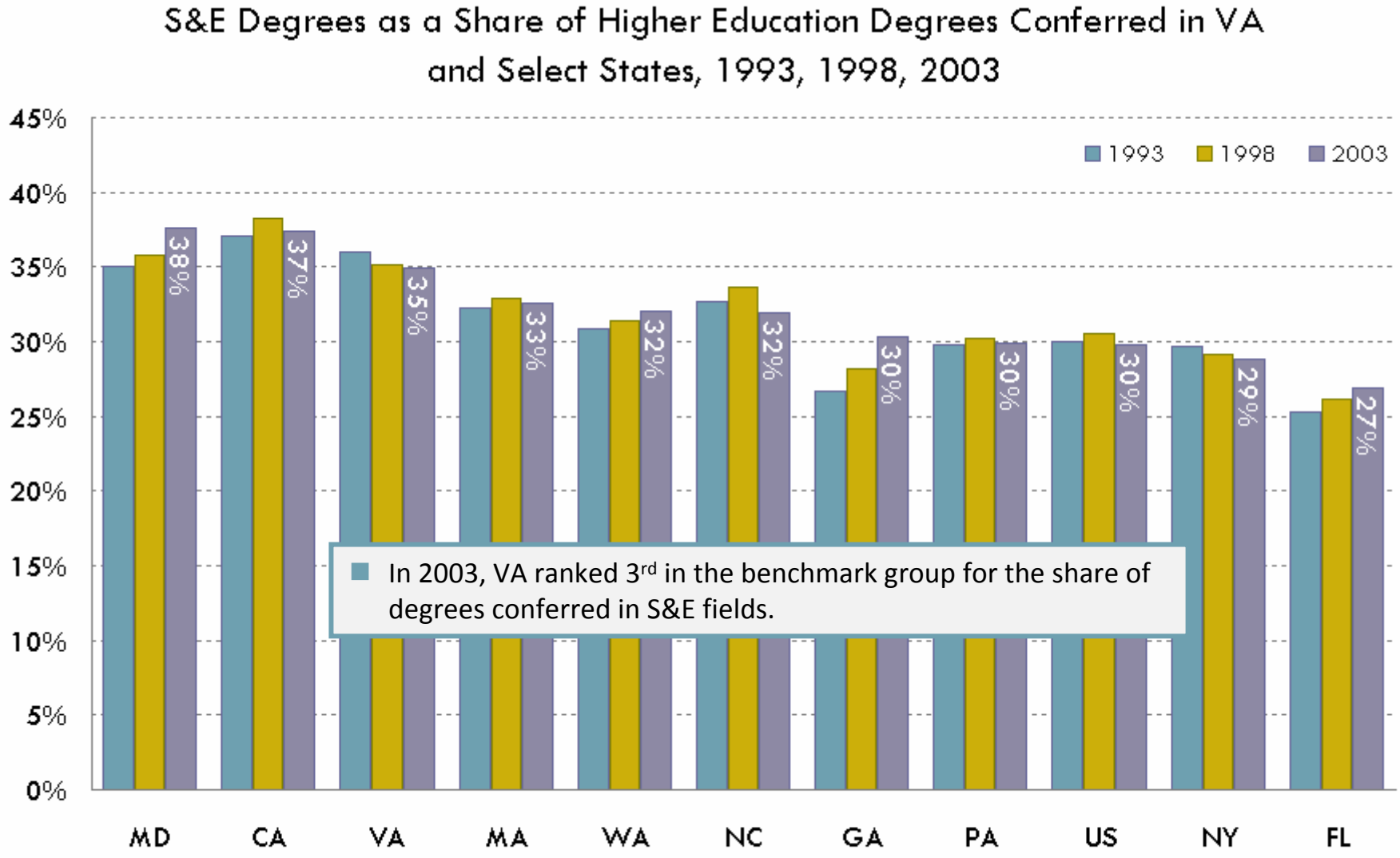




Source: The College Board

Human Resources

S&E Degrees

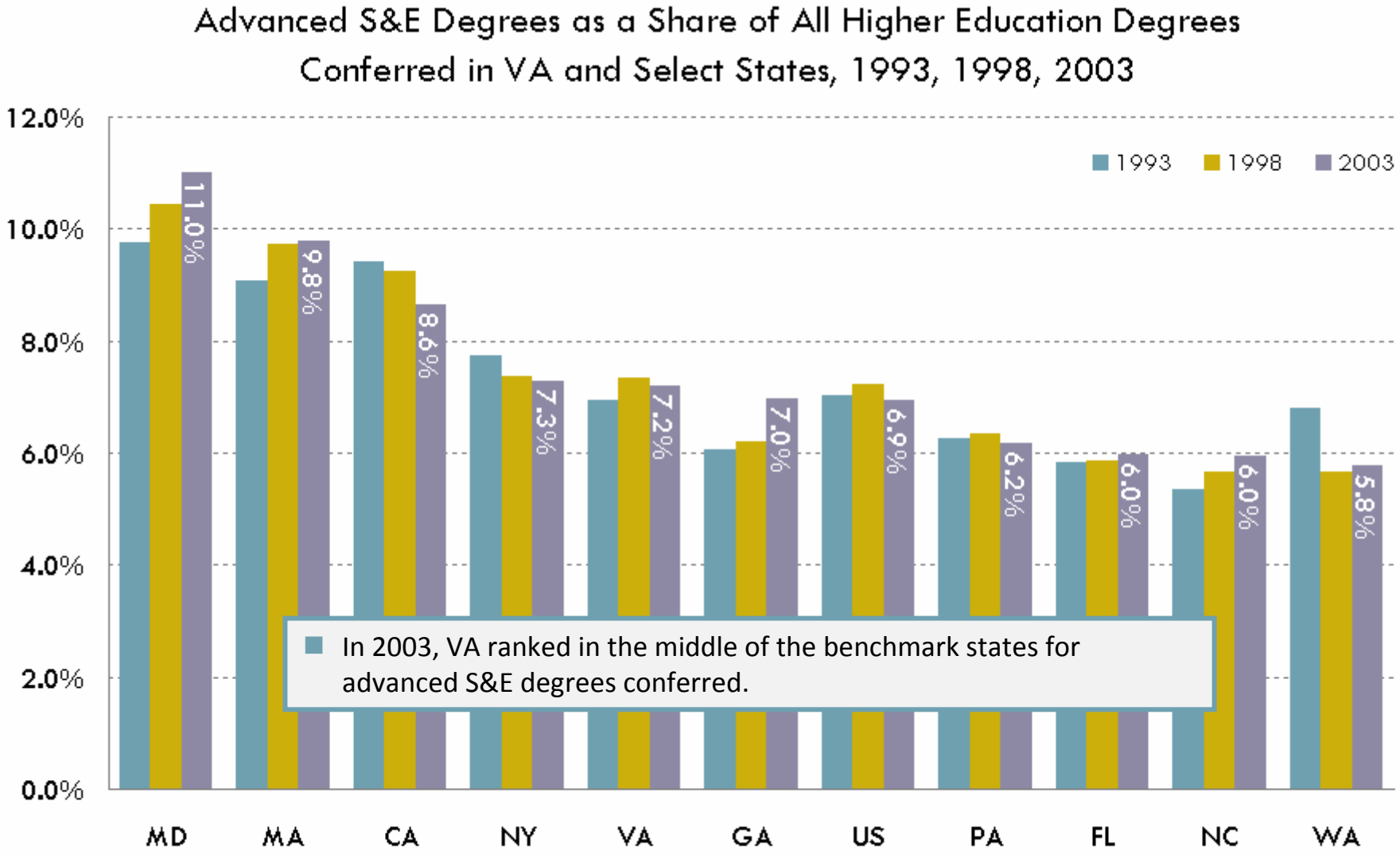


- In 2003, VA ranked 3rd in the benchmark group for the share of degrees conferred in S&E fields.

Note: S&E fields include physical, life, earth, ocean, atmospheric, computer, and social sciences; mathematics; engineering; and psychology.
Source: National Center for Education Statistics

Human Resources

Advanced S&E Degrees



- In 2003, VA ranked in the middle of the benchmark states for advanced S&E degrees conferred.

Note: Advanced S&E degrees include master's and doctoral degrees.

Source: National Center for Education Statistics

Innovation Resources

Section IV

Innovation Resources

R&D Expenditures

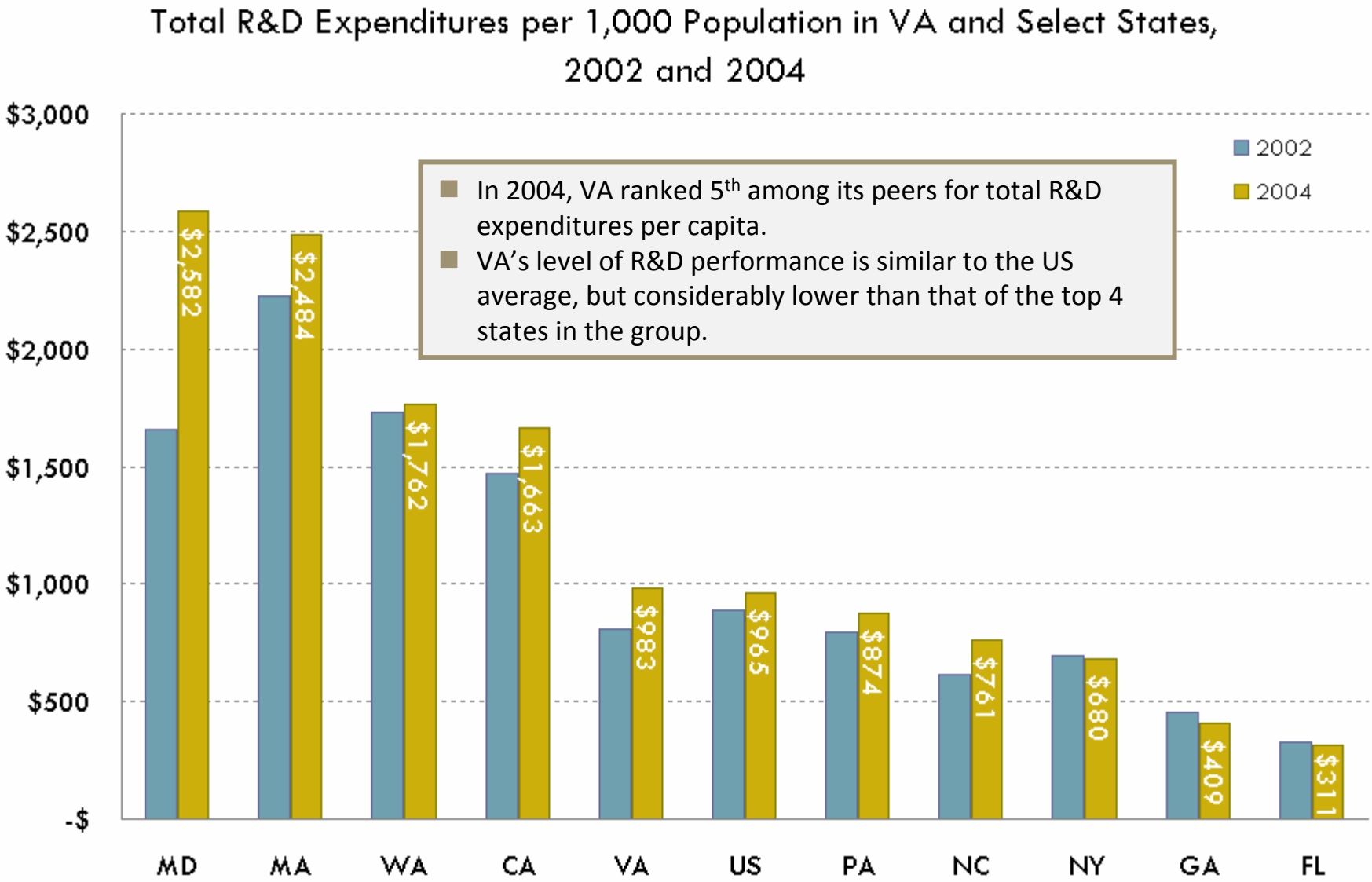
Category Significance: As manufacturing industries become increasingly technology-intensive, greater investments in basic and applied research and development (R&D) are required to develop new products and to improve existing products and production processes. As mentors of the future S&E workforce, universities can play a critical role in building R&D linkages with industry.

Virginia's Performance

- In 2004, VA's total R&D expenditures per capita mirrored the national average.
- VA ranked 7th among the benchmark states for industrial R&D performance in 2003—significantly lower than industrial R&D performance nationally. In addition, the Federal government was the source of a very high share of VA's industrial R&D funding (45%).
- VA ranked near the bottom of the group for academic R&D expenditures in 2005, but growth of academic R&D expenditures was very high (averaging 11% per year from 2000-2005).
- VA ranked highly (3rd)among its peers for federal R&D performance.

Innovation Resources

Total R&D per Capita



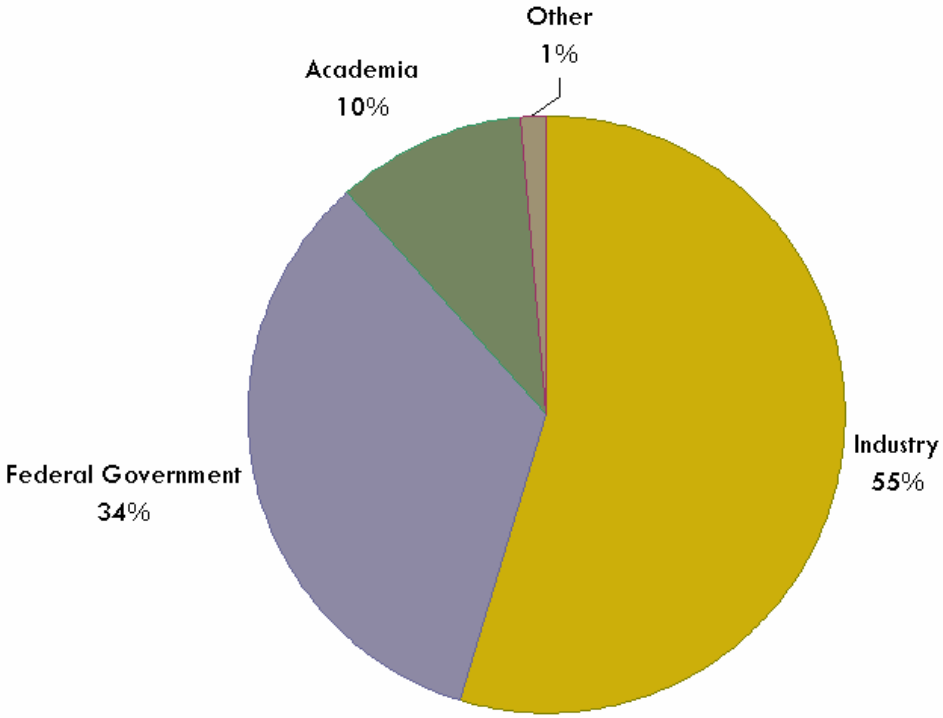
- In 2004, VA ranked 5th among its peers for total R&D expenditures per capita.
- VA's level of R&D performance is similar to the US average, but considerably lower than that of the top 4 states in the group.

Source: National Science Foundation and US Census Bureau

Innovation Resources

Total R&D per Capita

Breakdown of R&D Expenditures in VA by Peformer, 2003

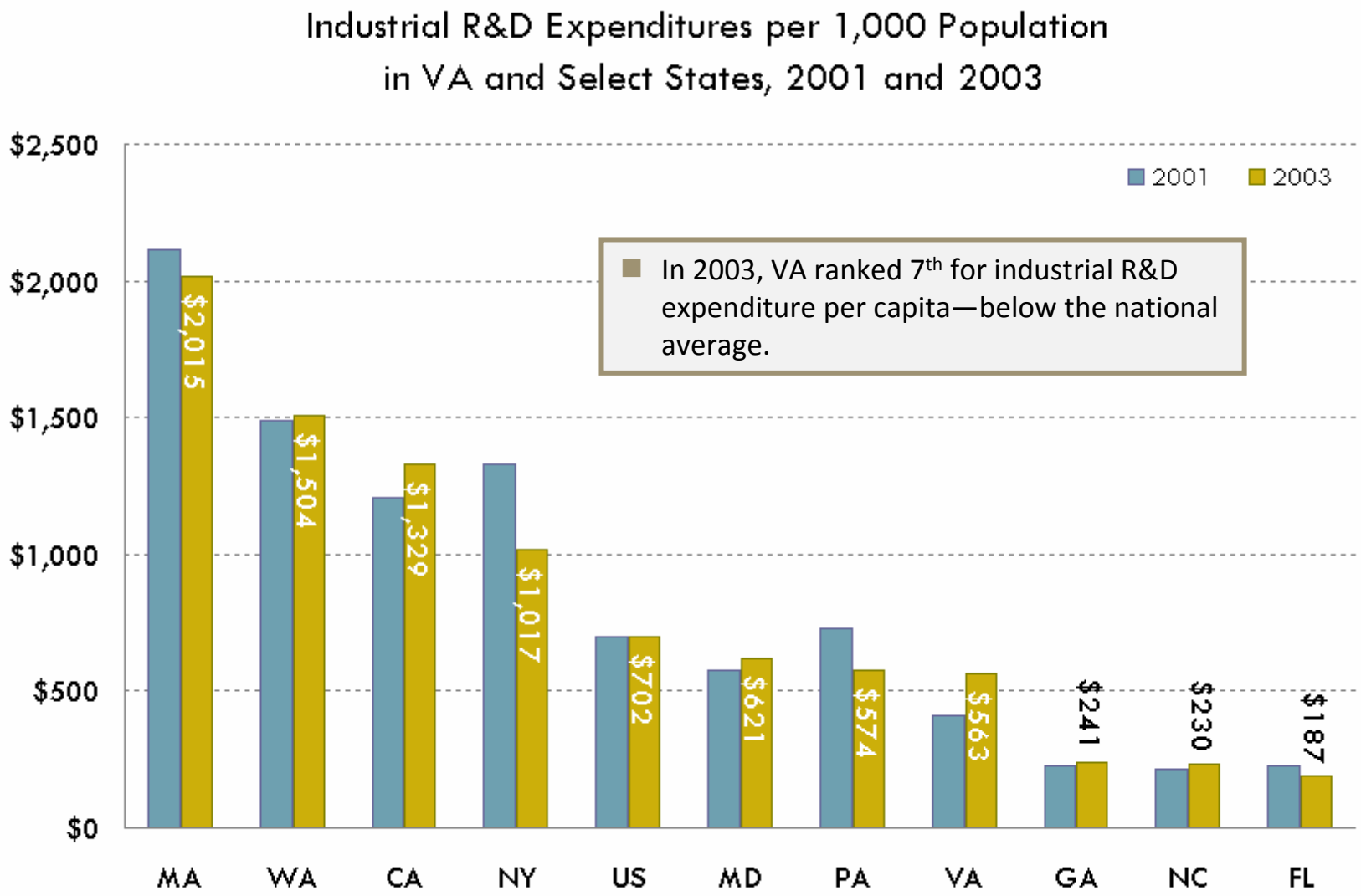


- In 2003, the largest share of VA's total R&D was performed by industry, followed by the federal government and academia.
- Nationally, industry and academia typically perform a greater share of R&D (70% and 14%), and the federal government a much smaller share (8%).

Note: Federal government R&D includes R&D performed by Federally Funded R&D Centers and Federal agencies. In VA, R&D peformed by Federal agencies account for the largest share of Federal government R&D.
Source: National Science Foundation

Innovation Resources

Industrial R&D per Capita



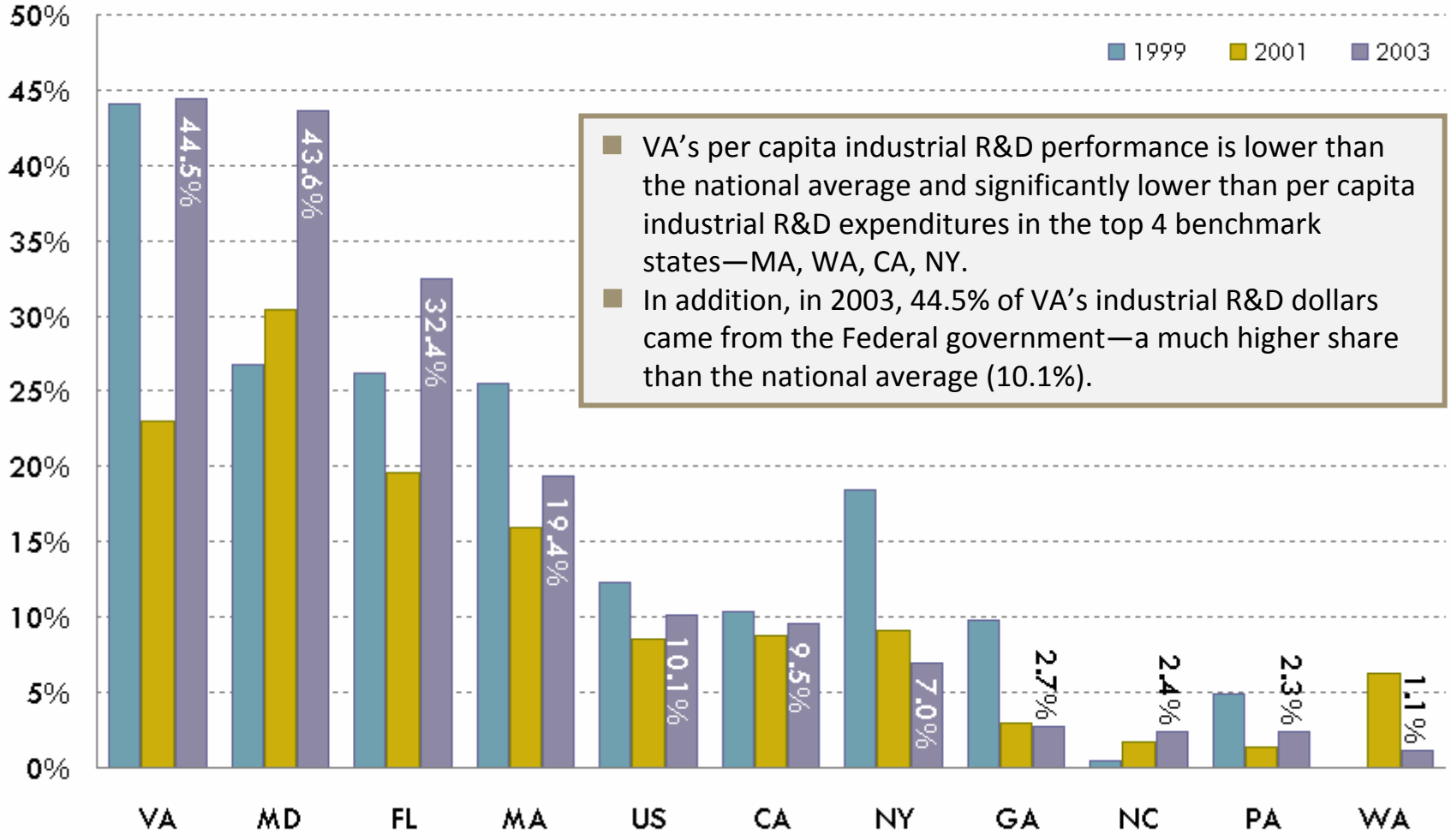
In 2003, VA ranked 7th for industrial R&D expenditure per capita—below the national average.

Source: National Science Foundation and US Census Bureau

Innovation Resources

Industrial R&D

Share of Industrial R&D Expenditures Coming from the Federal Government in VA and Select States, 1999, 2001, 2003

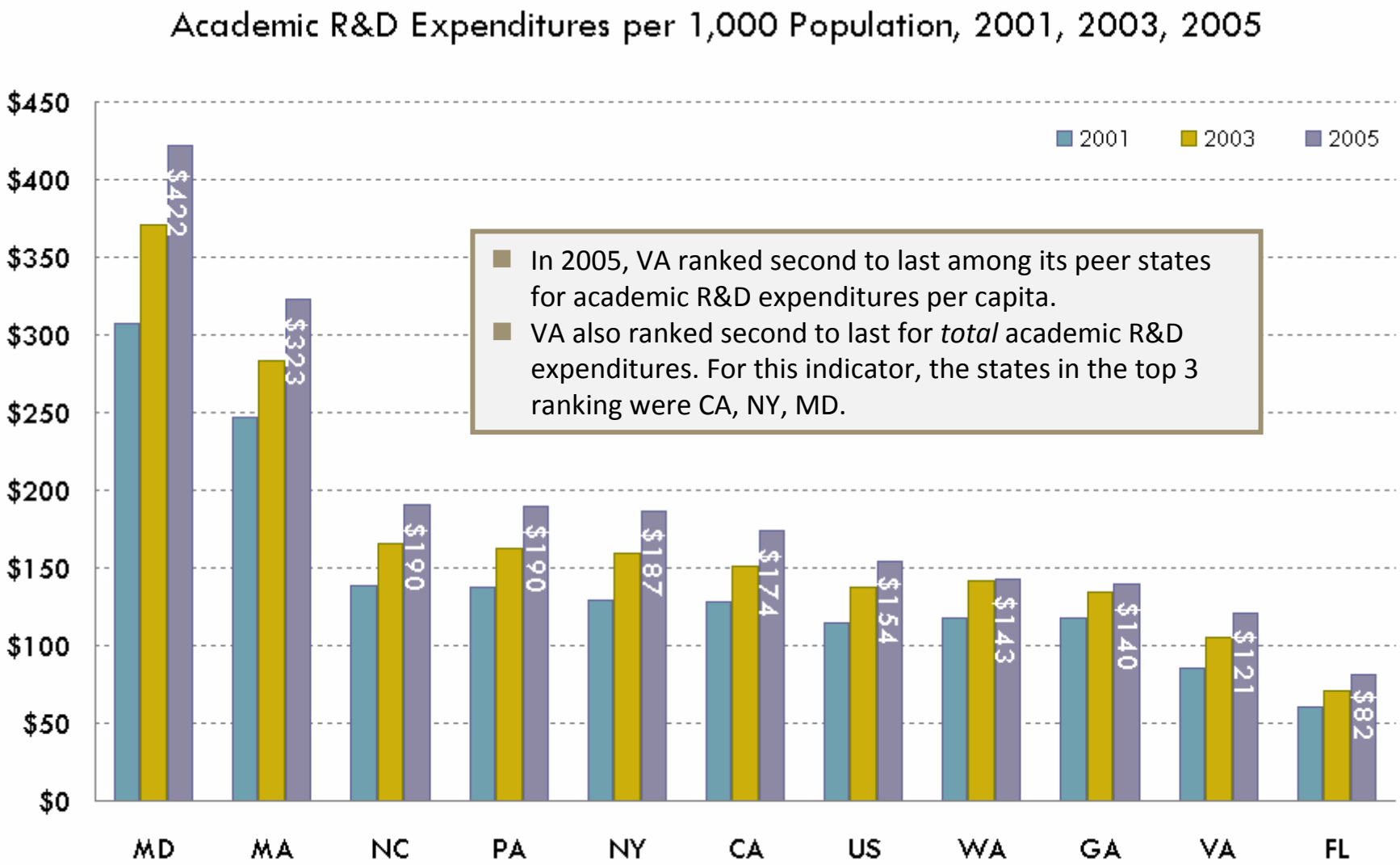


- VA's per capita industrial R&D performance is lower than the national average and significantly lower than per capita industrial R&D expenditures in the top 4 benchmark states—MA, WA, CA, NY.
- In addition, in 2003, 44.5% of VA's industrial R&D dollars came from the Federal government—a much higher share than the national average (10.1%).

Source: National Science Foundation

Innovation Resources

Academic R&D

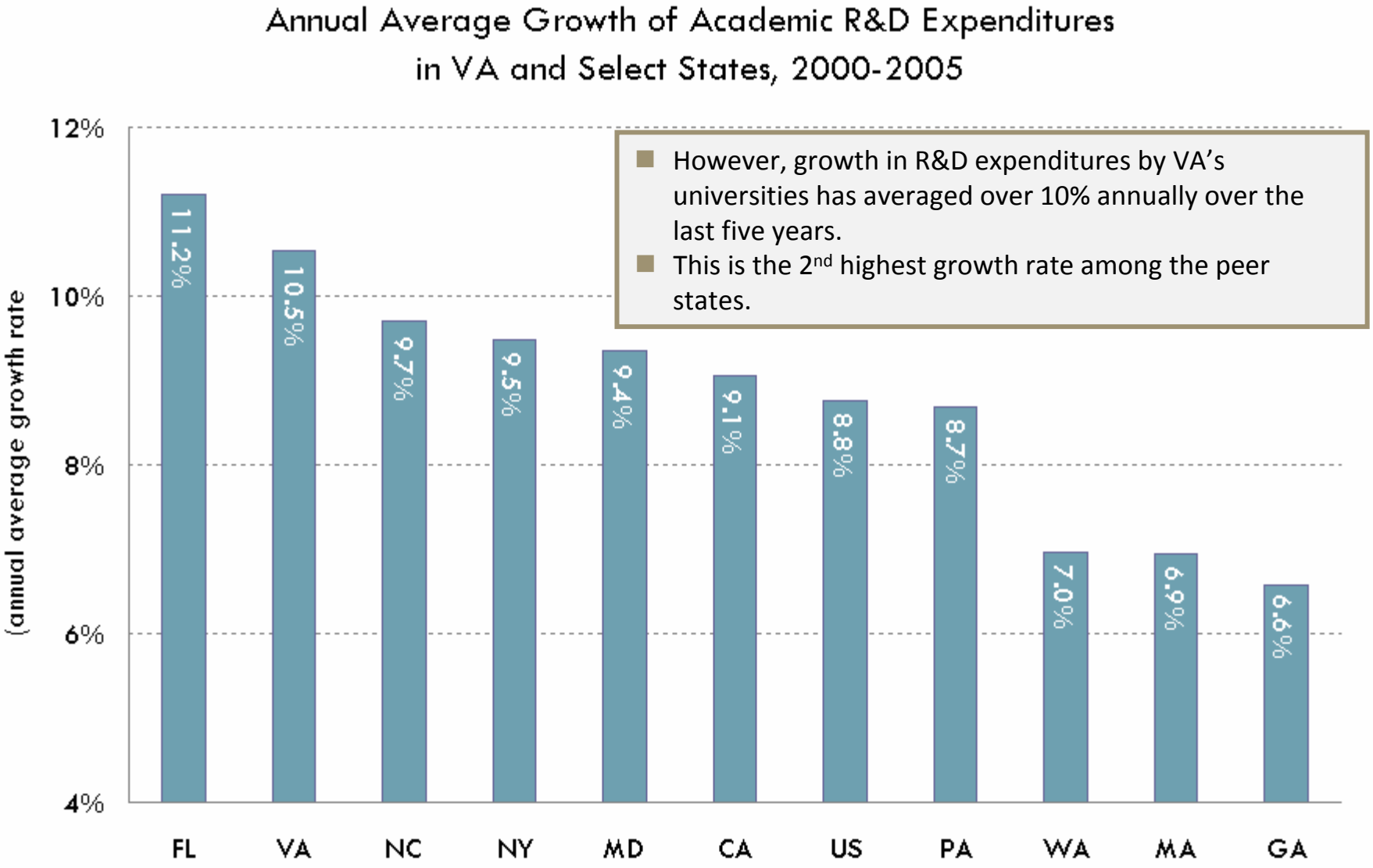


- In 2005, VA ranked second to last among its peer states for academic R&D expenditures per capita.
- VA also ranked second to last for *total* academic R&D expenditures. For this indicator, the states in the top 3 ranking were CA, NY, MD.

Source: National Science Foundation and US Census Bureau

Innovation Resources

Academic R&D

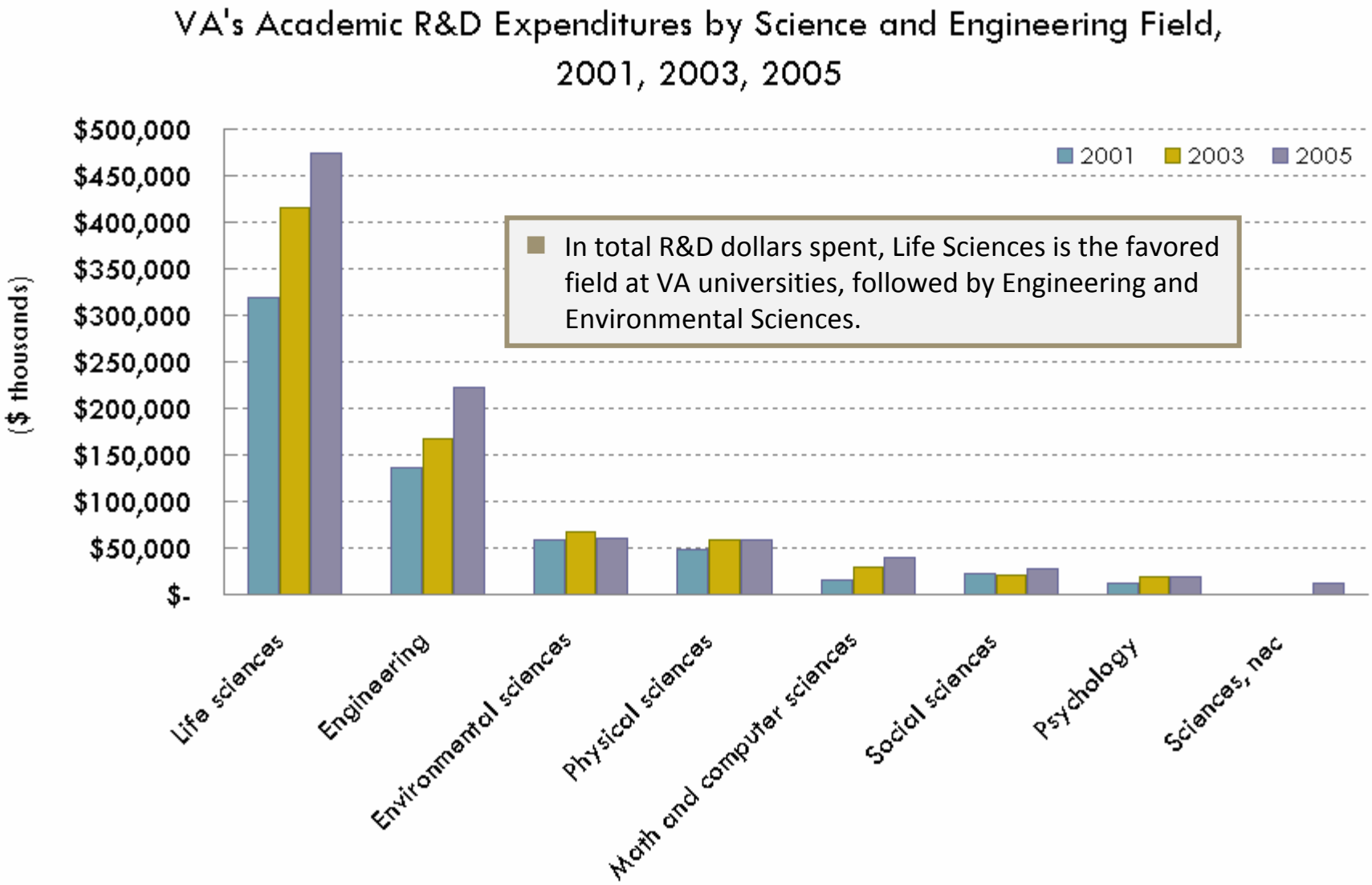


- However, growth in R&D expenditures by VA's universities has averaged over 10% annually over the last five years.
- This is the 2nd highest growth rate among the peer states.

Source: National Science Foundation

Innovation Resources

Academic R&D

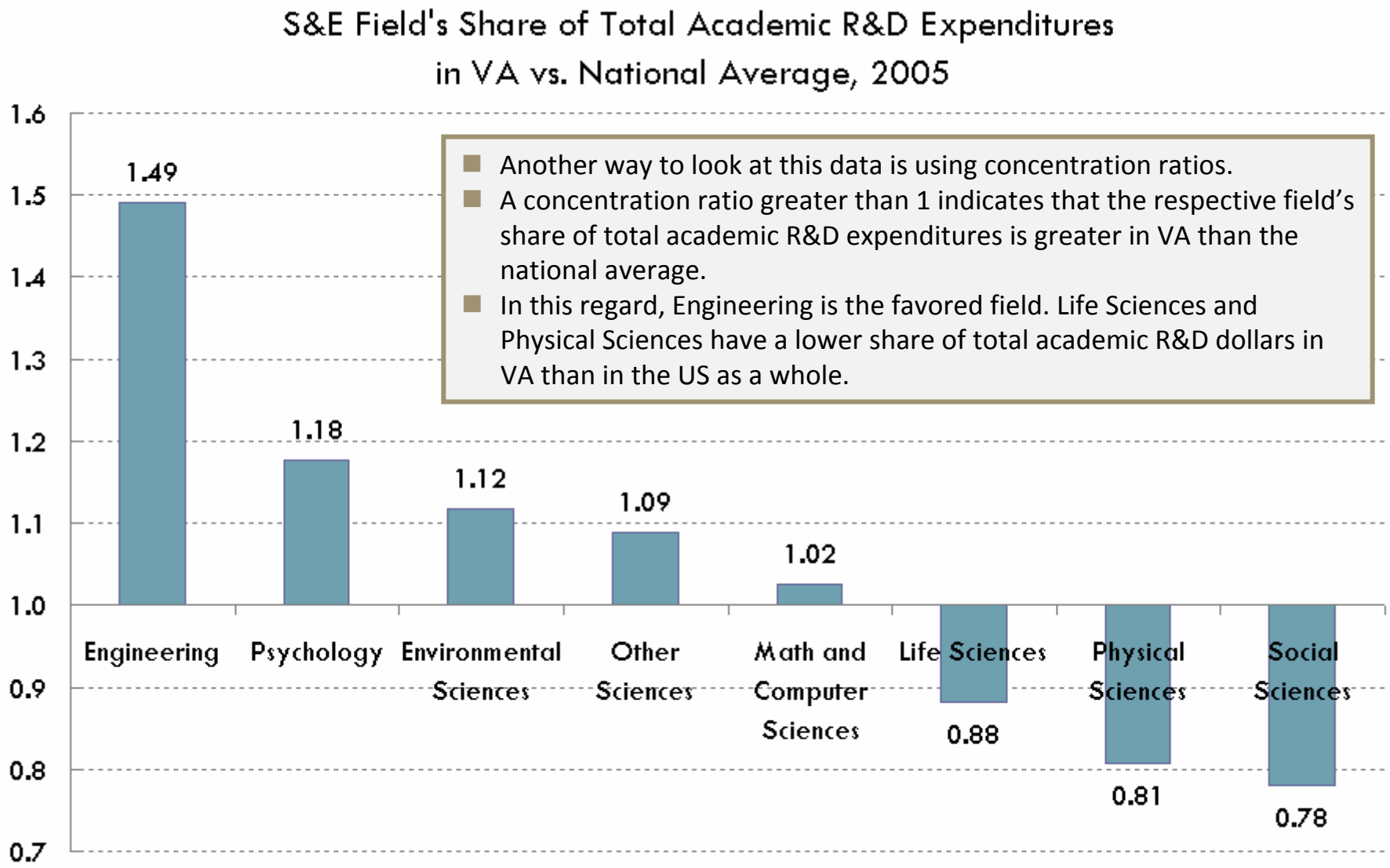


- In total R&D dollars spent, Life Sciences is the favored field at VA universities, followed by Engineering and Environmental Sciences.

Source: National Science Foundation

Innovation Resources

Academic R&D

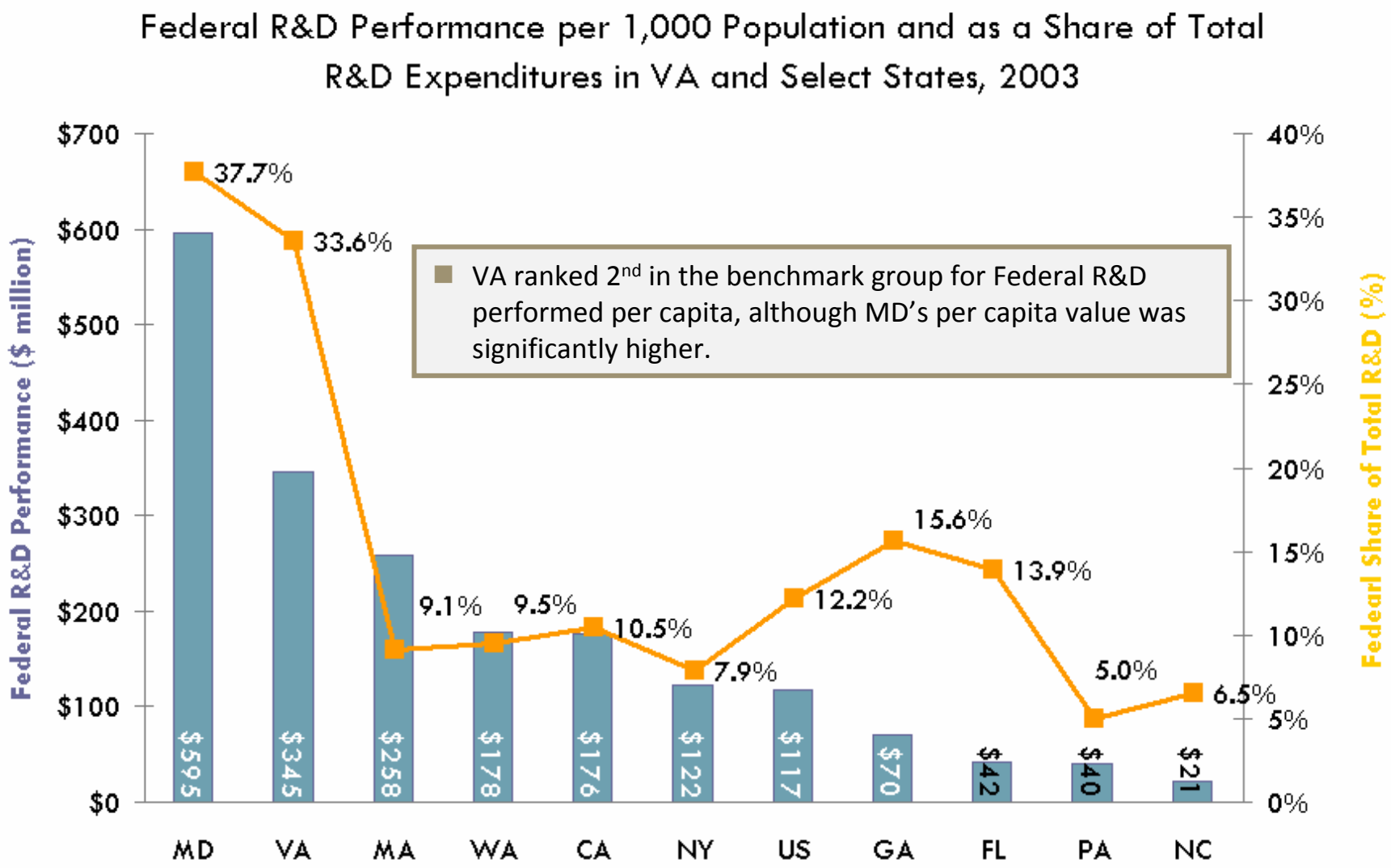


- Another way to look at this data is using concentration ratios.
- A concentration ratio greater than 1 indicates that the respective field's share of total academic R&D expenditures is greater in VA than the national average.
- In this regard, Engineering is the favored field. Life Sciences and Physical Sciences have a lower share of total academic R&D dollars in VA than in the US as a whole.

Source: National Science Foundation

Innovation Resources

Federal R&D per Capita



Source: National Science Foundation and US Census Bureau

Innovation Resources

Research Outputs

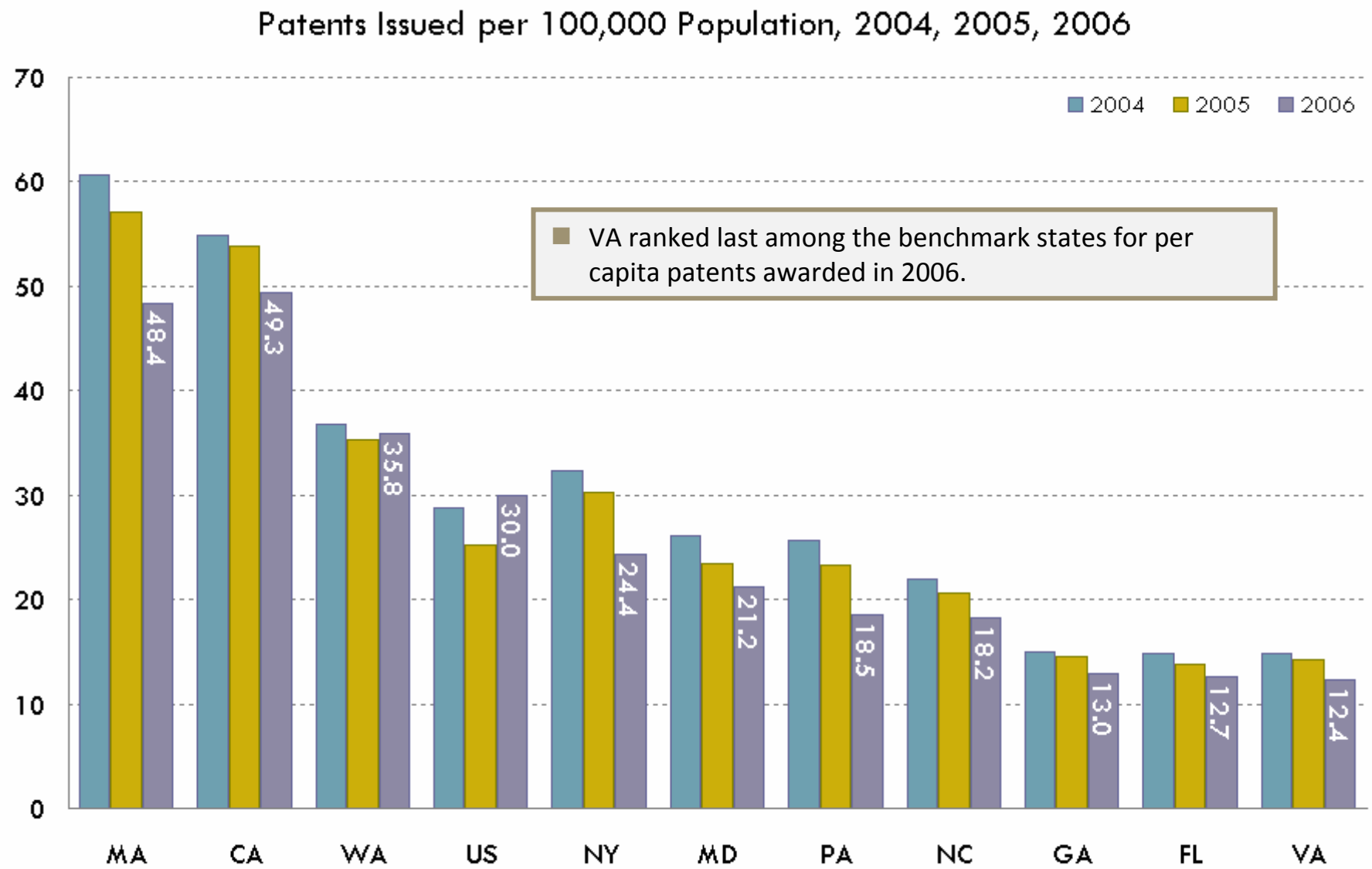
Category Significance: What is the return on a company's or a government's investment in R&D? Research outputs include patents, publications, and trained scientists and engineers. Other R&D outputs that are increasingly being tracked are commercializable products and technology-based startups. As in other enterprises, R&D productivity (e.g., $ spent per patent) is one measure of return, as are economic impacts (e.g., number of tech-based start-ups and VC attracted).

Virginia's Performance

- In terms of research outputs, VA ranked last among benchmark states for patents per capita and 7th for publications per capita in 2006.
- During the 2002-2006, only one VA company won FDA approval for a biologic therapeutic.
- Looking at R&D productivity, for the period 1996-2005, VA ranked at the top of the benchmark group in average R&D expenditures per start-up. However, VA's startups might have been less R&D-intensive than in other states, e.g., VA may have had more IT services and diagnostic start-ups than pharmaceutical or biotechnology start-ups.
- VA ranked 7th in academic R&D expenditures per publication for the 2002-2006 period.

Innovation Resources

Patents per Capita



- VA ranked last among the benchmark states for per capita patents awarded in 2006.

Source: US Patent & Trademark Office and US Census Bureau

Innovation Resources

Patenting Organizations

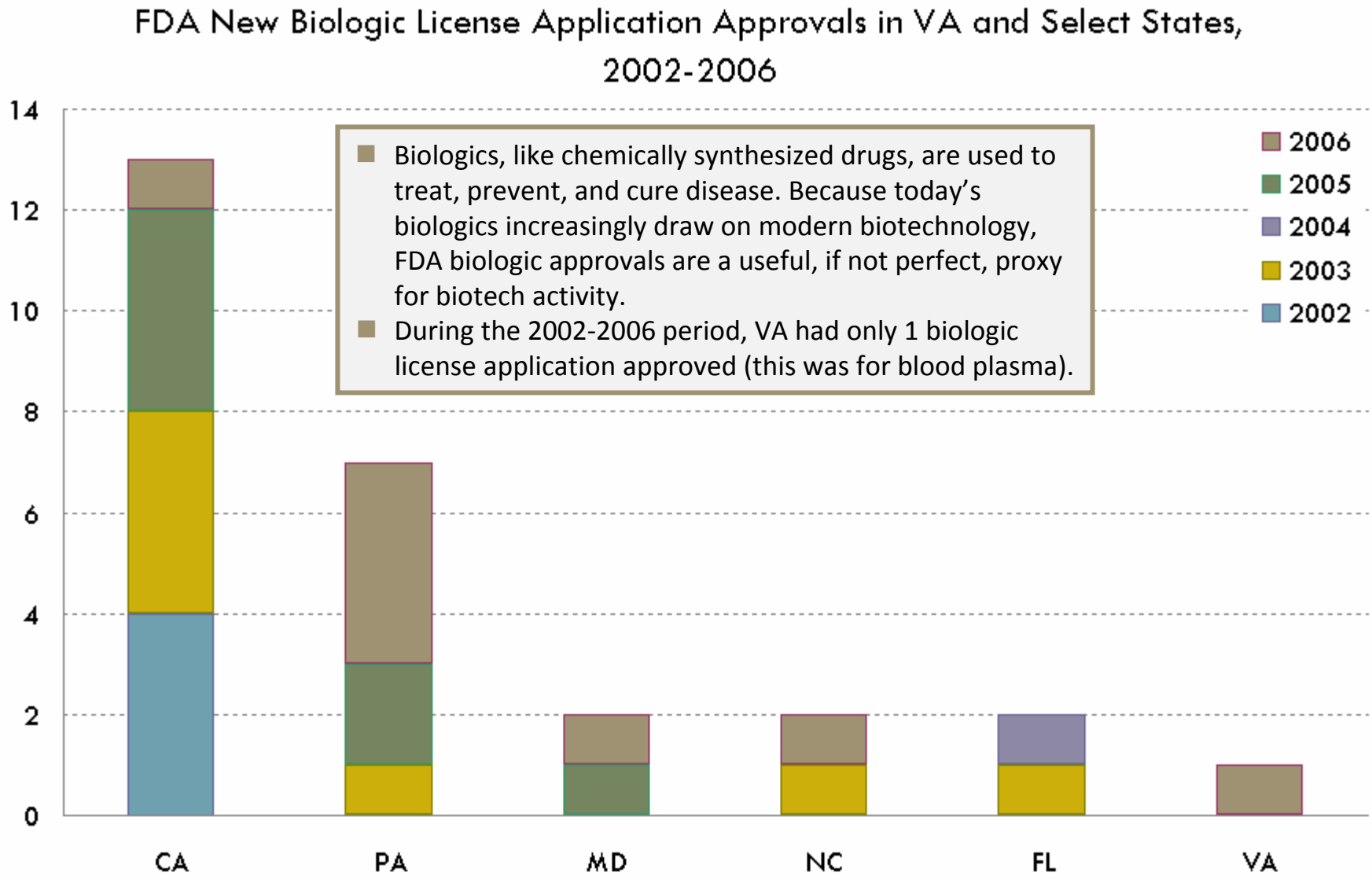
VA's Leading Patenting Organizations, 2001-2005

Rank	Organization	# of patents	Rank	Organization	# of patents
1	Individually Owned Patents	1,344	15	Siemens VDO Automotive Corp	41
2	US Navy	315	16	US Army	39
3	Siemens Automotive Corp	178	17	CISCO Technology Inc	38
4	Philip Morris Inc	71	18	Samsung Electronics Inc	38
5	BAE Systems Information	58	19	Hubbell Inc	37
6	Hamilton Beach/Proctor-Silex Inc	56	20	Virginia Commonwealth University	32
7	University of Virginia	56	21	Northrop Grumman Corp	31
8	ITT Manufacturing Enterprises Inc	56	22	Southeastern Universities Research Association	31
9	E.I. Du Pont de Nemours & Company	55			
10	Shipley Company Inc	54			
11	IBM Corp	51			
12	Ericsson Inc	45			
13	Lockheed Martin Inc	44			
14	Virginia Tech	42			

Source: US Patent & Trademark Office

Innovation Resources

Biologic Licenses

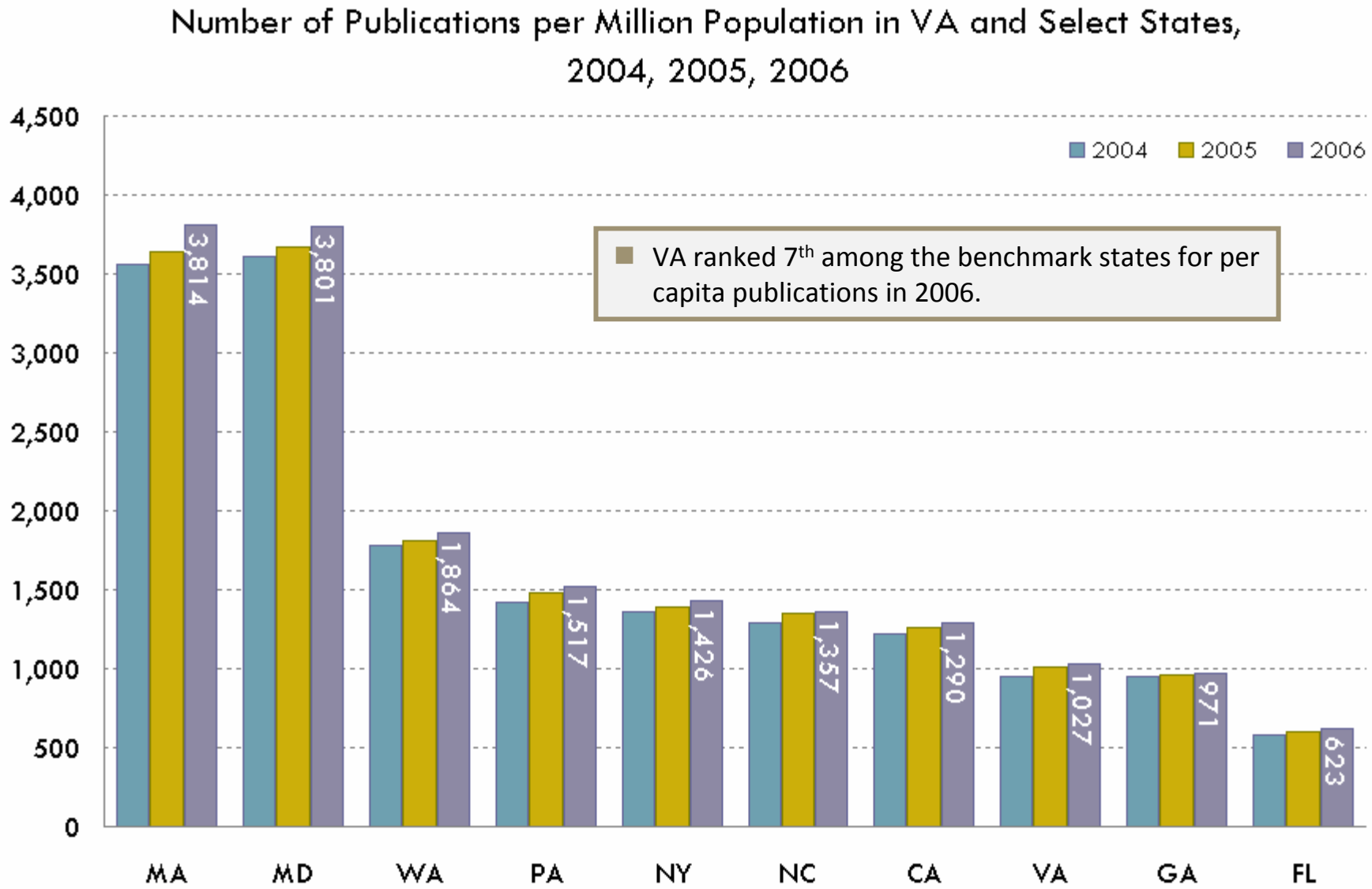


- Biologics, like chemically synthesized drugs, are used to treat, prevent, and cure disease. Because today's biologics increasingly draw on modern biotechnology, FDA biologic approvals are a useful, if not perfect, proxy for biotech activity.
- During the 2002-2006 period, VA had only 1 biologic license application approved (this was for blood plasma).

Source: US Food & Drug Administration

Innovation Resources

Publications per Capita



- VA ranked 7th among the benchmark states for per capita publications in 2006.

Source: ISI Web of Science and US Census Bureau

Note: Includes publications in all fields, by a wide variety of organizations, universities, and individuals in the state.

Innovation Resources

Publishing Organizations

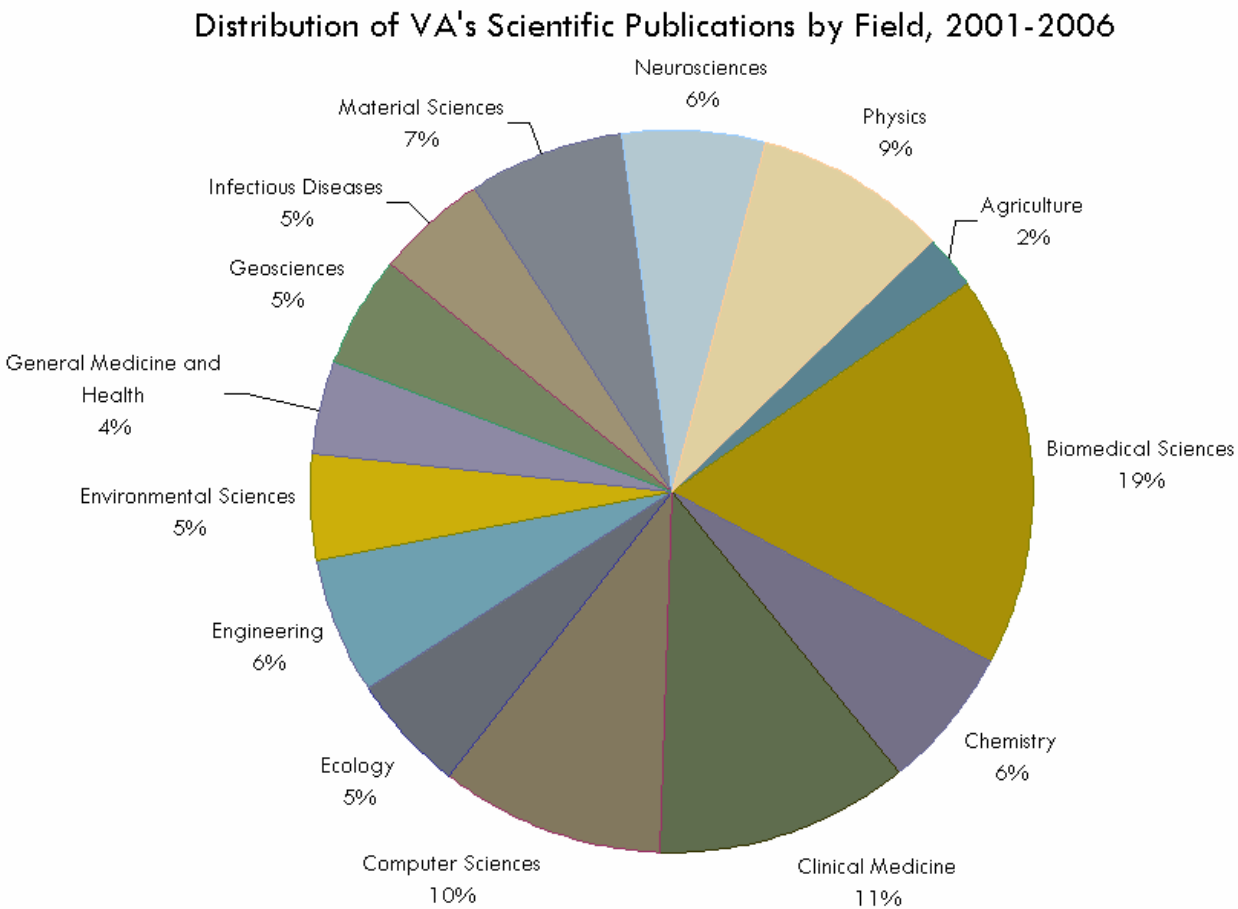
VA's Leading Publishing Organizations, 2001-2005

Rank	Organization	# of publications	Rank	Organization	# of publications
1	University of Virginia	9,475	15	James Madison University	320
2	Virginia Tech	7,378	16	US Department of Agriculture	315
3	Virginia Commonwealth University	4,944	17	National Science Foundation	282
4	NASA	2,071	18	McGuire Dept of Veteran Affairs Medical Center	277
5	George Mason University	1,783	19	Virginia Institute of Marine Science	266
6	College of William & Mary	1,479	20	US Air Force	248
7	Old Dominion University	1,288	21	University of Richmond	221
8	US Navy	1,132	22	Norfolk State University	207
9	Eastern Virginia Medical School	920	23	US Environmental Protection Agency	180
10	University of Virginia Health System	822	24	Inova Fairfax Hospital	172
11	Thomas Jefferson National Accelerator Facility	793	25	Philip Morris Inc	159
12	US Geological Survey	630			
13	Hampton University	396			
14	Science Applications Intl Corp (SAIC)	370			

Source: ISI Web of Science

Innovation Resources

Scientific Publications

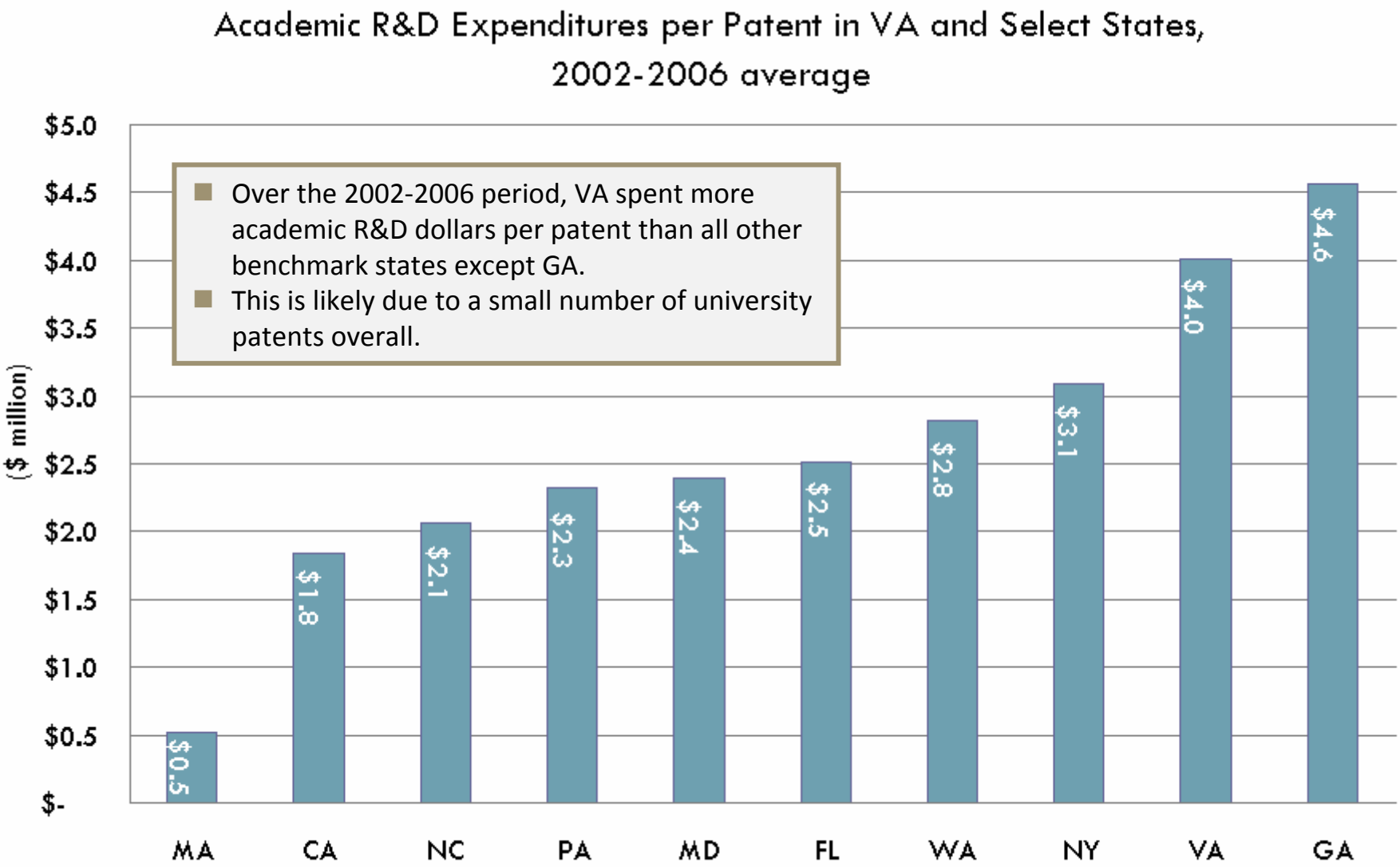


Source: ISI Web of Science

- Similar to the national trend, VA publications are heavily weighted towards the medical and life sciences (45%).
- There is also significant activity in:
  - Material sciences and chemistry (13%)
  - Environmental and ecological sciences (10%), and
  - Computer sciences (10%).

Innovation Resources

R&D Productivity



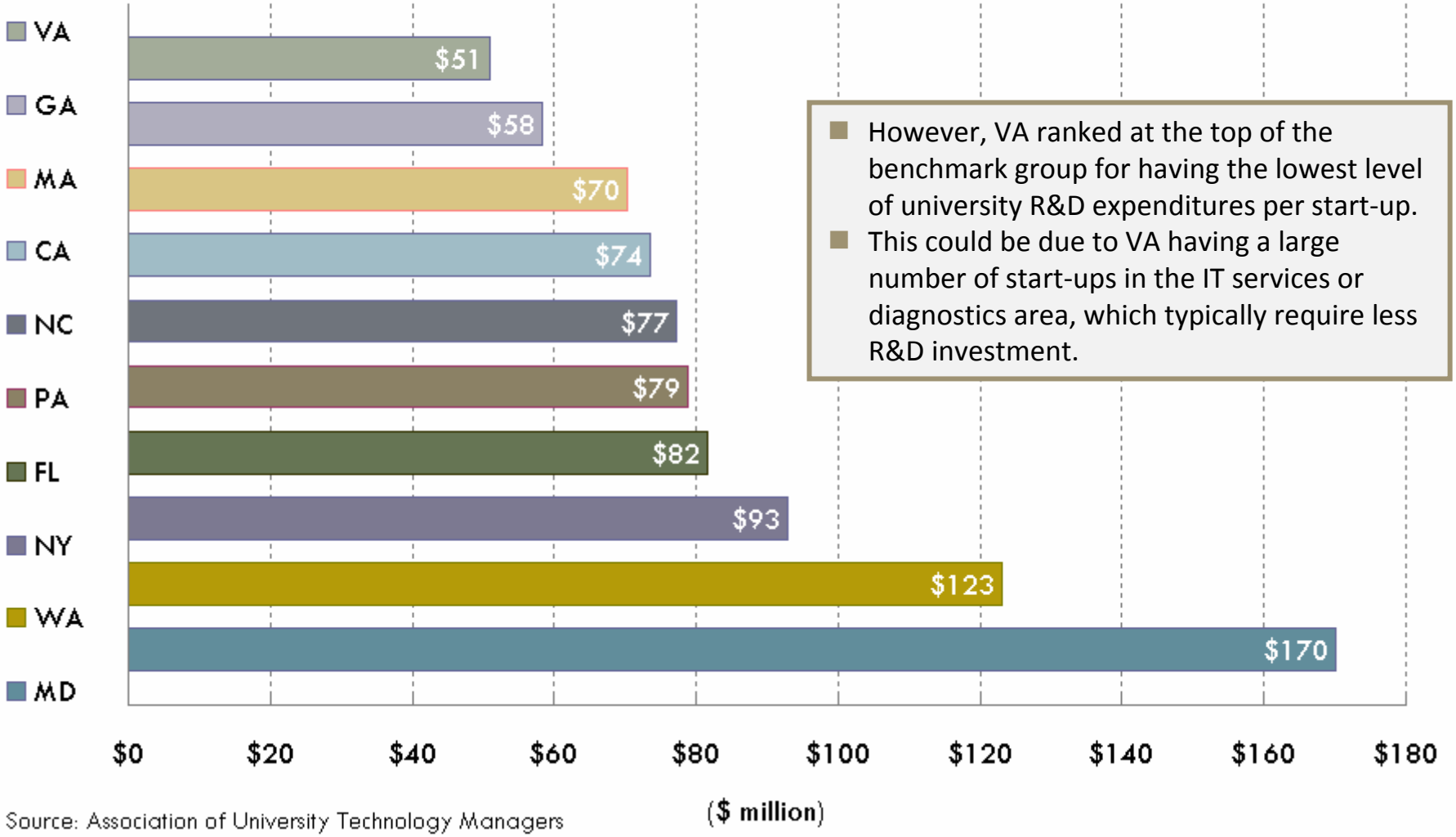
- Over the 2002-2006 period, VA spent more academic R&D dollars per patent than all other benchmark states except GA.
- This is likely due to a small number of university patents overall.

Source: National Science Foundation and US Patent & Trademark Office

Innovation Resources

R&D Productivity

University R&D Expenditures per Start-Up
in VA and Select States, 1996-2005 average



- However, VA ranked at the top of the benchmark group for having the lowest level of university R&D expenditures per start-up.
- This could be due to VA having a large number of start-ups in the IT services or diagnostics area, which typically require less R&D investment.

Source: Association of University Technology Managers

Innovation Economy Outcomes

Section V

Innovation Economy Outcomes

Economic Performance

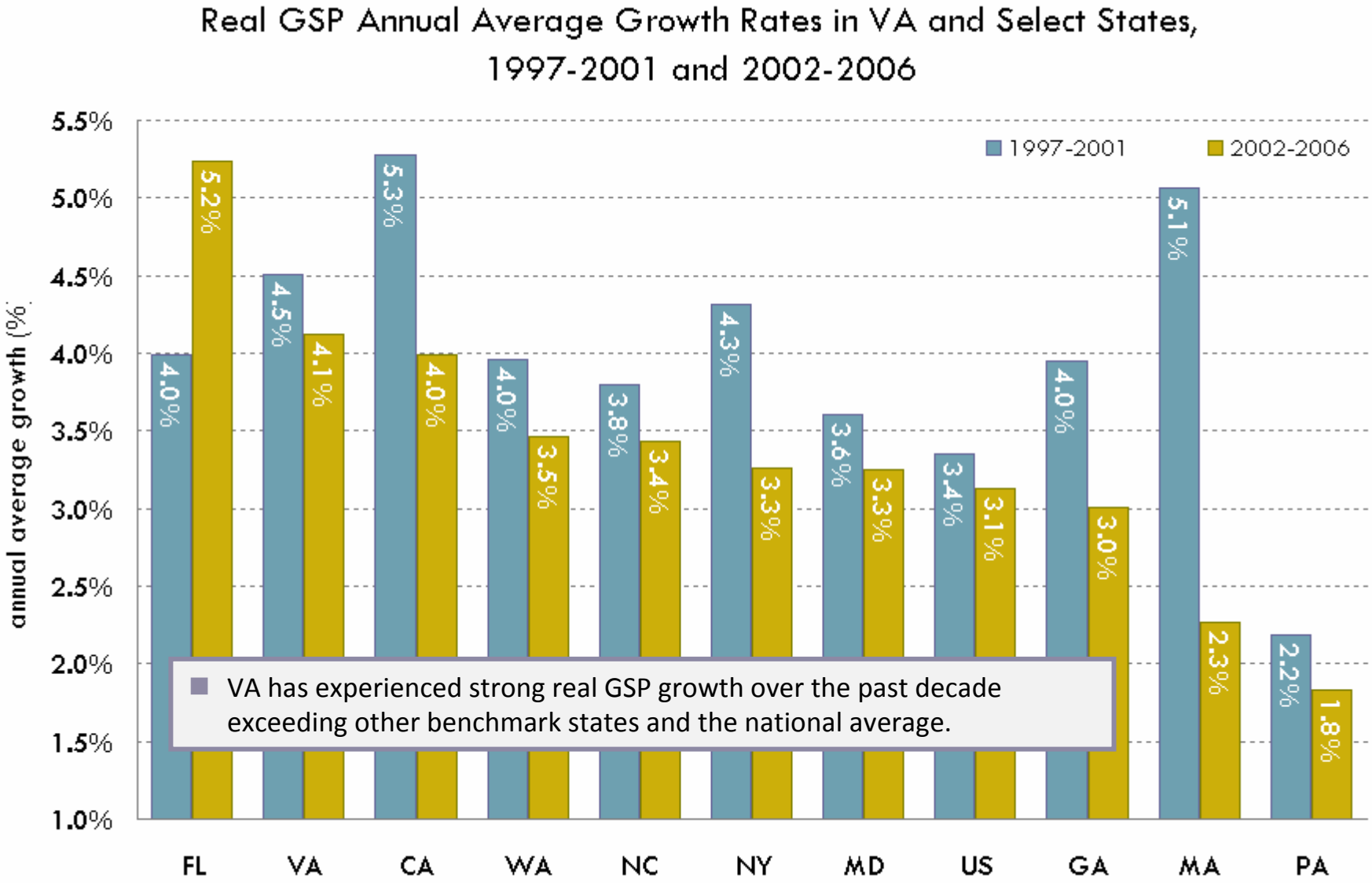
Category Significance: Ultimately, the reason why states enact policies to improve competitiveness is to bring about sustained economic growth, better jobs, and increased incomes for citizens. Indicators of economic performance include real gross state product growth (adjusted for inflation), real GSP per capita growth (economic output growth adjusted for population growth), and export growth (global competitiveness and outward orientation).

Virginia's Performance

- From 2002-2006, VA performed well among its peers in achieving high levels of real GSP (ranking 2nd) and high rates real GSP per capita growth (ranking 4th).
- Much of this growth has been led by the service sectors, and many of these sectors' growth rates have benefited directly or indirectly from Federal government agency growth or Federal government contracts (e.g., IT services, research and engineering services, aerospace and national security, etc.).
- Among the benchmark states, VA had the poorest export growth from 2002-2006. The state's overall export base is low, measured either in total dollars or as a share of GSP. Virginia's weak outward orientation is a concern.

Innovation Economy Outcomes

Real GSP Growth



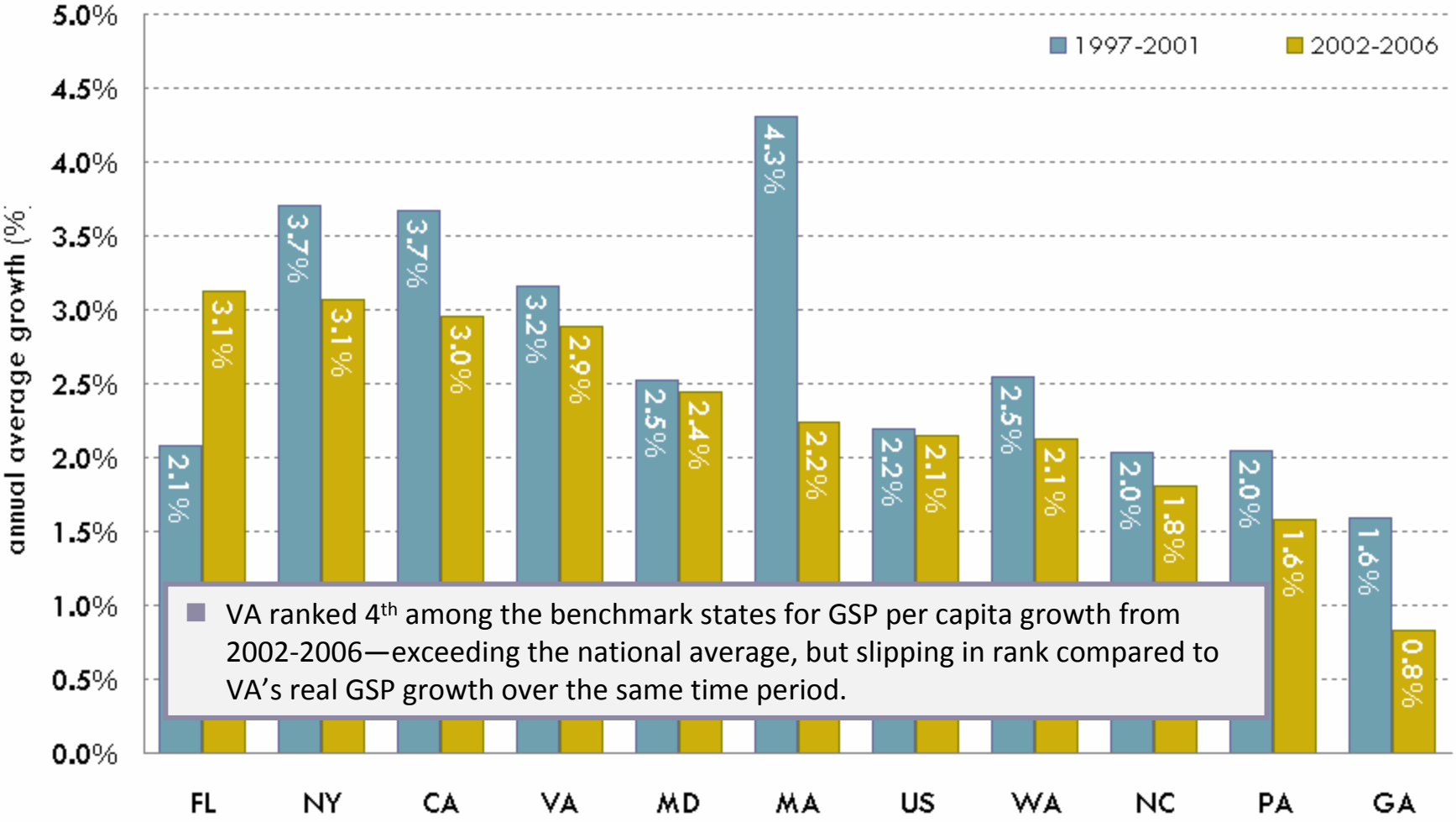
- VA has experienced strong real GSP growth over the past decade exceeding other benchmark states and the national average.

Source: US Bureau of Economic Analysis

Innovation Economy Outcomes

Real GSP per Capita Growth

Real GSP per Capita Annual Average Growth in VA and Select States, 1997-2001 and 2002-2006



- VA ranked 4th among the benchmark states for GSP per capita growth from 2002-2006—exceeding the national average, but slipping in rank compared to VA's real GSP growth over the same time period.

Source: US Bureau of Economic Analysis

Innovation Economy Outcomes

Export Growth

Growth in Total Exports in VA and Select States, 2002-2006		
	Annual Average Growth (%) 2002-2006	Exports ($ million) 2006
MD	11.2%	$ 7,597.9
PA	10.8%	$ 26,333.9
US	10.6%	$1,037,143.0
FL	9.4%	$ 38,544.5
NY	9.2%	$ 57,369.3
WA	8.9%	$ 53,074.9
CA	8.5%	$ 127,746.1
NC	7.6%	$ 21,218.2
MA	7.6%	$ 24,047.0
GA	6.9%	$ 20,073.3
VA	5.5%	$ 14,104.0

Source: US International Trade Administration

- Although it is the 7th largest economy in the group, VA ranked 9th for the value of its 2006 total exports (ahead of MD).
- VA ranked last among the benchmark states for its annual export growth from 2002-2006.

Innovation Economy Outcomes

Export Share of GSP

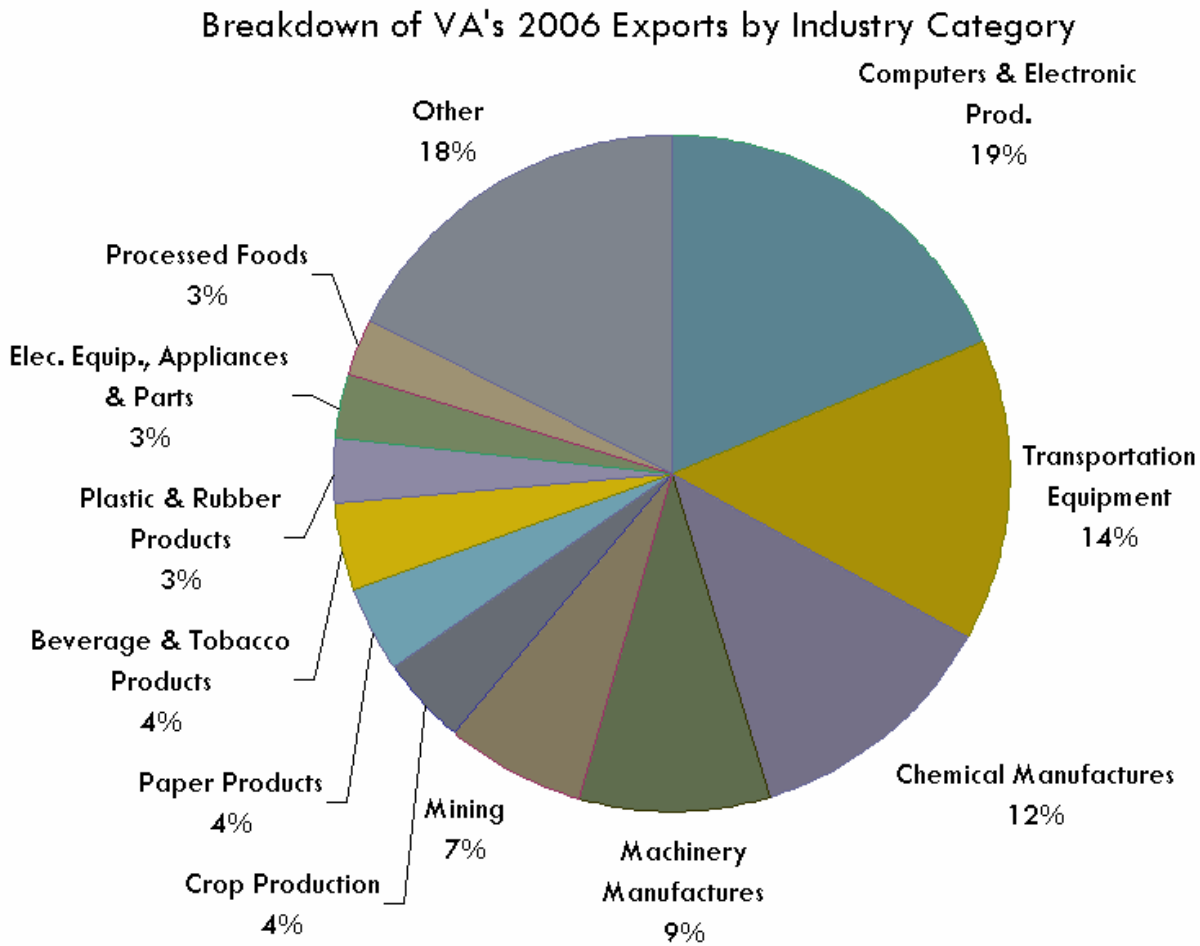
Exports as a Share of GSP in VA and Select States, 2001-2006						
	2001	**2002**	**2003**	**2004**	**2005**	**2006**
WA	15.5%	15.0%	14.2%	13.4%	14.0%	18.1%
US	7.3%	6.7%	6.6%	7.0%	7.3%	7.9%
CA	8.2%	6.9%	6.7%	7.3%	7.2%	7.4%
MA	6.2%	5.9%	6.4%	7.1%	6.9%	7.1%
NC	5.9%	5.0%	5.3%	5.6%	5.5%	5.7%
NY	5.2%	4.5%	4.6%	4.9%	5.3%	5.6%
FL	5.5%	4.7%	4.5%	4.8%	5.0%	5.4%
GA	4.9%	4.7%	5.1%	5.8%	5.7%	5.3%
PA	4.3%	3.7%	3.7%	4.0%	4.6%	5.2%
VA	4.2%	3.8%	3.6%	3.6%	3.5%	3.8%
MD	2.6%	2.2%	2.3%	2.5%	2.9%	2.9%

Source: US International Trade Administration

- VA's exports as a share of GSP is relatively small (3.5%-4%).
- In all other benchmark states (except MD and WA), exports range from 4%-8% of GSP.
- In addition, VA's exports as a % of GSP stayed flat during the 2002-2006 period. Export share increased in all the other benchmark states and in the US as a whole during this time period.

Innovation Economy Outcomes

VA Exports by Sector



Source: US International Trade Administration

- In 2006, VA's top 3 exporting industries were:
  - Computers & Electronics (19%)
  - Transportation Equipment (14%)
  - Chemicals (12%)

Innovation Economy Outcomes

Innovation Performance

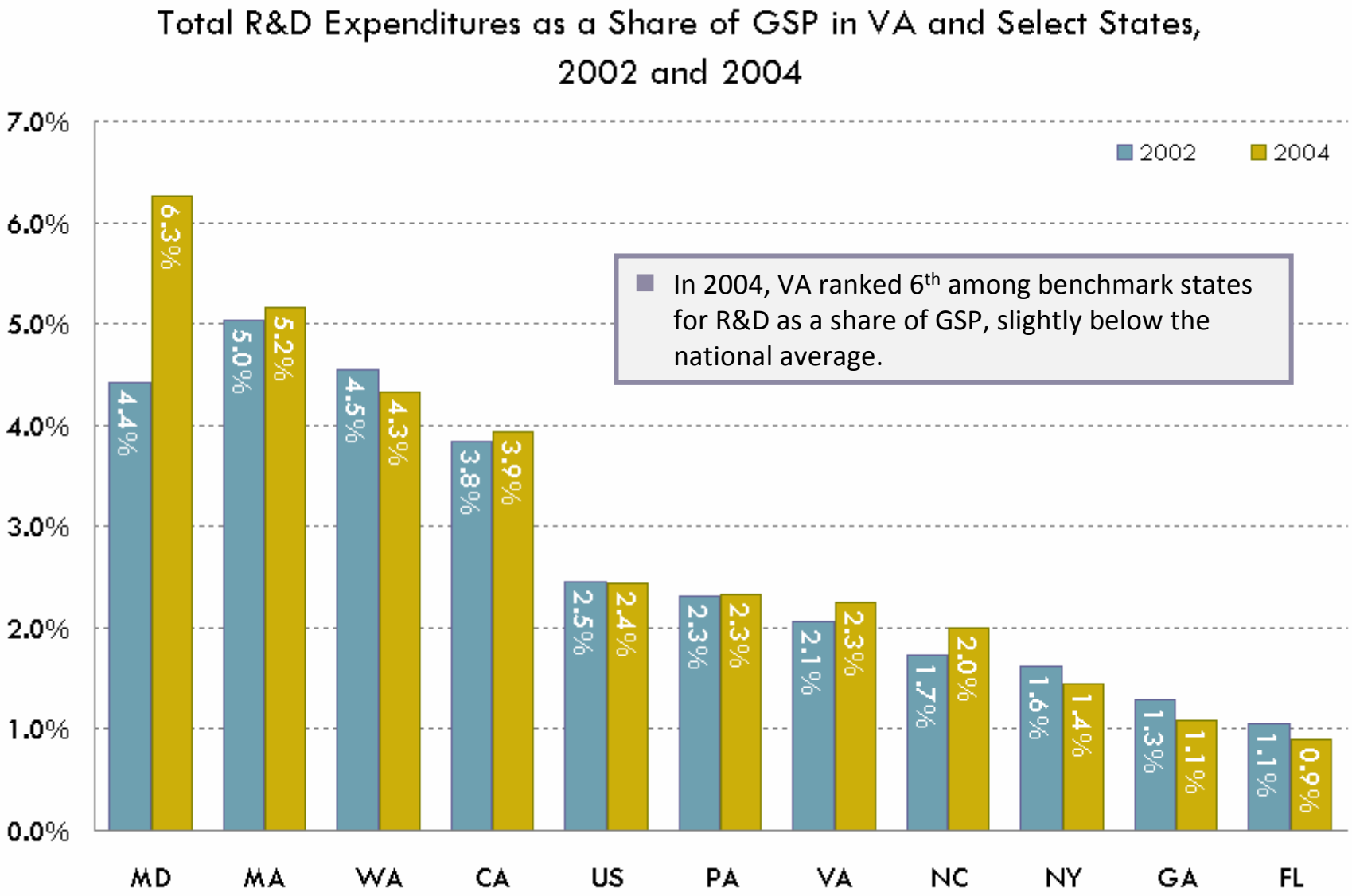
Category Significance: Current research indicates that total R&D expenditure as a share of GDP is critical to a country's innovation performance. OECD countries typically have R&D to GDP ratios of 2%-4%. Developing countries typically have R&D to GDP ratios of 0 to 1.5% . At the state level, the picture is more nuanced, because of significant factors such as the location of Federal and industrial R&D centers. Also important is the ability of universities to perform both world-class basic research as well as R&D that is useful to industry.

Virginia's Performance

- In 2004, VA's R&D to GSP ratio (i.e., the intensity of R&D relative to other economic activity) was slightly below the national average, placing VA 6th among the benchmark states.
- VA ranked 4th in the group in licensing revenue as a share of academic R&D expenditures—ahead of CA and MA.
- Compared to its low ranking in total academic R&D expenditures compared to its peers (9th), VA ranked slightly higher in average annual university licenses executed and start-ups launched over the 2001-2005 period.

Innovation Economy Outcomes

R&D Share of GSP



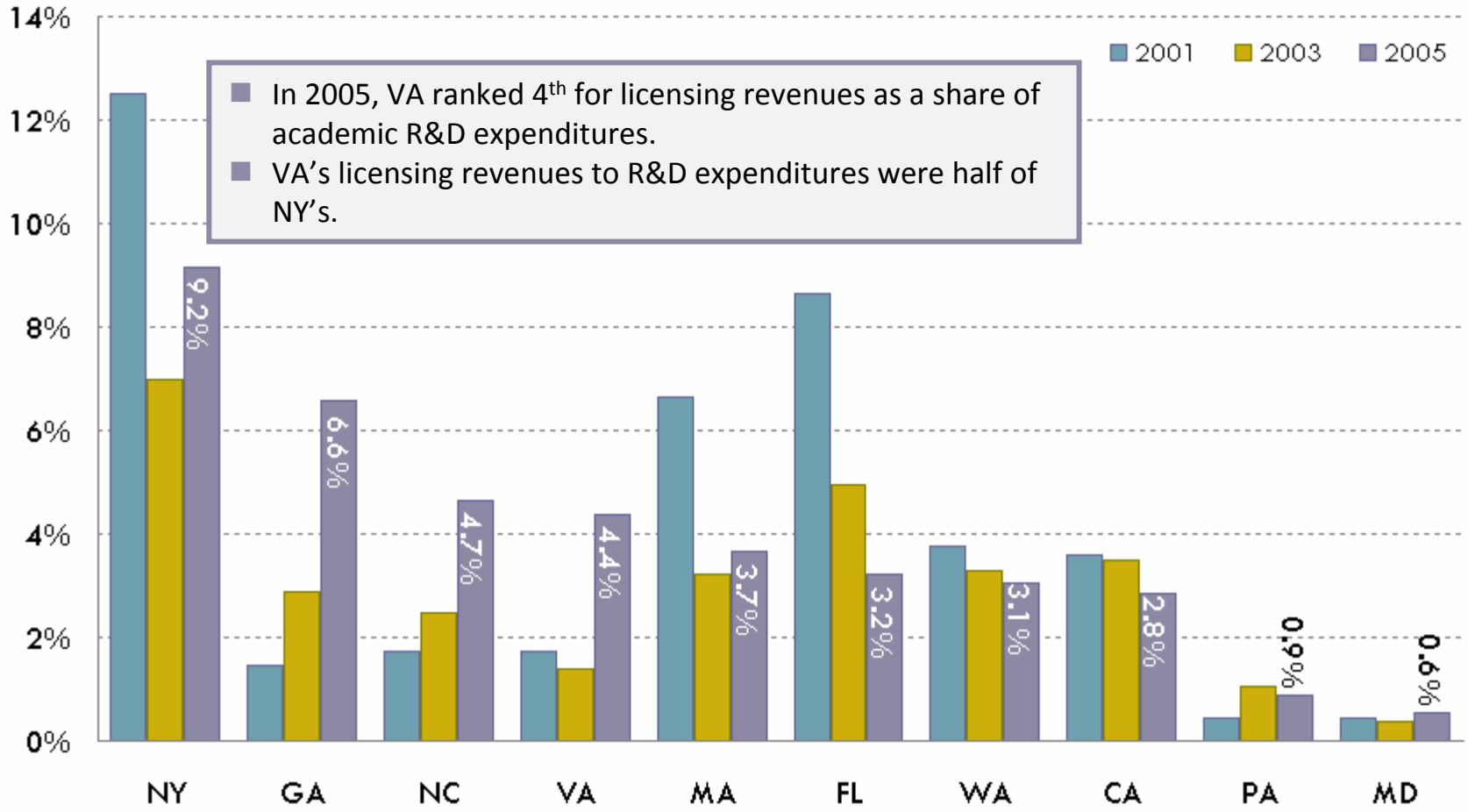
- In 2004, VA ranked 6th among benchmark states for R&D as a share of GSP, slightly below the national average.

Source: National Science Foundation and US Bureau of Economic Analysis

Innovation Economy Outcomes

Licensing Revenues

University Licensing Revenues as a Share of Academic R&D Expenditures in VA and Select States, 2001, 2003, 2005



- In 2005, VA ranked 4th for licensing revenues as a share of academic R&D expenditures.
- VA's licensing revenues to R&D expenditures were half of NY's.

Note: The 2005 licensing revenue data for GA excludes significant income from the sale of the rights to an HIV/AIDS-related drug by Emory University. If included, GA's licensing revenues as a share of academic R&D expenditures is 51.7% in 2005.

Source: Association of University Technology Managers

Innovation Economy Outcomes

Licenses & Start-Ups

Rankings by Academic R&D Expenditures, Licenses Executed, and Start-Ups Launched for VA and Select States, 2001-2005			
Rank	Total Annual Academic R&D Expenditures, 2005 ($ million)	# of Licenses Executed 2001-2005 average	# of Start-Ups Launched 2001-2005 average
1	CA ($6,272.9)	CA (463)	CA (46)
2	NY ($3,604.4)	MA (267)	MA (35)
3	MD ($2,357.1)	NY (206)	PA (24)
4	PA ($2,353.6)	NC (181)	NY (24)
5	MA ($2,079.5)	MD (177)	NC (20)
6	NC ($1,652.0)	PA (170)	GA (16)
7	FL ($1,448.6)	GA (127)	FL (15)
8	GA ($1,274.4)	**VA (105)**	**VA (13)**
9	**VA ($914.2)**	FL (92)	MD (12)
10	WA ($901.1)	WA (91)	WA (4)

Source: National Science Foundation and Association of University Technology Managers

- As compared to its level of total academic R&D expenditures in 2005, VA ranked slightly higher in average annual licenses executed and start-ups launched.
- As compared to their levels of total academic R&D expenditures, MD ranked significantly lower in the research output categories, and MA ranked significantly higher.

Innovation Economy Outcomes

Firm Dynamism

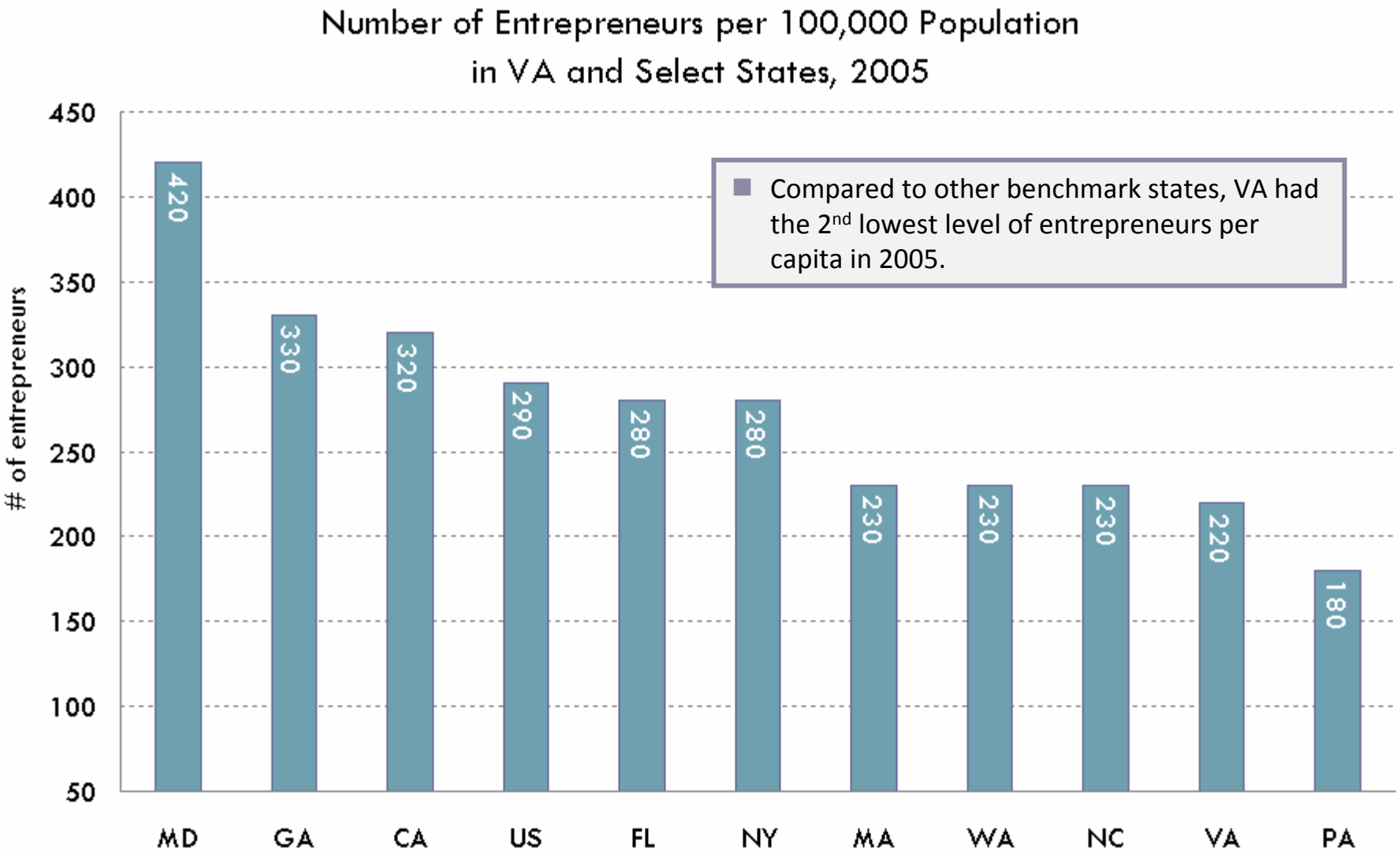
Category Significance: In a dynamic economy, both new company startups and failures are common. This churning is indicative of both a high level of entrepreneurship and a healthy business environment, but also market discipline. In terms of company growth in high-tech or knowledge-intensive industries, Deloitte's Tech Fast 500 list captures strong percentage-based growth in technology-based industries.

Virginia's Performance

- In 2005, VA ranked 8th in entrepreneurs per capita and new business start-ups per 1,000 establishments among the benchmark states. These indicators are for all entrepreneurs and business start-ups, not technology based start-ups in particular.
- However, VA ranked 2nd in the benchmark group for net business creation (business start-ups minus business closures).
- VA also ranked 2nd in the benchmark group in 2005 for Tech Fast 500 companies. All but one of VA's Tech Fast 500 were in ICT industries (software, internet, communications networking). Their rapid growth may be related to significant growth in Federal government procurement of ICT services during this period.

Innovation Economy Outcomes

Entrepreneurs Per Capita

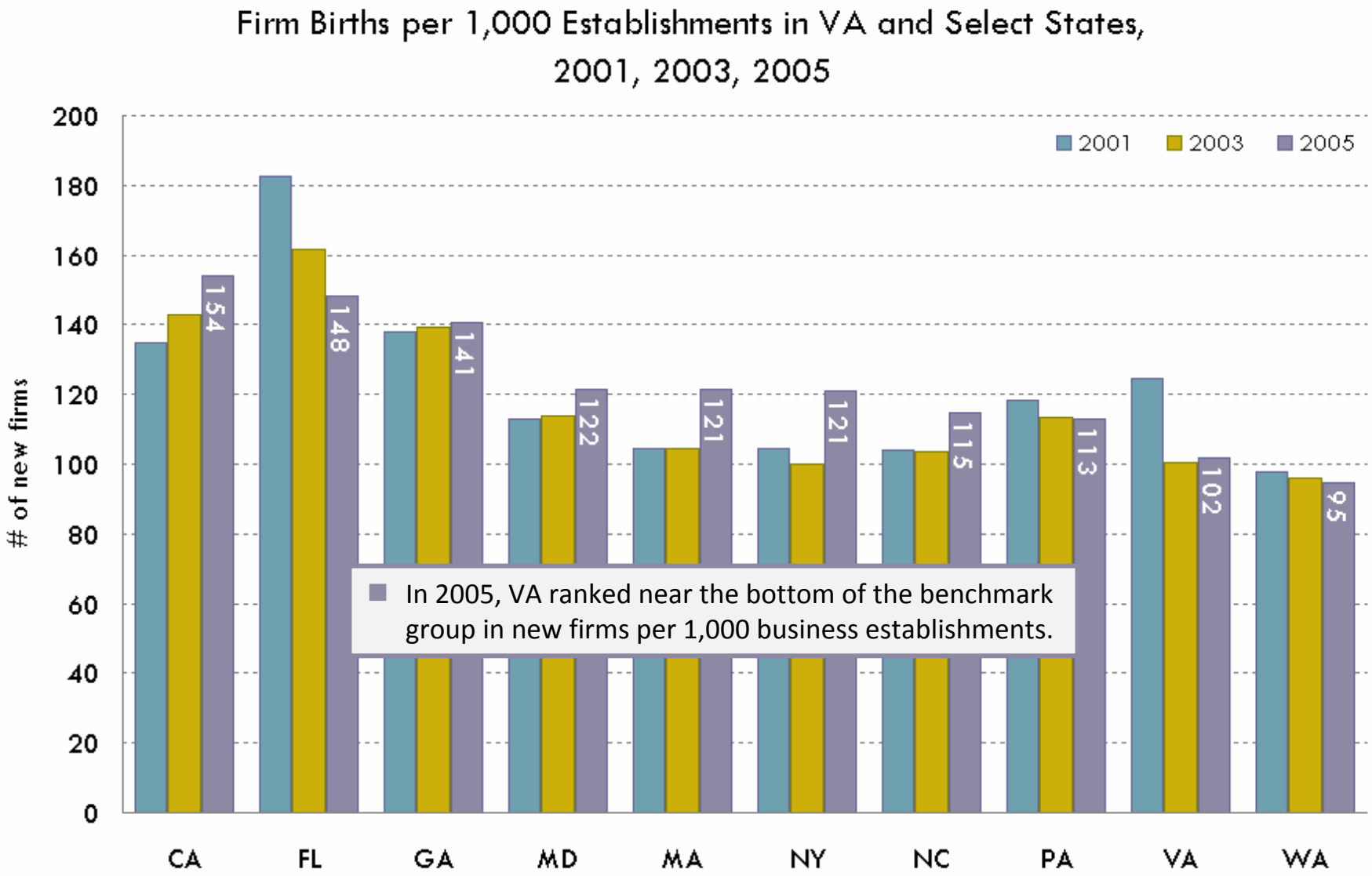


- Compared to other benchmark states, VA had the 2nd lowest level of entrepreneurs per capita in 2005.

Source: Kauffman Foundation

Innovation Economy Outcomes

Firm Births

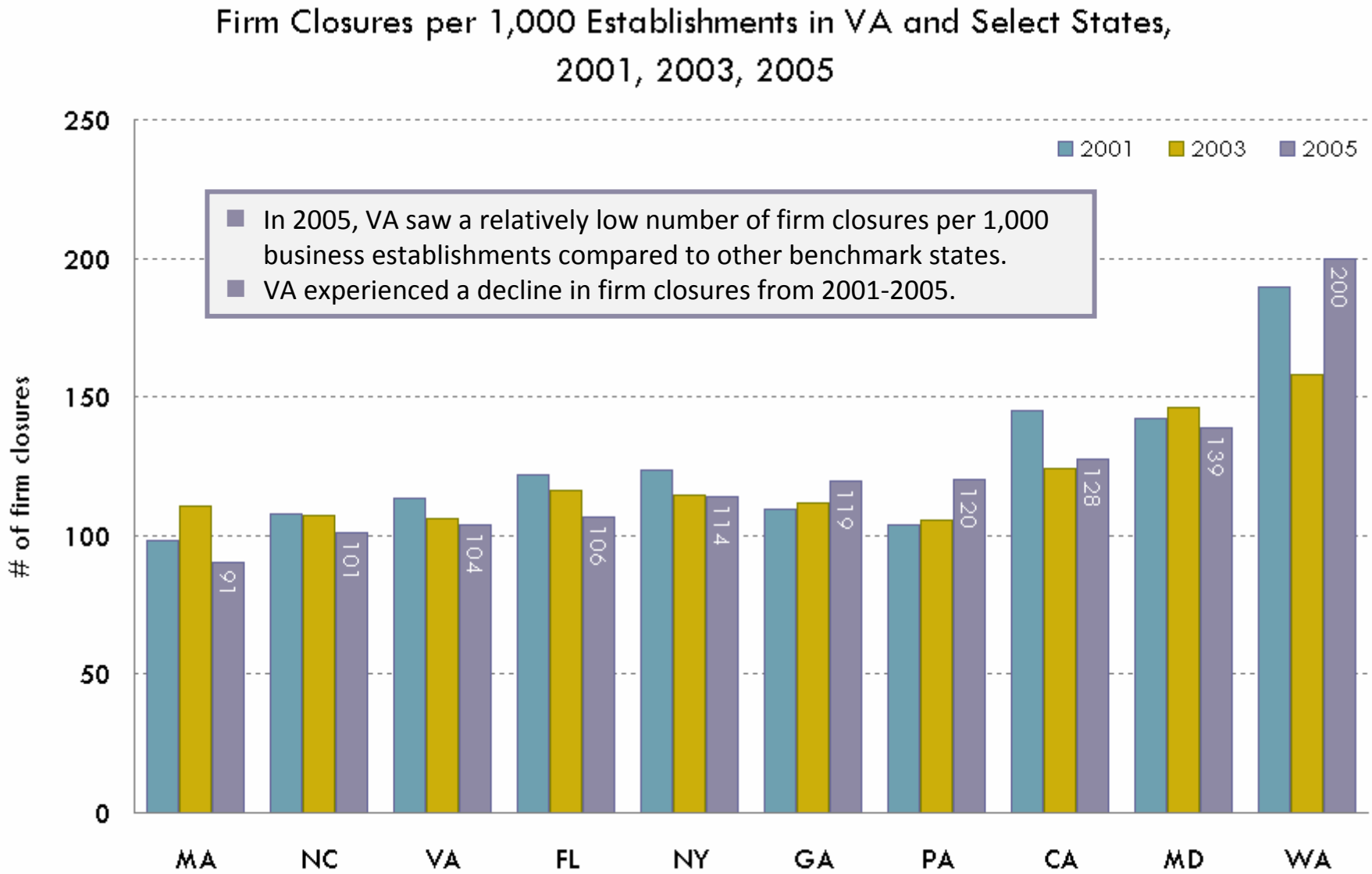


In 2005, VA ranked near the bottom of the benchmark group in new firms per 1,000 business establishments.

Source: US Small Business Administration and US Bureau of Labor Statistics

Innovation Economy Outcomes

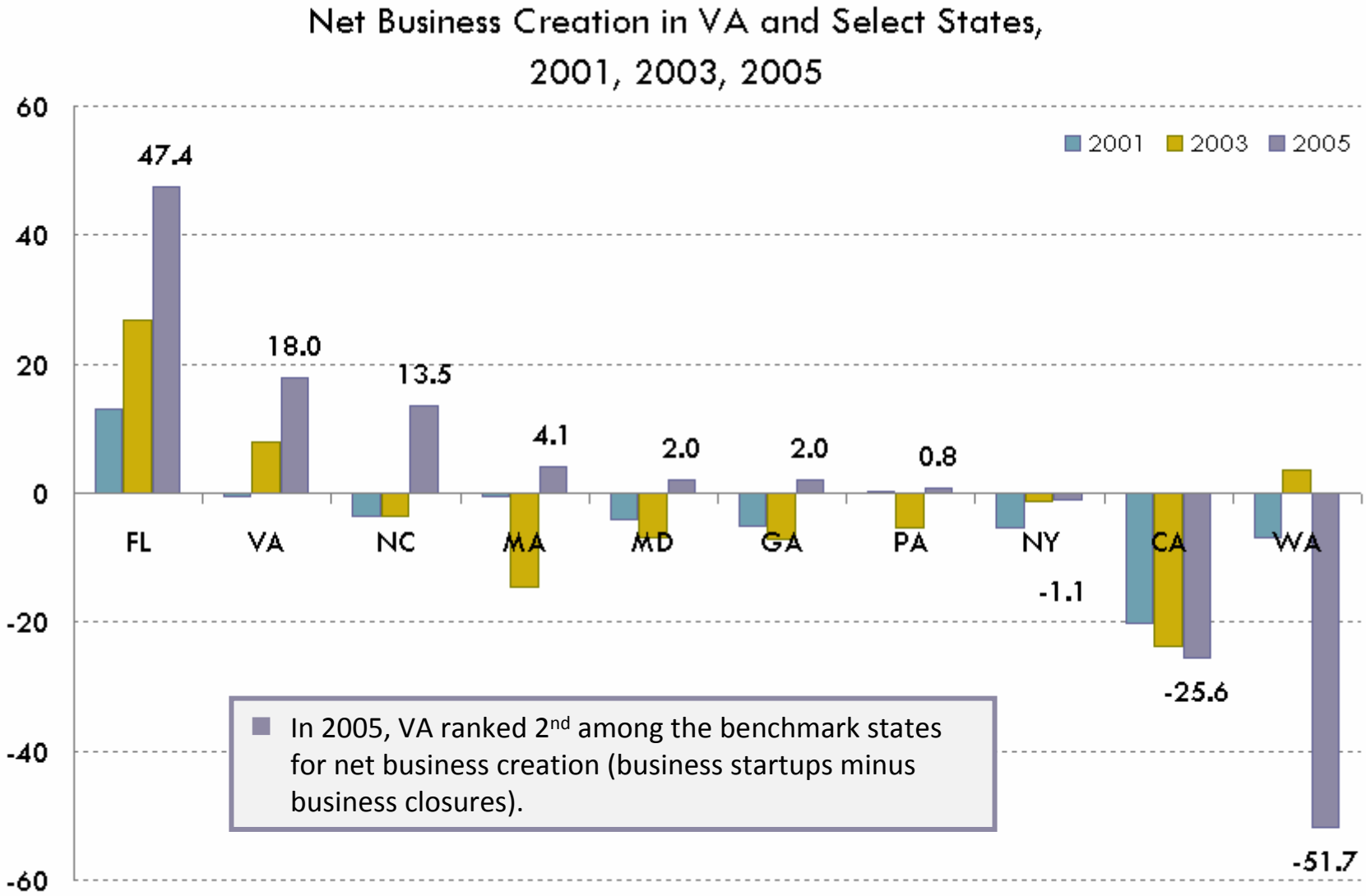
Firm Closures



Source: US Small Business Administration and US Bureau of Labor Statistics

Innovation Economy Outcomes

Net Business Creation

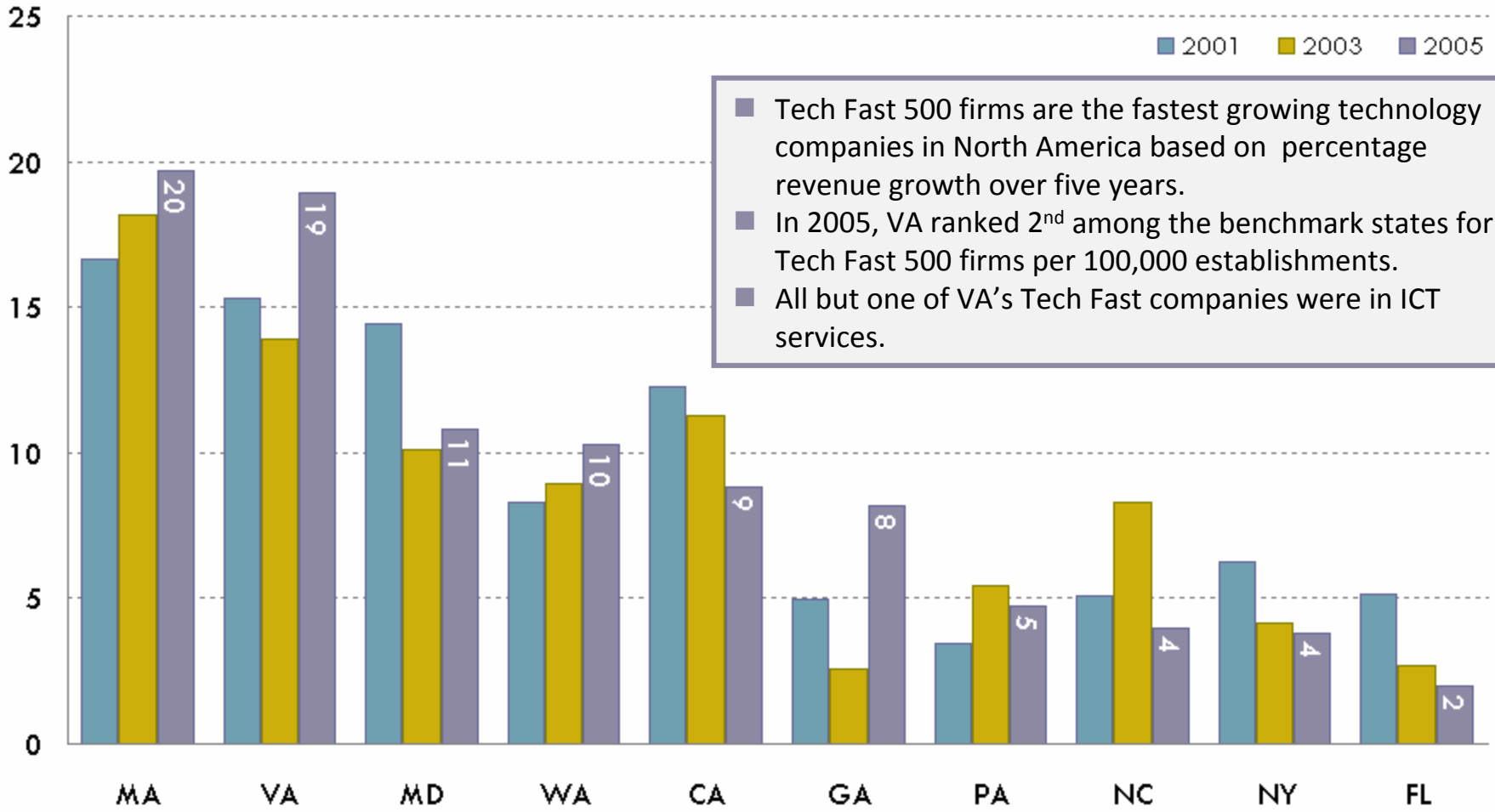


- In 2005, VA ranked 2nd among the benchmark states for net business creation (business startups minus business closures).

Source: US Bureau of Labor Statistics

Innovation Economy Outcomes

Tech Fast 500 Firms



- Tech Fast 500 firms are the fastest growing technology companies in North America based on percentage revenue growth over five years.
- In 2005, VA ranked 2nd among the benchmark states for Tech Fast 500 firms per 100,000 establishments.
- All but one of VA's Tech Fast companies were in ICT services.

Source: Deloitte & Touche and US Bureau of Labor Statistics

List of Benchmark Indicators & Data Sources

Section VI

Financial Resources

Indicators & Sources

Venture Capital

- Total annual venture capital investments (by state)
- Venture capital investments per capita (by state)
- VA venture capital investments as a share of total US venture capital investments (VA only)
- Distribution of venture capital investments by industry sector (VA and US)
- Venture capital investments by stage of financing (VA and US)

Source: PricewaterhouseCoopers/National Venture Capital Association/Thomson Financial MoneyTree™ Survey

Micro & Small Business Loans

- Micro loans (<$100K) per 100,00 population (by state)
- Small business loans (<$1 million) per 100,000 population (by state)

Source: US Small Business Administration

SBIR & STTR Awards

- Dollar value of Small Business Innovation Research (SBIR) awards per 10,000 population (by state)
- Dollar value of Small Business Technology Transfer (STTR) awards per 10,000 population (by state)

Source: US Small Business Administration

Human Resources

Indicators & Sources

Labor Force

- Annual average labor force growth rate (by state)

Source: US Bureau of Labor Statistics

- Annual average population growth rate (by state)
- Annual average growth rate of population age 25-34 (by state)
- Net domestic migration (by state)
- Net international migration (by state)
- VA total net migration trends (VA only)

Source: US Census Bureau

Education

- Average 4th- and 8th-grade science National Assessment of Education Progress (NAEP) scores (by state)
- Average 4th- and 8th-grade math NAEP scores (by state)

Source: National Center for Education Statistics

- Share of students taking Advanced Placement (AP) exam (by state)
- Share of students scoring 3+ on AP exam (by state)

Source: The College Board

- Science & engineering (S&E) degrees as a share of all higher education degrees conferred (by state)
- Advanced S&E degrees as a share of all higher education degrees conferred (by state)

Source: National Center for Education Statistics

Innovation Resources

Indicators & Sources

Research & Development Expenditures

- Total research and development (R&D) expenditures per 1,000 population (by state)
- Breakdown of R&D expenditures in VA by performer (VA only)
- Industrial R&D expenditures per 1,000 population (by state)
- Share of industrial R&D expenditures coming from the Federal government (by state)
- Academic R&D expenditures per 1,000 population (by state)
- Annual average growth rate of academic R&D expenditures (by state)
- VA's academic R&D expenditures by science & engineering (S&E) field (VA only)
- S&E fields' share of total academic R&D expenditures (VA and national average)
- Federal R&D performance per 1,000 population and share of total R&D expenditures (by state)

Source: National Science Foundation

Research Outputs

- Patents issued per 100,000 population (by state)
- VA's leading patenting organizations (VA only)

Source: US Patent & Trademark Office

- FDA new biologic license application approvals (by state)

Source: US Food & Drug Administration

- Continued on next slide

Innovation Resources

Indicators & Sources

Research Outputs

- Number of publications per million population (by state)
- VA's leading publishing organizations (VA only)
- Distribution of VA's scientific publications by field (VA only)

Source: ISI Web of Science

- Academic R&D expenditures per patent (by state)

Source: National Science Foundation and US Patent & Trademark Office

- University R&D expenditures per start-up (by state)

Source: Association of University Technology Managers

Innovation Economy Outcomes

Indicators & Sources

Economic Performance

- Real GSP average annual growth rate (by state)
- Real GSP per capita average annual growth rate (by state)

Source: US Bureau of Economic Analysis

- Total exports and average annual export growth rate (by state)
- Exports as a share of GSP (by state)
- Breakdown of VA's exports by industry category (VA only)

Source: US International Trade Administration

Innovation Performance

- Total R&D expenditures as a share of GSP (by state)

Source: National Science Foundation

- University licensing revenues as a share of academic R&D expenditures (by state)
- Number of licenses executed and start-ups launched (by state)

Source: Association of University Technology Managers

Innovation Economy Outcomes

Indicators & Sources

Firm Dynamism

- Number of entrepreneurs per 100,000 population (by state)

Source: Kauffman Foundation

- Firm births per 100,000 population (by state)
- Firm closures per 100,000 population (by state)
- Net business creation (by state)

Source: US Small Business Administration and US Bureau of Labor Statistics

- Number of Technology Fast 500 firms per 100,000 establishments (by state)

Source: Deloitte & Touche

Assessing The Technology Industry Potential Of The Commonwealth Of Virginia

December 14, 2007

P18176

Task 3: Virginia's Technology Opportunities

SRI International

Prepared for the Virginia Economic Development Partnership

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Technology Opportunities for Virginia

Research, innovation, and technology are major drivers of the U.S. and global economies. While everyone might agree that they are important to economic growth and competitiveness, the linkages among them are far less clear. Even the terminology can be confusing. What is a technology, and how is this different from a high-tech industry? Broadly speaking, technology is the application of science to meet societal needs. As a recent *Technology Platforms* report[1] by the European Commission points out, technology breakthroughs are important because they:

- Can lead to radical change in an industry sector (e.g., the unbundling of music and video distribution caused by the creation of the iPod);
- May reconcile competing policy objectives with an eye on sustainable development (e.g., renewable energy and agricultural biotechnology);
- Ensure that industries with significant strategic and economic importance maintain a leading edge (e.g., pharmaceuticals and aerospace); and
- May help revive or restructure traditional industries that are currently in decline (e.g., steel or consumer electronics)

It is important to acknowledge that a technology—like biotechnology, for example—may have the potential for revolutionizing an industry, but may not translate into significant revenues or jobs today or even 5-10 years from now. A prime example is the U.S. biotechnology industry, which has been unprofitable since its inception in 1973. The U.S. biotechnology industry reported a net loss of $5.6 billion in 2006 on total industry revenues of $58.8 billion.[2] It is also important to note that the economic development gains associated with new technologies do not necessarily reside in the technology's birthplace. For example, new semiconductor products are often being developed and patented in the United States, but production from the very outset is carried out at fabrication plants located in Taiwan or China.

The frontiers of science and technology are being pushed out in an enormous array of scientific fields. For example, the scientific community is placing a major emphasis on biotechnology and nano/MEMS technologies because they represent technology platforms with extensive applications across many industries. In addition, advanced computational methods are being utilized productively in dozens of technical fields. One could, without exaggeration, identify 10 to 20 emerging technologies in each traditional areas of science (e.g., biology, chemistry physics, etc.). As a result, to specify and review all "over the horizon" technologies likely to yield productive commercial applications would be a daunting if not impossible exercise. Therefore, in order to highlight those technology arenas with a strong potential for contributing to innovation and economic benefits to Virginia, particularly within the confines of the time and resources available, it is necessary to conduct a selection process that to the maximum extent possible matches and integrates technologies with relevant industry potential in the Commonwealth.

For any given industry—chemicals, aerospace, pharmaceuticals, electronics, energy, etc.—there are numerous technology needs and equally many technology possibilities for addressing these needs. Yet,

[1] European Communities (2004). *Technology Platforms: From Definition to Implementation of a Common Research Agenda*, ftp://ftp.cordis.europa.eu/pub/technology-platforms/docs/tp_report_defweb_en.pdf
[2] Ernst & Young (2007). *Beyond Borders: The Global Biotechnology Report 2007*, p.17.

technology development and commercialization are characterized by very high levels of uncertainty and risk. In addition to the difficulties involved in technology creation, a considerable range of other factors can make technology commercialization untenable at any point in time—cost, consumer or industry willingness to adopt the technology, or deleterious side effects to name a few. Ultimately, the greatest share of the economic value generated by a new technology may reside with the companies that acquire that technology, adapt it, and develop the requisite business and financial model innovations to move the product or process into the public domain.

To determine an initial list of technology fields for further exploration, the SRI team designed a methodology to approach technology opportunities for Virginia through an economic development lens. The team first identified several industry sub-clusters that utilize technologies and generate new technologies. The team then screened the industry sub-clusters to identify the top five industries for our analysis based on the following economic development and technology criteria:

- Have a solid or established economic base in Virginia;
- Are high-growth industries, nationally and globally, utilize technologies, and have the potential for being transformed by critical emerging technologies globally;
- Can draw on Virginia's existing or emerging industrial, university or Federal R&D assets; and
- Are subject to other unique factors, such as proximity to the Federal Government markets, current or potential economic development impact on regions in the state outside of Northern Virginia, etc.

Drawing from the industry clusters listed in the table below, the SRI team selected the following technology-oriented industry clusters with the highest selection criteria scores: (1) Information Technology Services, (2) Health Care and Biomedical Sciences, (3) Energy and Environment, (4) Chemicals and Materials, and (5) Transportation and Logistics.

Technology-Oriented Industries Selection Matrix

Industry Cluster	Industry Sub-Clusters	Current Industry Base	Growth Potential	Existing R&D Assets	Other Factors[3]	Total Score
National Security and Aerospace	Aerospace	✓	✓	✓	✓✓	✓
	National Security	✓✓	✓✓	✓✓✓	✓✓✓	✓✓
Agriculture and Food	Agriculture and Processed Food	✓✓	✓✓	✓	✓	✓
Biomedical and Health Care	Health Care	✓✓✓	✓✓✓	✓✓	✓✓	✓✓✓
	Biomedical Sciences	✓	✓✓✓	✓✓	✓	✓✓
Chemicals and Materials	Chemicals	✓	✓✓	✓	✓✓	✓✓
	Materials	✓✓	✓✓✓	✓	✓✓	✓✓✓
Energy and Environment	Energy	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Environment	✓	✓✓	✓✓	✓✓	✓✓
Information and Communications	IT Services	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
	Telecom	✓✓	✓✓	✓	✓✓	✓✓
	Electronics	✓	✓✓	✓	✓	✓
Transportation and Logistics	Transportation and Logistics	✓✓	✓✓✓	✓	✓✓✓	✓✓✓

The team then conducted research to specify a well grounded cross-section of relevant technologies for each of the five industry clusters selected. Since the list of technologies associated with any one industry is almost endless and it is beyond the scope of this project to cover all technologies, as noted above, the SRI team identified technologies characterized by: (1) strong market demand in numerous application areas, (2) early stage of development—indicating there is still time for Virginia actors to enter and to become prominent players in this field, and (3) existing R&D assets on which Virginia can build.

This report contains an assessment for each of the five technology-oriented industry clusters. The assessments begin with an overview of the cluster, including definition, subsectors, market dynamics, etc., and continue by providing detail on two specific technologies per industry cluster, with particular scope for development in Virginia. The assessment concludes by presenting an inventory of key assets for each cluster, including a geographical mapping of these assets.

[3] Other Factors include proximity to Federal market clients, regional distribution of industries and economic development considerations, and other considerations.

A Cross-Section of High Impact Technologies by Industry Cluster		
Technology-Based Industry Cluster	**Technology**	**Description**
Health Care and Biomedical	Point-Of-Care Diagnostics	Diagnostic tests are important in accurately diagnosing disease, but also in monitoring blood sugar, cholesterol, hormone levels, and other indicators of a patient's response to treatments. A new generation of diagnostics technologies based on advances in nanotechnology, microsystems, biotechnology and information technology could significantly reshape modern health care. Point-of-care (POC) testing allows patient diagnoses by non-specialists outside the hospital or the physician's office.
	Computational Technologies	Bioinformatics and computational biology provide a research platform to acquire, manage, analyze, and display large amounts of data. Both draw on analytical methods borrowed from computer science, mathematics, statistics, and the physical sciences. The promise of bioinformatics and computational biology is to reduce the volumes of genomic and proteomic data being generated to a usable form for researchers, so they may make predictions and test biological and biomedical hypotheses.
Information Technology	Health IT	Health information technology (IT) enables "comprehensive management of medical information and its secure exchange between health care consumers and providers." With low adoption rates, health IT is a relatively nascent market, which would indicate that there is much potential for market growth and penetration.
	Cybersecurity	Cybersecurity is the use of information technology to protect "information against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional."[4] According to Business Insights, the global cybersecurity market was $13.8 billion in 2006, and will grow to $20.6 billion in 2010, with a CAGR of 13%.
Chemical and Materials	Nanomaterials	Nanotechnology involves objects generally less than 100 nanometers in size and exploits the unique properties of materials at this scale. Nanomaterials are made from variety of raw materials such as carbon or silver and come in a wide array of shapes and sizes with unique and interesting properties. Some estimates suggest that the "nanotechnology market" will be worth more than $1 trillion by 2015.

[4] http://glossary.its.bldrdoc.gov/fs-1037/dir-019/_2726.htm.

A Cross-Section of High Impact Technologies by Industry Cluster		
	Biopolymers	Biopolymers, often called bioplastics in the industrial sector, are biologically-derived polymers with a variety of useful functional uses such as: stabilizers, thickeners, gellants, binders, dispersants, lubricants, adhesives, and drug-delivery agents. Concerns about waste from plastic products, increasing cost, and demand for healthier processed foods are some of the factors driving increased adoption of biopolymers, which could account for 5% of the global plastics market by 2010.
Clean Energy and Environment	Fuel Cells and Distributed Hydrogen	A fuel cell is an energy conversion device used to convert a fuel (chiefly hydrogen) to energy. "Fuel cells can potentially achieve the highest fuel to electricity conversion efficiencies of any generating technology available today," [5] although the adoption today is limited by the high cost. Global market revenues are projected to grow at a very high CAGR of 27% between 2006 and 2016, from $1.4 billion to $15.6 billion. Hydrogen offers huge market potential but also high risk because this technology is in early stages of development.
	Carbon Capture and Storage	Carbon sequestration is "a way to reduce greenhouse gas emissions…. Interest has been increasing in the carbon sequestration option because it is very compatible with the large energy production and delivery infrastructure now in place."[6]
Transportation and Logistics	Radio-Frequency Identification (RFID)	RFID is "an automated data capture technology that uses low-power radio waves to communicate between readers and tags or contact-less cards."[7] RFID technologies are on the cusp of becoming critical enabling technologies for a wide variety of sectors, such as retail, health care and pharmaceuticals, manufacturing, payment systems, and security, identification and authentication.
	"Smart" Roads	"Smart" roads are intended to solve or ameliorate the congestion created by the fact that, in the past 20 years, the United States has added only 2% more roadways, while the number of cars has increased by 50% and the number of miles driven by 77%.[8] The technologies underpinning smart roads are diverse, including embedded sensors and magnetic strips as well as batteries (or other power sources) and wireless transmitters to relay information.

[5] Business Insights, The Future of Distributed Power Generation: New technologies, changing economics and the impact of fuel cells, 2007, p. 57.
[6] MIT Carbon Capture & Sequestration Technologies. http://sequestration.mit.edu/technology_overview/index.html.
[7] SRIC-BI, *RFID Technologies*, 2007, p. 9.
[8] Hampton, Bill, "Smart Roads," *Business Week*, http://www.businessweek.com/adsections/smartcars/smcaroads.htm.

Information Technology Services

Cluster and Technology Overview

Description and Major Subsectors

Information technology (IT) is defined by the Information Technology Association of America (ITAA) as "the collection of products and services that turn data into useful, meaningful, accessible information."[9] For the purposes of this study, SRI is defining the Information Technology Services industry sector as comprising mainly the software component of IT, and composed of three major sub-sectors (described in further detail below): Programming, Systems Design, & Data Services, Computer Software Development, and Internet Service Providers (ISPs).

According to International Data Corporation (IDC), in 2006 end users spent $1.16 trillion on IT worldwide (both hardware and software), and IT spending will grow at a 6.3% compound annual growth rate (CAGR), reaching $1.48 trillion in 2010.[10] In addition, IDC expects worldwide software spending to reach $327 billion in 2010, growing at a five-year CAGR of 7.7%. The largest markets comprise discrete manufacturing, the services industries, and government. Healthcare, communications, and government are the fastest-growing markets. Also, spending on IT services worldwide is expected to reach $587 billion in 2010, reflecting a five-year CAGR of 5.8%. The largest markets are government, banking, and discrete manufacturing. The U.S. Bureau of Labor Statistics projects a 68% increase in output growth rate from 2002 to 2012 for the IT industry, making it the fastest growing sector in the U.S.[11] Total US spending on information technology accounts for almost 40 percent of global spending on information technology (including hardware).[12]

[9] http://www.itaa.org/news/docs/industryoverview.pdf.
[10] http://www.idc.com/getdoc.jsp?containerId=prUS20514107.
[11] http://www.doleta.gov/BRG/Indprof/IT_profile.cfm.
[12] http://www.itaa.org/news/docs/industryoverview.pdf.

Sub-Sectors Overview		
IT Services Sub-Sector	Description	Examples of Large Companies
Programming, Systems Design, & Data Services	Provides services such as IT consulting, data processing, technology outsourcing, and systems integration. Advises clients on software and hardware purchase decisions and usage. Designs and delivers integrated turnkey computer systems.	EDS, Accenture, CSC
Computer Software Development	Produces packaged ("off the shelf") and custom software products. There are three major types of software: operating systems (e.g., Microsoft Windows); user applications (e.g., word processors, spreadsheets and games); and network applications (e.g., email and web browsers).	Microsoft, Oracle, Computer Associates, Electronic Arts
Internet Service Providers	Companies in this sub-sector provide services to users such as Internet access, technical support, and web design and hosting.	AOL, AT&T, Microsoft, Earthlink, Verizon, Comcast

Following the IT downturn after the information technology bubble of the late 1990's, the IT Services market has improved due to factors such as higher PC sales, corporate investment in software upgrades, and demand for Internet security solutions.[13] Globalization has also had a strong impact on the IT industry, resulting in the outsourcing of many services to East and South Asia. Due to its proximity to and relationship with the federal government, Virginia's IT Services industry is somewhat shielded from this factor. Regarding federal IT, GEIA finds that federal agencies are under pressure to decrease costs, while focusing on "consolidating redundant systems, creating cross-agency initiatives, outsourcing IT functions and services, and coordinating their systems with other agencies." Overall, agencies are purchasing IT solutions "that apply across an entire agency and less on isolated products and services."[14] This emphasis on system consolidation plays on Virginia's core strength in systems integration.

High Growth Potential Technologies for Virginia

Health Information Technology

Health information technology (IT) enables "comprehensive management of medical information and its secure exchange between health care consumers and providers."[15] Health IT technologies include electronic health record (EHR) technology (software used to track all aspects of patient care including practice management functions), technology for the secure exchange of authorized information, technology to order medical tests and prescriptions online, and clinical decision support tools.

[13] http://www.soc.duke.edu/NC_GlobalEconomy/information/overview.php.
[14] http://www.eagleeyeinc.com/Search.FPC?Pg=2250.
[15] http://www.hhs.gov/healthit/.

According to a recent report published by the National Academies of Sciences, a "vision has emerged in which health IT would be used universally to improve the administrative efficiency of health-care entities, provide a key information source for evidence-based practice, enhance clinical outcomes, and help contain escalating health-care costs."[16] However, up until now, the main challenges to widespread adoption of health IT are "uneven distribution of costs, benefits, and incentives; the sheer scale and cost of achieving widespread adoption; concerns about privacy and security, limited public awareness about benefits; and reluctance on the part of institutions and individuals to adopt new technologies and associated changes in practices."[17]

With low adoption rates, health IT is a relatively nascent market, which would indicate that there is much potential for market growth and penetration. Indeed, as mentioned previously, IDC finds that healthcare is one of the fastest-growing markets for IT worldwide,[18] and Gartner also reports a "swift upsurge in healthcare IT spending."[19] The Business Communications Company estimates that the U.S. health IT market size was $16.38 billion in 2005, and expects it to reach $34.7 billion by 2011, a 13.4% AAGR.[20] This is strong growth in health IT is not surprising considering the aging of the baby boomer population and the accompanying sharp increase in demand for health care services. This excessive strain greatly increases the need for a more efficient health care system, and serves as a catalyst for adoption of health IT solutions.

The Greater Washington Initiative found that the Washington, DC region needs to "focus IT strategies on … emerging opportunities in health care data management"[21] because "the region's expertise with such vast government projects also creates a potential for providing comprehensive technology solutions to commercial firms" in fields such as healthcare management.[22] Virginia's strong Health Care & Biomedical Sciences cluster and its vibrant IT Services clusters position the state to take the lead as both an early adopter and a developer in this new field of health IT. In addition, health IT is part of the presidential technology agenda, which set a goal for universal usage and adoption of EHRs in the next 10 years.[23] As such, Virginia's proximity to the federal government is a key advantage in this field, since adoption of health IT by the federal government, one of the largest buyers of health care, would drive adoption in the other sectors. Furthermore, expanding into health IT could also be an opportunity to both play on Virginia's strength in systems integration and further develop its computer software development sub-sector, since health IT will require competencies in both areas.

There is significant interest in the Commonwealth for the further development of health IT. The list below, of organizations which submitted proposals to the Virginia Health Information Technology Council, demonstrates that interest in health IT can be found throughout Virginia's various regions.

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[16] Institute of Medicine and National Research Council of the National Academies, *A Brief Assessment of the Office of the National Coordinator for Health Information Technology*, 2007, p. 9. http://www.nap.edu/catalog/12048.html.
[17] Ibid.
[18] http://www.idc.com/getdoc.jsp?containerId=prUS20514107.
[19] Gartner Healthcare Summit, *2006 Post Summit Report*. p.2.
http://www.healthcareitsummit.com/us/tools/HIT_07_PostEventSum_FINAL.pdf.
[20] Business Communications Company, *Healthcare Information Systems*, September 2006.
http://www.piribo.com/publications/it_ehealth/healthcare_information_systems.html.
[21] Greater Washington Initiative, *Information Technology, Communications & New Media in Greater Washington*, April 2005, p. 4.
[22] Ibid, p. 26.
[23] http://www.whitehouse.gov/infocus/technology/economic_policy200404/chap3.html.

Virginia Health Information Technology Proposals	
Region	**Organizations**
Central Region (including West Central and Eastern Regions)	PatientKeeper – Richmond, Accenture / UVA, MedVirginia, PatientKeeper – Rural, Garnett Medical Records, Misys, Centra Health, Carilion Clinic, Medical Automation Systems, Northern Neck Middle Peninsula Telehealth Consortium
Hampton Roads Region	SDSI, Riverside Health System/Bearingpoint, Eastern Virginia Medical School, Hampton University Proton Therapy Institute, Riverside Medical Group, Cardiovascular Associates, Cardiology & Arrhythmia Consultants
Northern Virginia Region	The Northern Virginia Health Information Collaborative, Prince William Health System, Virginia Hospital Center, GMU, RAM Consulting, INOVA Health System-Erickson Retirement Communities, Urgent Medical Care / USMD, Professional Health Resources, Virginia EHR Alliance
Southside Region	Community Care Network of Virginia
Southwestern Region	Competitive Edge, CareSpark, OneCare
Valley Region	Senior Navigator, Shenandoah Independent Practice Association, Valley Health
Statewide	Value Options, eClinical Works, eHealth Initiative Foundation, IntraNexus, S&P Solutions, Cambridge Systems, Collective Journey Towards Excellence, Vaceris, Prism, Nightingale, OpenMinds, Xstor, Axolotl

Source: Virginia Health Information Technology Council, http://www.healthitcouncil.vi.virginia.gov/summaries.htm

Cybersecurity

Cybersecurity is the use of information technology to protect "information against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional."[24] Software-based cybersecurity technologies include network protection software (e.g., firewalls and virtual private networks [VPN]), content protection software (e.g., anti-virus, anti-spyware, and spam filtering), encryption software (e.g., public key infrastructure), password protection software, and communications security software. Hardware-based cybersecurity products include firewall/VPN hardware, card-based and biometric access controls, encryption hardware, and telephone security devices.

According to Business Insights, the global cybersecurity market was $13.8 billion in 2006, and will grow to $20.6 billion in 2010, with a CAGR of 13%. Business Insights also predicts that "[n]ew security areas such as security information management and vulnerability and patch management will grow rapidly up to 2010."[25] There is also huge market potential for cybersecurity in the United States. The National Academies states that, "[g]iven the growing importance of cyberspace to nearly all aspects of national life, a secure cyberspace is vitally important to the nation, but cyberspace is far from secure today."[26] The Civitas Group also affirms that, "[d]espite the post-September 11 focus on security, the security market is still relatively untapped in the United States and internationally."[27] A current estimate of the U.S. cybersecurity market is $8.7 billion, driven by consulting/risk assessment and outsourcing activities, followed by sales of encryption hardware, biometric access controls, spam filers, and VPN hardware

[24] http://glossary.its.bldrdoc.gov/fs-1037/dir-019/_2726.htm.
[25] Business Insights, *Future Opportunities in IT Security*, 2007, p. 25.
[26] National Research Council and National Academy of Engineering, *Toward a Safer and More Secure Cyberspace*, 2007, p. 1. http://www.nap.edu/catalog.php?record_id=11925.
[27] Civitas Group, *The Homeland Security Market*, November 2006, p. 6. http://www.civitasgroup.com/reports/20061208.pdf.

and software. The Freedonia Group also predicts that the U.S. information security market "will grow 19 percent annually through 2008 driven in part by efforts to integrate security on enterprise-wide bases."[28]

In terms of federal spending, according to the Greater Washington Initiative, federal contracts for cybersecurity are expected to increase by 27% nationally over the next five years.[29] In 2006 the federal government spent $18 billion on homeland security, and approximately 8% was directed towards cybersecurity.[30]

Virginia is well-positioned to be a strong player in the cybersecurity market. Virginia can leverage expertise from both its strong National Security sector and its solid IT Services cluster, along with its proximity to the federal government / Department of Homeland Security. Virginia has the leading expertise in systems integration necessary to meet the demand from both the public and private sectors for comprehensive, integrated security systems, as well as use this as an opportunity to enhance its software development capabilities. Also, Virginia's cybersecurity R&D assets include: the first university program on information systems security in the U.S., George Mason University's Center for Secure Information Systems; DoD's Command, Control, Communications, and Intelligence Research and Development Center at MITRE (C3I FFRDC); and R&D efforts at private companies, such as GBS Laboratories and Smart Technology.

Cluster and Technology Foundations

Cluster Fundamentals

Virginia's Information Technology Services industry was selected for inclusion in this report because of its strengths along several dimensions. For one, IT Services has a strong industry base (see following table) because of Virginia's proximity to the federal government. Its employment concentration is extremely high – over two-and-a-half times the national average statewide and over six times the national average in Northern Virginia. Demand for skilled workers in the region continues to outpace supply. Through surveys with employers in Northern Virginia and surrounding areas, the Greater Washington Initiative found a real shortage of workers with skills in system integration, web services, data management, data mining, and network management.[31] Also, relative to other sectors, this sector experienced the highest growth in number of establishments (16%) from 2003 to 2005, which probably reflects IT's lion's share of venture capital funding in Virginia (74% in 2006 for IT-related industries). In addition, as described in further detail below, Virginia possesses significant R&D assets, including private and university R&D facilities, which are strong producers of patents and publications.

Furthermore, there are many new opportunities for growth into promising markets such as health IT and cybersecurity, which play on Virginia's competitive advantages such as its proximity to the nation's capital and its related expertise in other areas, such as national security and health care. The

[28] http://www.freedoniagroup.com/Information-Security.html.
[29] Greater Washington Initiative, *Information Technology, Communications & New Media in Greater Washington*, April 2005, p. 3.
[30] http://www.homelandsecurityweekly.com/features/us-market-forecast-140-billion-010507.
[31] Greater Washington Initiative, *Information Technology, Communications & New Media in Greater Washington*, April 2005, p. 16.

confluence of all these strengths and opportunities make IT Services an industry that cannot be overlooked.

Technology Development Assets

There is significant R&D activity in IT Services in Virginia, particularly in the private and university R&D laboratories. There are at least twenty private R&D centers. Smart Technology, Inc. and GBS Laboratories focus on cybersecurity R&D. Insight Therapeutics conducts health IT R&D, specifically in health management programs, data safety monitoring, and data management and analysis. University R&D, which comprises at least twelve labs in Virginia, is also thriving. In particular, George Mason University has recently opened two security-related IT R&D centers, Center for Secure Information Systems and C4I Center, which are among the nation's first such university centers.

Virginia University IT R&D Centers		
University	Center	Description
George Mason University	Center for Computational Fluid Dynamics	Uses a systematic application of computing systems and computational solution techniques to mathematical models formulated to describe and simulate fluid dynamic phenomena.
George Mason University	Center for Distributed and Intelligent Computation	Focuses on the design, development, and implementation of distributed and intelligent systems.
George Mason University	Center for Secure Information Systems	The nation's first university research program in information systems security, including information secrecy, integrity, and availability problems.
George Mason University	Center of Excellence in Command, Control, Communications, Computing and Intelligence (C4I Center)	Performs research in military applications of IT, including information systems, modeling and simulation, sensing and fusion, communications and signal processing, C3 architectures, and command support and intelligent systems.
Old Dominion University	The Virginia Modeling, Analysis and Simulation Center (VMASC)	A multi-disciplinary modeling, simulation and visualization collaborative research center.
The College of William & Mary	SciClone Cluster	A heterogeneous cluster computing system designed to support a variety of activities in Computational Science.
University of Virginia	Center for the Management of Information Technology	Promotes research and education in areas relating to the management of information technology through a program of interdisciplinary cooperation.
University of Virginia	Center for Risk Management of Engineering Systems	Develops theory, methodology and technology to assist in the management of risk for a variety of engineering systems.
University of Virginia	Virginia Center for Grid Research	Performs research and solves issues surrounding the operation, deployment and use of large distributed data and computing systems.
Virginia Tech	Center for Geospatial Information Technology	Integrates geospatial information technology into the university's research, teaching, and outreach mission.
Virginia Tech	Center for Wireless Telecommunications	Helps companies develop new products and services using wireless technologies, including the deployment of wireless broadband in rural Virginia through the use of LMDS.
Virginia Tech	Center for Human Computer Interaction	Works on diverse basic and applied projects in such areas as multimedia information systems, digital libraries, visualization of scientific data and processes and virtual environments.

Virginia Federal IT R&D Centers		
Agency	Facility	Description
Department of Defense	Defense Advanced Research Projects Agency (DARPA)	The central research and development organization for the Department of Defense, which sponsors revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.
Department of Defense	Office of Naval Research (ONR)	Coordinates, executes, and promotes the science and technology programs of the United States Navy and Marine Corps through schools, universities, government laboratories, and nonprofit and for-profit organizations.
Department of Defense	Air Force Office of Scientific Research (AFOSR)	Supports Air Force goals of control and maximum utilization of air, space, and cyberspace by investing in basic research efforts for the Air Force in relevant scientific areas.
Department of Defense / MITRE	Command, Control, Communications, and Intelligence Research and Development Center (C3I FFRDC)	Supports the development and fielding of electronically-based air defense systems through information systems technology coupled with domain knowledge.

Research Outputs

IT R&D organizations in Virginia produced 3,413 publications between 2001 and 2006, with Virginia Tech and four other universities leading the way. In terms of patent activity in Virginia, apart from the U.S. Navy, the leaders were mainly private sector firms. In 2006 1,002 patents related to IT and telecommunications were granted in Virginia.

Virginia Leading IT R&D Organizations by Publication Output	
Organization	Publications (2001-2006)
Virginia Tech	1012
University of Virginia	596
George Mason University	596
College of William and Mary	261
Old Dominion University	228
NASA	196
Virginia Commonwealth University	146
United States Navy	131
Science Applications International Corporation	66
Mitre Corp	55

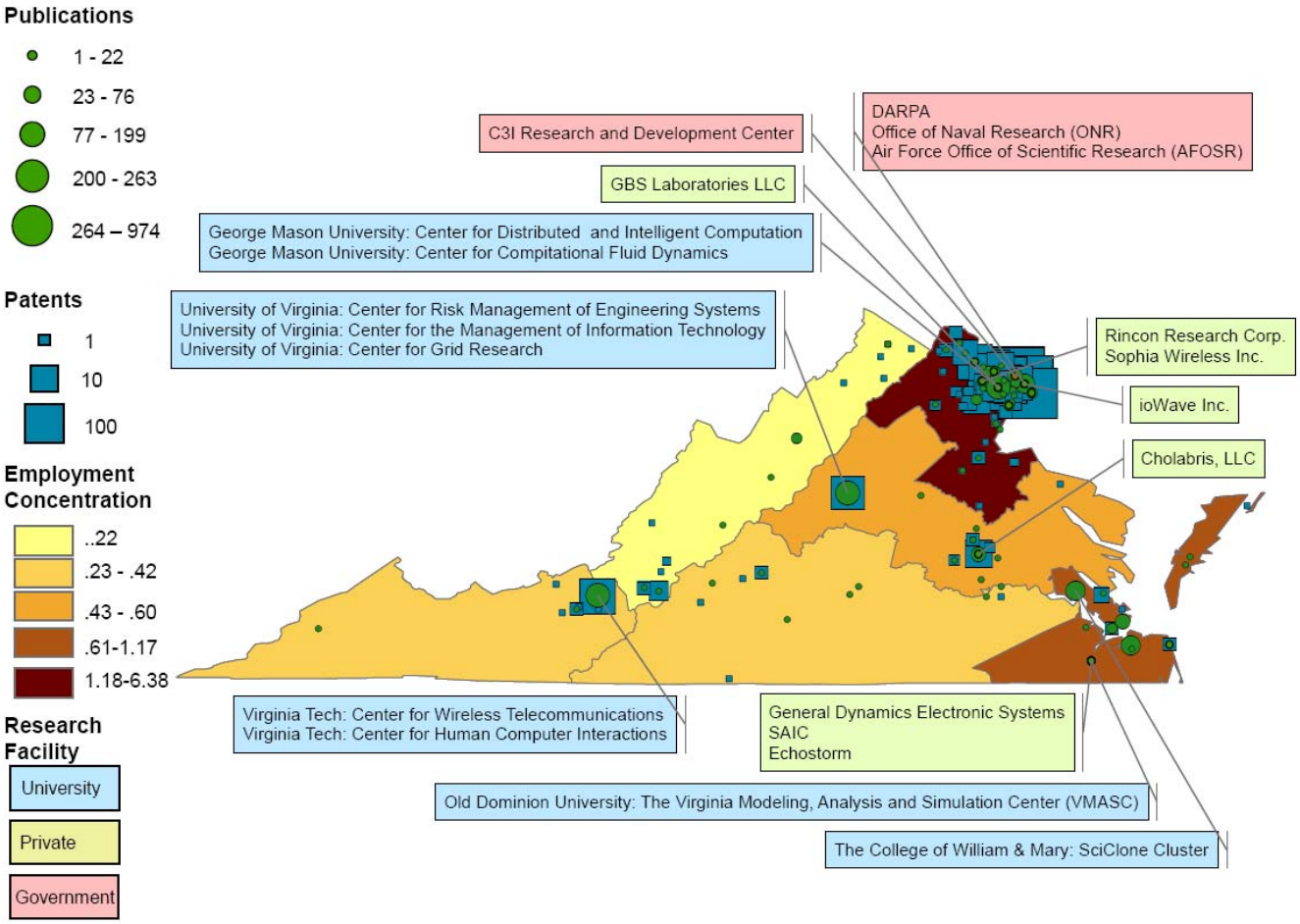
Source: SRI Analysis of ISI Web of Science Data

Patent Assignee Organizations for Virginia Developed Technologies	
Organization	Patents (2006)
United States Navy	24
IBM	20
Cisco Technology, Inc.	12
Cadence Design Systems, Inc	8
America Online, Inc	7
Verizon Services Corp	7
ATC Technologies, LLC	6
Current Technologies, LLC	6
Freescale Semiconductor, Inc.	6
Lockheed Martin Corporation	6

Note: Assignee may not be located in Virginia, but at least one inventor listed on the patent is based in Virginia.
Source: SRI Analysis of Delphion Data

Cluster Map

Publication and patent activity in Virginia tends to be concentrated around the universities, and also in Northern Virginia. This is not surprising considering Northern Virginia's proximity to the nation's capital, which also explains the region's notably high employment concentration, the highest in the state followed by Hampton Roads.



Health Care and Biomedical Sciences

Cluster and Technology Overview

Description and Major Subsectors

The Health Care sector includes companies and organizations that deal with the prevention, treatment, and management of illness and the preservation of mental and physical well-being. The Biomedical Sciences sector emphasizes the research and product development side of health care. Biomedical companies and organizations perform molecular, cellular, and biochemical research into how cells, tissues, and organs function in health and disease states, and how to translate this knowledge into the development of better therapeutics. These two sectors include several very large industry sub-sectors: hospitals; physicians and other professional services; nursing homes and home health care; pharmaceuticals; diagnostics; medical devices; and medical equipment.

Sub-Sectors Overview		
Sub-Sector	Description	Examples of Large Companies
Hospitals	Companies that provide general medical and surgical services and other hospital services.	HCA, Ascension Health, Tenet Healthcare
Physicians, Dentists, Other Professional Services	Companies that provide general medical, surgical, dental, optometric and other services.	Individual or partner-owned practices
Nursing Homes and Home Health Care	Companies and non-profit charities that operate 60,000 long-term care facilities (assisted living centers and nursing and retirement homes), as well as provide various health care services.	HCR Manor Care, Sun Healthcare Group, Sava Senior Care
Pharmaceuticals (including Diagnostics)	Companies that develop, manufacture and sell chemical or biological substances for medical and veterinary use, including branded and generic drugs and biopharmaceuticals; vaccines; vitamins; nutritional supplements; drug delivery systems; and diagnostics.	Bristol-Myers Squibb, GlaxoSmithKline, Pfizer
Medical Devices	Companies that develop, manufacture and sell implantable devices, such as stents, pacemakers, artificial hearts, orthopedic devices, etc.	Johnson & Johnson, Medtronic, Boston Scientific
Medical Equipment	Companies that develop, manufacture, and market medical and dental instruments, supplies, or surgical equipment, including syringes, respiratory care equipment, wheelchairs, X-ray equipment, magnetic resonance imaging (MRI) machines, laser systems, and so forth.	Johnson & Johnson, GE Healthcare, Boston Scientific

At both the individual and national level, health care expenditures are highly and positively correlated with income and age.[32] The United States spent $2 trillion in 2005, or 16% of gross domestic product (GDP)—a larger share of GDP than in any other developed country in the world (average for developed countries is 13%). The Centers for Medicare and Medicaid Services (CMS) estimate that U.S. health care expenditures grew at a CAGR of 7.8% from 2001 to 2005. CMS projects continued rapid growth in health care expenditures of 6.9% per year from 2006 to 2016. With increasingly higher average life spans and significant aging of the populations in the United States, European Union countries, China, Japan and Brazil, among others, global health care expenditures are likely to increase for the foreseeable future in gross terms and as a share of GDP. The World Health Organization estimates global world health expenditures totaled $4.1 trillion in 2004.[33]

Health care and biomedical sciences draw on a broad range of technological advances in health care delivery, information management, drugs and drug delivery systems, diagnostics, medical devices, and medical equipment. Specific health care technologies, such as electronic medical records, telemedicine, point-of-care diagnostics, and radio-frequency identification (RFID) inventory control, are important inputs into the national healthcare system. Improvements to these technologies and higher adoption rates of such technologies in the coming decades will improve healthcare delivery efficiency and increase cost savings. This is important, since close to half of U.S. healthcare expenditures today are financed by the Federal government, and future government funding of health care spending is unsustainable at the currently projected rate of increase. When health care industry analysts model future health care expenditures based on historical trends, they find that U.S. health care expenditures as a percentage of GDP could rise from 16% today (only 5% in 1960) to between 25%-35% in 2050.[34]

[32] Organization for Economic Co-operation and Development (OECD) countries spend a larger share of their GDP on health, spending on average more than 11%, compared with 4.7% for countries in African and South-East Asia regions. This translates to per capita spending of about 3,080 international dollars (US$ 3170) in OECD countries compared with 102 international dollars (US$ 36) in countries in the African and South-East Asia regions, which are much poorer. World Health Organization, *World Health Statistics 2007*, http://www.who.int/whosis/whostat2007_10highlights.pdf.
[33] http://www.who.int/whosis/whostat2007_10highlights.pdf
[34] Federal Reserve Bank of San Francisco (2005). "More Life vs. More Goods: Explaining Rising Health Expenditures," *FRBSF Economic Letter*, 27 May 2005, http://www.frbsf.org/publications/economics/letter/2005/el2005-10.html

Health Care Technology Market Outlook			
Technology	Description	Estimated Market Size	Estimated Growth Potential
Information Technology[1]	Applications include electronic medical records, telemedicine, medical imaging, and scenario simulation. Future advances in these areas are anticipated to greatly reduce health care administrative costs, enhance medical treatment efficiency, and stimulate further research in areas such as epidemiology and disease research.	$29.4 billion (2006, global)	5% CAGR through 2015
Virtual Reality[1]	Healthcare applications include education and training, visualization of medical data for medical diagnosis, and minimally invasive surgery. Advanced imaging technologies (CT scans, MRI, and PET scans) enabling 3D virtual representations of organs have underpinned development in this technology.	$200 million (2008, global)	10% CAGR through 2010
Radio-frequency Identification (RFID)[1]	Bar coding and radio-frequency identification technology is being implemented in inventory control and supply chain management at hospitals and pharmacies, as well as in visitor and staff identification at hospitals, etc., for permitting or denying access.	$474 million (2008, global)	60% CAGR through 2012
Point-of-Care Diagnostics[2]	A new generation of diagnostics technologies based on advances in nanotechnology, microsystems, biotechnology and information technology. Point-of-care (POC) testing allows patient diagnoses by non-specialists outside the hospital or the physician's office.	$10 billion (2005, global)	6% CAGR through 2010

Source: [1]MarketResearch.com, [2]Business Insights

On the biomedical side, one of the most visible technological advancements is in the area of "biotechnology". Modern biotechnology is built upon a diverse set of technologies that manipulate cellular, subcellular, or molecular components in living things for use in product and process applications across a wide range of industries—though medical biotechnology remains the dominant application area. Advances in molecular biology and biochemistry have helped researchers to better understand the molecular pathways of disease and to identify proteins produced by the human body in small quantities but with important functions. New recombinant DNA technology has enabled researchers to produce some of these critical proteins in quantities sufficient for therapeutic use (e.g., insulin, growth hormone, monoclonal antibodies, etc.) The first biologic therapeutic, or biopharmaceutical—human insulin—was introduced in 1982, and 142 biopharmaceutical products have entered the global market since then. Biopharmaceuticals currently account for 10% of the global pharmaceutical market.[35] In addition to contributing to the development of new therapeutics (e.g., pharmaceuticals and biopharmaceuticals) and preventatives (i.e., vaccines), biotechnology has led to the development of new diagnostic techniques and novel approaches to treating genetic diseases or diseased tissues and organs—e.g., stem cell

[35] Zika, E., et al. (2007). *Consequences, Opportunities and Challenges of Modern Biotechnology for Europe*. Joint Research Centre Reference Reports. Brussels: European Commission.

therapy, tissue engineering, and gene therapy. However, considerable R&D remains to be done in this last category of emerging biotechnologies before they are ready for large-scale clinical adoption.

A significant milestone in mankind's entry into the biotechnology age was the completion of the draft sequence of the human genome in 2000. This highly successful, large-scale science project represented a departure from traditional, hypothesis-driven biological research (a small group of researchers working on a discrete problem). The Human Genome Project involved a vast number of actors collaborating internationally and across organizations in academia, federal labs, private labs and private companies. The nature of the project and the large bodies of data generated required parallel R&D and technological advances in biomedical research tools, e.g., the collection and analysis of large datasets (e.g., bioinformatics and computational biology); high-throughput screening and analysis (e.g., DNA microarrays and high-throughput DNA sequencers), and three-dimensional structure (e.g., proteins) modeling and imaging. Therefore, fundamental to future advances in biotechnology-based medicine are concurrent advances in computational technologies.

Biomedical Technology Market Outlook

Technology	Description	Estimated Market Size	Estimated Growth Potential
Therapeutics[1, 2]	These include small-molecule drugs (pharmaceuticals and generics) and biologics (biopharmaceuticals and biosimilars). Industry growth has slowed considerably in recent years (from the double digits to 7%) due to a significant decline in R&D productivity.	$643 billion (2006, global)	3-10% CAGR through 2015
Preventatives[3]	The dominant growth segment within this technology area is vaccines. Analysts expect strong growth in this segment driven by influenza, hepatitis, cancer and HIV vaccines.	$10 billion (2007, global)	19% CAGR through 2012
In-Vitro Diagnostics[4]	These include tests based on clinical chemistry, immunochemistry, hematology, microbiology and DNA. Technologies that can identify genetic predisposition to disease are the vanguard in this area, as well as the convergence of medical imaging with diagnostics.	$30 billion (2005, global)	6% CAGR through 2010
Emerging Biotechnologies	Stem cell therapy, tissue engineering, gene therapy	n/a	n/a
Medical Devices[5]	Advances in molecular biology, bioengineering and biomaterials are expected to lead to significant improvements in implantable medical devices, such as stents, pacemakers, artificial valves and hearts, orthopedic devices, etc.	$150 billion (2005, global)	8% CAGR through 2010
Computational Technologies	Includes methods for data analysis, modeling, and simulation for the study of biological systems (e.g., computational biology), as well as the application of computational tools for expanding the use of biological and medical data (e.g., bioinformatics and pharmacogenomics).	n/a	n/a

Source: [1]IMS Health, [2]Business Insights, [3]Kalorama Information, [4]Business Insights, [5]Frost & Sullivan

High Growth Potential Technologies for Virginia

Point-Of-Care Diagnostics

Diagnostic tests are important for accurately diagnosing disease, but also for monitoring blood sugar, cholesterol, hormone levels, and other indicators of a patient's response to treatments. Typically, patients receive diagnostic tests at physicians' offices or in the hospital. However, the ability to monitor levels remotely—e.g., monitoring blood sugar levels in diabetics or red and white blood cell counts in cancer patients—is beneficial in providing information more quickly to the patient and to healthcare specialists. A new generation of diagnostics technologies based on advances in nanotechnology, microsystems, biotechnology and information technology could significantly reshape modern health care. Point-of-care (POC) testing allows patient diagnoses by non-specialists outside the hospital or the physician's office. It is a key enabling technology in the shift from conventional medicine to personalized medicine. At the public health level, point-of-care diagnostics used in conjunction with information systems could also help improve the design of clinical protocols by analyzing larger amounts of data on the target metric from many different locations, e.g., hospitals or clinics. This is desirable in terms of increasing the overall efficacy of health care and reducing costs.

For example, a Virginia contract research organization and a Virginia-based diagnostic company recently collaborated on the following challenge: Few hospitals have been able to achieve the standards for inpatient glycemic (i.e., blood sugar) control for critically ill patients recommended by the American Association of Clinical Endocrinologists/American College of Endocrinology (AACE). The "lack of integrated information systems that allow tracking and trending of glycemic control and hypoglycemia metrics" was cited as a barrier to the implementation of evidence-based glycemic control programs. AACE recommended "a system to track hospital glucose data on an ongoing basis to be able to assess the quality of care delivered." The Virginia-based diagnostic company developed a POC diagnostic test for measuring and monitoring inpatient glucose levels in hospitals. The contract research organization conducted a study at 10 U.S. hospitals to measure the value that the technology brought to health care professionals implementing and monitoring glycemic control protocols.

The study found statistically significant improvements (i.e., a decrease in average glucose levels) in 8 of the 10 hospitals following the implementation of the POC diagnostic technology. In addition, a higher proportion of glucose values were in the target range following implementation versus before installation (39.8% versus 30.1%).[36]

Another emerging and related POC diagnostic technology area is pharmacogenetic tests. Pharmacogenomics is the study of how a person's genetic makeup affects that individual's response to a particular medication. Many factors influence an individual's response to medicines, e.g., environment, age, state of health, etc. However, analysts predict that the development of pharmacogenetic tests will provide a critical link in personalized medicine identifying patients most likely to respond to a particular drug, to develop resistance to a drug, or to require modifications to dosage in a range of drugs.[37]

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[36] Bloomgarden Z, Mechanick JI (2007). Acute glycemic control in hospitalized patients: Evidence published since the American College of Endocrinology Position Statement. *Insulin*. 2007 2:12-23 and http://www.epsilongroup.com/disease.htm#poc.
[37] Marchant, Jeanette (2006). *Innovations in Diagnostics*, p.14. Business Insights report.

Virginia has a number of university research centers focusing on research related to POC technologies, e.g., the discovery of molecular biomarkers of disease that could serve as the basis for new diagnostic tests. Some of these include the Center for Comparative Oncology at Virginia Tech and the Center for Applied Proteomics and Molecular Research at George Mason University. Strong chemistry and biochemistry departments are also important in diagnostics research. On the clinical side, assets include research-oriented healthcare systems, such as the INOVA Health System and the University of Virginia Health System.

Small biomedical and diagnostic companies are clustered around the state's major universities.[38] Virginia also boasts a number of IT companies with the capacity to pivot and apply their information systems expertise to the diagnostics field in partnership with innovative biomedical companies. Information technology plays an important role in the relay of POC diagnostic data to a central database and the evaluation of these data that will lead to guidelines for improved clinical practice.

Computational Technologies

Bioinformatics and computational biology provide a research platform to acquire, manage, analyze, and display large amounts of data. Both draw on analytical methods borrowed from computer science, mathematics, statistics, and the physical sciences. Bioinformatics and computational biology tools are critical for the following reasons:

- They allow "classically" trained biomedical researchers to sift through masses of genomic data to understand and research specific areas of interest;
- They catalyze a systems approach (looking at the whole rather than the parts) to understanding biological organisms and vexing medical problems by facilitating the development of fundamental new research strategies; and
- They enable researchers to make useful predictions about biological responses to environmental and other perturbations (e.g., introduction to a bacteria or virus).

Every time a genome is fully sequenced, scientists have access to a complete list of every gene, and thus every protein, an organism can make. The completion of human genome project in 2000, together with fully completed genome sequences for many other organisms (from mammals to microbes), allow researchers to pursue, for the first time, experimental strategies that examine biological processes at the "genome-scale." On the other hand, the explosion of genomic information also presents the potential for information overload. The functions of 1% of the 60,000 human proteins that researchers recognize are difficult enough to remember, let alone the study of the other 99%. Therefore, the promise of bioinformatics and computational biology is to reduce the volumes of genomic and proteomic data being generated to a usable form for researchers, so they may make predictions and test biological and biomedical hypotheses.[39]

Many of Virginia's universities have centers dedicated to bioinformatics and computational biology research pursuits. These include Virginia Commonwealth University's Center for the Study of Biological Complexity and Virginia Tech's Bioinformatics Institute, among others. In addition, the location of the new

[38] Some University of Virginia diagnostic start-ups include ContraVac, HemoSonics, Phthisis Diagnostics and MicroLab Diagnostics.
[39] This explanation of bioinformatics and computational biology draws heavily on information from the University of Virginia Health System website, http://www.healthsystem.virginia.edu/internet/bims_scbb/compbiol.cfm.

Howard Hughes Medical Institute campus in Loudon County and the SRI Center for Advanced Drug Research in Rockingham County will also advance biomedical research activity in the state. In the private sector, companies such as life sciences informatics company, INCOGEN, are collaborating with universities and medical schools to create new computational research platforms. For example, in 2004, INCOGEN won a $2 million, two-year Phase II SBIR award from the National Cancer Institute to continue its proteomics collaboration (focusing on the discovery of cancer biomarkers) with the College of William and Mary and Eastern Virginia Medical School.

Cluster and Technology Foundations

Cluster Fundamentals

The Health Care and Biomedical Sciences industry cluster was selected by the SRI team based on its established industry base and strong growth potential. Measured by employment, this industry sector was Virginia's fifth largest in 2005. The aging of the U.S. population is driving strong growth in health care services, and the Bureau of Labor Statistics identifies health care service occupations and scientific and professional occupations in the pharmaceutical and biomedical industries as future high-growth occupations, especially for graduate-degree holders. Within Health Care and Biomedical Sciences, the pharmaceutical and medical equipment industry segments are at a very rudimentary stage of development, representing only 2 percent of total cluster employment. However, the biomedical sciences is a sector in which Virginia may be able to build based on current university R&D strengths, strong market demand, and nascent private sector activity. The pharmaceutical industry segment includes diagnostic companies, and this is an area where Virginia has university start-up activity. Virginia also has a very high concentration of IT service companies, some of whom would be capable of pivoting and moving towards health care and biomedical applications.

Technology Development Assets

The majority of Virginia's Healthcare and Biomedical R&D centers belong to universities. The only private R&D center with more than 50 employees is the Wyeth Consumer Healthcare Company in Richmond that specializes in pharmaceutical and consumer health care products. The universities conduct research on topics such as the genomic basis of disease, regenerative medicine, bioinformatics, and clinical research on cancer. There are two biomedical federal R&D centers, both affiliated with the Department of Defense, whose topics of research into advancing U.S. military technology include some biomedical and medicine applications.

Virginia University Biomedical R&D Centers		
University	Center	Description
James Madison University	SRI Center for Advanced Drug Research	Improve the productivity of the pharmaceutical industry, help our nation respond to biothreats, and develop life-saving treatments for neglected and orphan diseases. The CADRE mission is the creation of new diagnostics, therapeutics, and vaccines for infectious and neglected diseases and for biodefense. The Center combines SRI's well-established expertise in drug discovery, computational biology, and preclinical development with a new proteomic laboratory to develop these solutions.
George Mason University	Center for Applied Proteomics and Molecular Science	Research in the Center will focus on the discovery and identification of biomarkers for early disease detection and risk assessment and the analysis of molecular pathways in diseased tissue to determine individualized and targeted treatment for patients.
George Mason University	Center for Biomedical Genomics	The CBMG studies the genomic basis of disease by determining differences in gene expression between diseased tissue and normal tissue. The Center uses genomic microarray printers to develop slides containing all the genes for a given organism. Research has focused on the genomic basis of fibrosis, obesity and cancer. Collaborations include work with INOVA Healthcare Systems.
George Mason University	National Center for Biodefense and Infectious Disease	NCBID scientists explore innovative approaches for prevention, diagnosis, and treatment of infectious diseases caused by biological agents, as well as the development of unique environmental detection methods for these agents.
University of Virginia	Morphogenesis & Regenerative Medicine	The goal of the Institute was to identify topics in which the University of Virginia could build on existing strengths in biomedical sciences to become an international leader in research and education. It identified Morphogenesis and Regenerative Medicine (initially called "Biodifferentiation") as a broad-based, thematic, and integrative initiative in which to make a major long term investment.

Virginia University Biomedical R&D Centers		
Virginia Commonwealth University	Center for the Study of Biological Complexity	The mission of the Center is to build an academic community centered on integrative discovery science, systems biology and the principles of complexity to address the challenges of the life sciences revolution of the 21st century. The Center develops and supports critical infrastructure and core capabilities at VCU in genomics, proteomics, and computational systems biology and bioinformatics.
Virginia Tech	Fralin Biotechnology Center	An interdisciplinary research center at Virginia Tech whose purpose is to bring scientists from different disciplines together under one roof to solve some of biology's more complex challenges.
Virginia Tech	Virginia Bioinformatics Institute	Serves as a flagship bioinformatics research institute wedding cutting-edge biological research with state-of-the-art computer science. It encourages research collaboration to increase the understanding of molecular, cellular, and environmental interactions that affect human health, agricultural systems, and the environment.
Virginia Tech	Virginia Tech Center for Genomics	Represents an interdisciplinary effort to provide a focus for research and teaching in functional genomics, statistical genetics, bioinformatics, and molecular engineering.
Virginia Tech	Virginia Tech - Wake Forest School of Biomedical Engineering and Sciences	Purpose is to "provide a framework for the generation and dissemination of knowledge through research and education for the improvement of human and animal health through cooperative advancement in engineering, science and medicine."
Virginia Tech	Center for Comparative Oncology	An academic center for basic and clinical research on cancer. The mission of CeCO is to study the development of cancer in animals and in people, to develop new ways to diagnose cancer and to find new treatments to control and cure it.
Virginia Tech	Center for Molecular Medicine and Infectious Diseases	Design preventive strategies that include designing more effective vaccines, reducing exposure levels to chemicals, and use of immune modulation. Special research emphasis is placed on the use of recombinant DNA technology, gene cloning, analysis of genes and proteins, murine cell culture for immunological analysis, cell signaling and array analysis. Act as a resource center for molecular biological and immunological work involving infectious diseases, immune-mediated diseases.

Virginia Federal Biomedical R&D Centers		
Agency	Facility	Description
Department of Defense	Defense Advanced Research Projects Agency (DARPA)	DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.
Department of Defense	Air Force Office of Scientific Research (AFOSR)	AFOSR's technical experts foster and fund research within the Air Force Research Laboratory, universities, and industry laboratories to ensure the transition of research results to support USAF needs. Using a carefully balanced research portfolio, research managers seek to create revolutionary scientific breakthrough, enabling the Air Force and U.S. industry to produce world-class, militarily significant, and commercially valuable products.

Research Outputs

Biomedical sciences R&D organizations in Virginia produced 5,712 publications between 2001 and 2006, with the University of Virginia, Virginia Commonwealth University, and Virginia Tech leading the way. Patent activity in Virginia was relatively low, with most of the activity coming from private sector firms. In 2006, 24 patents related to biomedical sciences were granted in Virginia.

Virginia Leading Health Care and Biomedical Sciences R&D Organizations by Publication Output	
Organization	Publications (2001-2006)
University of Virginia	2138
Virginia Commonwealth University	1708
Virginia Tech	697
University of Virginia Health System	390
Eastern Virginia Medical School	261
George Mason University	141
United States Navy	122
College of William and Mary	104
Old Dominion University	80
Virginia-Maryland Regional College of Veterinary Medicine	71

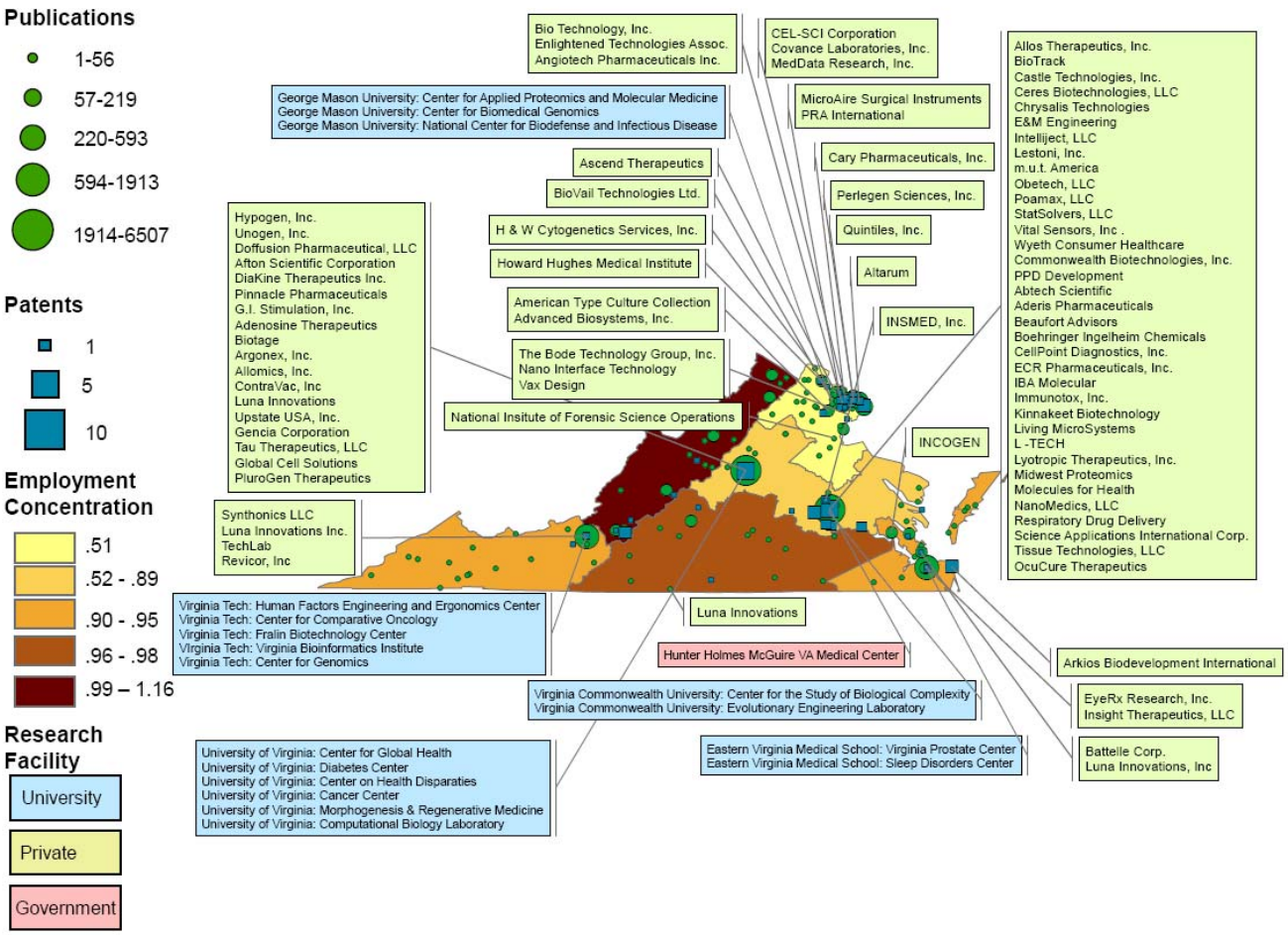
Source: SRI Analysis of ISI Web of Science Data

Patent Assignee Organizations for Virginia Developed Health Care and Biomedical Technologies	
Organization	Patents (2006)
Nordt Development Co., Inc.	4
E-Vision, LLC	3
Virginia Commonwealth University	3
Essilor International (Compagnie Generale d'Optique)	2
Ethicon, Inc.	2
GelZone, Inc.	2
Georgetown University	2
Interhealth Nutraceuticals Incorporated	2
New River Pharmaceuticals Inc.	2
Nutrition 21, Inc.	2

Note: Assignee may not be located in Virginia, but at least one inventor listed on the patent is based in Virginia.
Source: SRI Analysis of Delphion Data

Cluster Map

Publication and patent activity in Virginia tends to be concentrated mainly in Northern Virginia and around the major universities. There are also pockets of activity in the Southside and Valley regions, which are the regions that also have the highest employment concentration in the health care and biomedical sciences field.



Materials and Chemicals

Cluster and Technology Overview

Description and Major Subsectors

Advanced materials have been called a "third wave of revolutionary innovation", with potential impact on the same scale as the IT revolution or biotechnology.[40] The OECD asserts that materials technology, alongside genetics technology, energy technology, brain technology, and information technology, will be a "great enabler" or "fundamental shapers of the next stages of the human enterprise".[41] Materials technologies, such as concrete, have been employed since the dawn of civilization. The importance of materials technologies is so profound that history is often viewed through the lens of dominant material of the day, from the Stone Age, to the Bronze Age, to the Iron Age, to the age of steel, silicon and beyond. The development of artificial materials such as Rayon and synthetic materials such as Nylon in the early 20th century ushered in a new materials era and forged a bond between the chemicals and materials industries. The chemicals industry also underwent a transformation in the late 19th and early 20th century with a technological revolution centered on synthetic dyes, soda ash and explosives that ultimately lead to the creation of giant market leading firms such as DuPont and BASF.

Materials and chemicals are both "generic technologies", i.e., they enable advances in a broad range of sectors throughout the economy. Many of the technologies that make modern society possible are based directly or indirectly on advances in the materials and chemicals industry. Significant consumers of chemical products include the consumer products industry, the automotive industry, the construction industry, the textile industry, and agriculture.[42] Approximately one quarter of U.S. jobs are in industries that depend on inputs from the chemicals industry.

The materials and chemicals industry is broad and therefore difficult to measure accurately. The American Chemistry Council reports that the industry directly employs 900,000 workers in the United States and is further responsible for an additional 5.8 million associated jobs in related businesses.[43] Non-industry estimates are more conservative, but each job in the chemical industry creates as estimated 2 and 5 related jobs in the broader economy.[44] The U.S. Department of Commerce estimated revenues of $709 billion in the U.S. chemicals industry in 2006, up 12% from the previous year.[45] These estimates include a significant portion of the materials market, notably synthetic materials and composites which are largely produced by chemicals firms. Other significant materials markets include metals such as steel and aluminum, valued at $77.6 billion and $5.9 million respectively, in 2006.[46]

From metals to advanced composite materials to laundry detergent, the Chemicals and Materials industry produces a broad range of products that rely on a diverse set of technologies. The table below

[40] http://motresearch.bus.sfu.ca/Papers/Commercialisation_IJTM_Final.pdf
[41] http://www.oecd.org/dataoecd/41/16/35391210.pdf
[42] The European Chemical Industry in Worldwide Perspective. CEFIC. December 2006.
[43] http://www.americanchemistry.com/s_acc/sec_article.asp?CID=136&DID=576
[44] Based on estimates from CEFIC and the American Chemistry Council
[45] Standard & Poors
[46] Datamonitor

highlights several significant sub-sectors, based on product produced, within this industry. Several large industry players such as BASF or Dow Chemical Company produce a range of products across several sub-sectors, while other firms such as Mosaic Co. are focused on more targeted products and markets.

Sub-Sectors Overview		
Sub-Sector	Description	Examples of Large Companies
Metals	Properties such as ductility, tensile strength, availability, and low cost of production kept metals at the forefront of the materials industry throughout the 20th century. Innovation in the metals industry has driven the development of new alloys with desirable properties and more efficient manufacturing processes. Steel and aluminum are the two largest products in the U.S. industrials metals sector. The U.S. steel market fragmented, but international competition, technological innovation, and rising materials costs are driving consolidations within the sector. The Aluminum market by contrast is already highly concentrated with the top two North American producers responsible for 28% of global production.[47]	ArcelorMittal, Alcan Inc., Alcoa Inc.
Synthetic Materials	Synthetic materials are derived from a variety of feedstock materials. Celluloid, one of the first synthetics, was developed in the 1860's using cellulose molecules from plants. It was not until the early to mid 20th century that scientists developed materials derived from petroleum feedstock, ushering a new era of materials such as Plexiglas, Teflon, and the spectrum of plastics and synthetic fiber materials that make many of today's products possible. Synthetic materials exhibit diverse characteristics including thermoplastics, thermosetting plastics, and elastomers.	BASF, ExxonMobil Chemical Company, Dow Chemical Company
Ceramics and Glasses	Ceramics are more difficult to produce and chemically far more complicated than metals, but demand for materials with extreme properties has brought ceramics to the forefront of materials research. Ceramic and glass materials are inorganic, nonmetallic materials composed of both metallic and nonmetallic elements. Ceramics are usually created using high-temperature processes. There is significant variation in the properties of different ceramic and glass materials, but typical properties that make these materials desirable include: hardness, corrosion resistance, and high strength at high temperatures. The electrical properties of ceramic materials vary significantly from highly effective insulators to semiconductors, to "high temperature" superconductors.	Corning

[47] Standard & Poors

Sub-Sectors Overview		
Composites	Composite materials are the combination of two (or more) natural or synthetic materials, one of which serves as the "bulk" or binding material while the other material provides strength and stiffness. The bulk or binding material is typically referred to as the "matrix," and the strengthening and stiffening material is commonly described as the "reinforcement," the "fiber reinforcement," or simply the "fiber."	DuPont, Dow Chemical, Eastman Chemical, Solutia, and PolyOne
Basic Chemicals	The basic chemicals industry produces both organic and inorganic chemicals. Basic chemical products are intermediate products that used in industrial processes and in the manufacture of products in the chemicals industry and beyond. Chemical products such as industrial gases and pigments are generally not included in this market segment.	BASF
Chemical Products	Dyes, detergents, and other household chemicals are examples of the diverse array of chemical products available in today's marketplace. Products in the paint, coatings, and adhesives segment are largely targeted commercial customers such as the construction industry or the furniture making industry. Household chemicals such as soap and cosmetics & toiletries such as perfume and toothpaste are one the few chemical industry segments targeted primarily at end consumers.	Proctor & Gamble, Colgate-Palmolive, Dupont
Agricultural Chemicals	The agricultural chemicals sector focuses on the production of fertilizers, herbicides, pesticides, and other agricultural chemicals. This is one of the smallest and most narrowly focused sectors of the chemicals industry. Agricultural chemicals have had a significant impact on agricultural productivity, but environmental impacts have led many to reconsider conventional usage patterns and may spur future innovations in this sector.	Monsanto, DuPont, Mosaic Co.

Chemicals and Materials are technology intensive industries. Developments in fields as diverse as biotechnology, nanotechnology, and computing could have significant impact on the future development of new chemical and material products. Among other factors, demand for new process with reduced environmental impact and demand for new materials with enhanced characteristics are driving innovation in the chemicals and materials market. The table below highlights several technologies that will likely have significant impact on future innovations in this market.

Chemicals and Materials Technology Market Outlook			
Technology	Description	Estimated Market Size	Estimated Growth Potential
Biopolymers	Biopolymers, often called bioplastics in the industrial sector, are biologically-derived polymers with a variety of useful functional uses such as: stabilizers, thickeners, gellants, binders, dispersants, lubricants, adhesives, and drug-delivery agents. Polymers are large molecules consisting of repeated structural units (monomers) connected by covalent chemical bonds. Unlike synthetic polymers, biopolymers often have extremely complicated structures which can be difficult to produce in large quantities. Environmental concerns and increasing petroleum costs are among the factors driving increased biopolymer development.	$2.7 billion (2007)	N/A
Biocatalysis	Biocatalysis is the use of biological mechanisms to catalyze chemical reactions. Many researchers believe that biocatalysts will someday be more energy efficient, cheaper, and produce fewer hazardous by-products than chemically catalyzed processes; however, for many potential applications, conventional processes still have a cost advantage. Directed evolution, metabolic engineering, synthetic biology, and protein engineering could all lead to significant improvements in the performance of biocatalytic agents.	$2 billion (2005)	6% CAGR through 2012
Nanomaterials	Most definitions of "nanotechnology" share three common characteristics: 1. *The scale of size*: nanotechnology involves objects generally less than 100 nanometers in size. 2. *Characteristics of matter at the nanoscale*: matter at this scale exhibit "unique behavior" and express "characteristics unique to nano size". 3. *Broad range of potential applications*: nanotechnology has potential applications in almost any conceivable field of science and technology.[48] Nanomaterials could have a significant impact in the chemicals sector as catalytic agents as well as the materials sector with the introduction of advanced composite materials incorporating nanomaterials such as nanoclays or carbon nanotubes.	N/A	Up to $1 trillion by 2015

[48] Igami, Masaturo and Teruo Okazaki. "Capturing Nanotechnology's Current State of Development via Analysis of Patents". OECD. 23-May-2007.

Chemicals and Materials Technology Market Outlook			
Smart Materials	Smart materials respond in specific, predictable ways to environmental stimuli such as temperature, voltage, pressure, magnetic fields, or light. Responses include changes in shape, color, form, phase, or electric, magnetic, or optical properties; responses can be both rapid and extreme. The behavior of many smart materials appears simplistic when viewed in isolation, but embedded in other products, theses materials have significant potential to simplify products, improve performance, or increase reliability. The technology is still in its infancy, but current applications already include piezoelectric speakers, self-dimming automobile mirrors, and self-expanding coronary artery stents.	$6 billion (2005)[49]	10% CAGR through 2010
Green Materials	Green Building Materials are not a single, clearly defined technology, but instead are the application of a diverse set of materials and chemicals technologies to enhance or supplant traditional materials such as lumber, siding, flooring, insulation, millwork and related components. Concerns including energy efficiency, indoor air quality, sustainability and environmental impact are driving the development and more widespread adoption of green building materials in residential, commercial, and industrial construction.	$2.2 billion (2006)[50]	17% CAGR through 2011
Process Control Technologies	The American Chemical Society argues that improvements in process control technologies will permit "higher capital utilization, improved yields, reduced waste production, and improved protection of human health, safety, and the environment."[51] Developments in fields such as MEMS sensors and biosensors, which provide accurate, real-time detection of chemical concentrations and contamination, could have a significant impact in process control for the chemicals and materials industry.	N/A	N/A
Computational Technology	Future breakthroughs in chemistry and materials research will increasingly rely on computation technologies enabled by high performance computing. Key computational technologies for this industry include molecular modeling, computational fluid dynamics, process simulation, and operations optimization.	N/A	N/A

[49] SRIC-BI
[50] ThomasAssociates International
[51] Technology Vision 2020

High Growth Potential Technologies for Virginia

Nanomaterials

Although interest in the research of characteristics of matter at the nanoscale had existed for years, the term "nanotechnology" was first introduced to the research community by Norio Taniguchi in 1974.[52] In 1986, Eric Drexler popularized the term in his much-debated book, *Engines of Creation: The Coming Era of Nanotechnology*, which charted a direction for the future of nanotechnology research and development[53]. However, the launch of the U.S. National Nanotechnology Initiative (NNI, 2000) marked the beginning of an international race to invest in nanotechnology. Some estimates suggest that the "nanotechnology market" will be worth more than $1 trillion by 2015. These estimates are problematic because it is difficult to define a market for nanotechnology, largely because it is difficult to define "nanotechnology" itself. A recent OECD analysis of nano-related R&D activity observed that there is no universally agreed upon definition for "nanotechnology", but noted that the definitions employed by national programs such as the NNI or the EU's 7th Framework Program share three common characteristics:

1. *The scale of size*: nanotechnology involves objects generally less than 100 nanometers in size.
2. *Characteristics of matter at the nanoscale*: matter at this scale exhibit "unique behavior" and express "characteristics unique to nano size".
3. *Broad range of potential applications*: nanotechnology has potential applications in almost any conceivable field of science and technology.[54]

Because of the broad range of potential applications for nanotechnology and the broad range of technologies encompassed by the term "nanotechnology", any market forecast must be viewed with significant skepticism. Despite this, nanotechnology's potential to revolutionize fields as diverse as materials, life sciences, and energy, assures the field's prominence in national science and technology programs. Additionally, many improvements in biosensors, pharmaceuticals, MEMS sensors, and microstructures are related to nanotechnology. Nanotechnology is still a technology in its infancy, but as of October 2007, the Project on Emerging Nanotechnologies reports that 580 consumer products or product lines contain nanotechnology components. More than 60% of these products are related to "health and fitness", notably cosmetics, clothing and other personal care products. Other consumer product applications include: "home and garden", "electronics and computing", "food and beverage", "automotive", and "appliances".[55]

Worldwide investments in nanotechnology were estimated to exceed $8.6 billion in 2004.[56] Lux Research estimates that that nanotechnology funding reached $12.4 billion worldwide in 2006.[57] Government's fund approximately half of global nanotechnology R&D, or $6.4 billion in 2006. Governments in North America, Europe, and Asia each contribute approximately one-third of the total

[52] Taniguchi, Norio, "On the Basic Concept of 'NanoTechnology,' Part II," Proc. Intl. Conf. Prod. Eng., Japanese Society of Precision Engineering, Tokyo, 1974.
[53] Drexler, Eric, Engines of Creation: The Coming Era of Nanotechnology, New York: Anchor Books, 1986.
[54] Igami, Masaturo and Teruo Okazaki. "Capturing Nanotechnology's Current State of Development via Analysis of Patents". OECD. 23-May-2007.
[55] Project on Emerging Nanotechnologies. http://www.nanotechproject.org/index.php?id=44&action=intro
[56] Lux Research. "Nanotechnology Spending to Hit $8.6bn". August 2004
[57] http://cohesion.rice.edu/CentersAndInst/ICON/emplibrary/Nanomaterial%20Volumes%20and%20Applications%20-%20Holman,%20Lux%20Research.pdf

public investment. Today, at least eight countries support comprehensive national nanotechnology research programs with budgets of more $100 million annually.[58] VC investment patterns can be seen as indicator of the potential for commercial applications within specific technology areas. In 2002, the latest year for which a detailed breakdown of investment patterns is available, "nanobiotechnology" attracted the most attention from venture capitalists, accounting for 52% of total investments, but nanomaterials also attracted a significant share of VC activity.

In 2005, Virginia was the 4th ranked state in a Lux Research nanotechnology development benchmark report that measured nanotechnology R&D activity, capacity, and funding. Virginia hosts a number of research facilities –both in its universities and the private sector- focused on nanotechnology. The NanoQuest Institute and University of Virginia, for example, brings together researchers active in nanotechnology from several different fields. With more than $20 million in recent instrumentation investments, University of Virginia is estimated to conduct more than $15 million in sponsored nanotechnology-related research annually. In the private sector, several firms are active in nanotechnology development, including: Luna Innovations, Nano Interface Technology Inc, 4Wave Inc., Nanosonic, Inc., and NanoChemonics, Inc. among others. The Virginia Nanotechnology Initiative, established in 2002 as a program of The Center for Innovative Technology, identifies several areas of strength for nanotechnology development in Virginia, including: nano biomedicine, functional nanomaterials, carbonaceous nanomaterials, and functional coatings.[59]

Nanomaterials are made from variety of raw materials such as carbon or silver and come in a wide array of shapes and sizes with unique and interesting properties. Several types of nanomaterials with high potential for future development are described in the table below.

[58] USA, Japan, South Korea, European Union, Germany, Taiwan, China, UK: M.C. Roco. "New Frontiers for Nanotechnology". 2006.
[59] http://www.vanano.org/

Nanomaterials		
Nanomaterial	Description	Implications for Chemicals and Materials Industry
Nanoparticles	"Nanoparticle" is a generic term used to describe particles that are smaller than 100nm. Particles of this size often exhibit properties that are substantially different than those of larger particles of the same material. Examples of these properties include increased chemical reactivity, very high surface area compared to volume, and tunable optical characteristics.	Some materials that do not act as catalysts at the macro-scale can serve as catalysts at the nanoscale; this creates a "new range of applications or alternative reaction pathways".[60] The market for nanocatalysis was estimated at $3.7 billion in 2004 and may exceed $5 billion by 2009; nanoparticles are the most significant component of this market space.
Nanoporous Materials	Nanoporous materials are structures with holes less than 100nm in diameter. These structures "combine the advantages of the porous structure with the physic-chemical-biological functionality of the material itself".[61] Notable functionally imparted by nanoscale materials include: increased specific surface area, reduced weight, and photonic properties.	Used to aid catalysis, nanoporous materials could be used in a broad range of chemical processes to add or subtract constituents in a controlled manner. In the materials industry, the thermal properties of nanoporous materials have already been exploited in products such as thermal insulating windows.
Nanocoatings	A nanotechnology-based thin film or coating is a layer of material, less than 100nm thick, applied to the surface of another material. When applied to a substrate, thin films impart new properties to the surface of the material. Significant enhancements to surface properties can include chemical reactivity, electrical conductivity, durability, optical qualities and thermal properties.	Examples of innovative materials using nano coatings include multi-functional corrosion protection for metals, such as protective coatings for steel or chromate-free, long-term corrosion protection for light metals
Carbon Nanotubes	Carbon nanotubes are made from sheets of grapheme structure carbon atoms that have formed hollow tubes a few nanometers in diameter; the compelling physical properties of carbon nanotubes (CNT) make these nanostructures one of the hottest fields of nanotechnology R&D. Physically, CNTs have tensile strength 100 times greater than steel at a small fraction of the weight and are highly efficient conductors of heat.	Embedded into composite materials, CNTs could be used to make super strong or flexible materials. Researchers at Canada's National Research Council, for example, are exploring the use of carbon nanotubes to reinforce concrete. CNTs could also be used to create stronger steel alloys. In the chemicals industry, CNTs, together other nanomaterials, make up approximately 2% of the nanocatalysis market place today.

[60] European Commission. "Nanoroadmap Synthesis Report". 2006.
[61] European Commission. "Nanoroadmap Synthesis Report". 2006.

Biopolymers

Biopolymers, often called bioplastics in the industrial sector, are biologically-derived polymers with a variety of useful functional uses such as: stabilizers, thickeners, gellants, binders, dispersants, lubricants, adhesives, and drug-delivery agents. Polymers are large molecules consisting of repeated structural units (monomers) connected by covalent chemical bonds. Differences in structures can affect properties of materials such as solubility, flexibility, and strength. The resulting materials can be used in a vast number of industrial and commercial applications. Unlike synthetic polymers, biopolymers often have well defined, but extremely complicated structures which can be difficult to produce in large quantities. Cellulose, agar, guar gum, and latex are all examples of well-known biopolymers. Estimated at 1% of the total world plastics market in 2003, some analysts suggest that biopolymers could account for nearly 5% of the global plastics market by 2010.[62] Several factors are driving increased interest in biopolymers across several sectors:

- Concerns about waste from plastic products are driving demand for biodegradable alternatives for products such as packaging. Biopolymer-based packaging is already available in several major European supermarket chains and both Walmart and IKEA introduced their first biopolymer-based packaged products in 2006.
- Increasing cost and concerns about the stability of petroleum supplies are driving demand for non-petroleum derived alternatives for many plastic products.
- Demand for healthier processed foods and for "functional" foods with specific health benefits are leading to increased use of biopolymers as thickeners, gellants, clarifying agents, emulsifiers, and stabilizers in the food processing industry.

The structural complexity that makes biopolymers so useful can also make them difficult to produce in large-quantities at an economically competitive price. While thousands of naturally occurring biopolymers exist, little information is available about the structure and functional characteristics of all but a handful of these substances. Studies to isolate and characterize biopolymers will be essential for the further expansion of the biopolymer industry. Advances in genomics are beginning to allow researchers to genetically modify microorganisms or plants to produce complex biopolymers that can later be extracted. Growing understanding of biotechnology processes such as fermentation will also play a significant role in the biopolymer industry, making complex biopolymers easier, and more economical, to produce.

The most significant application areas for biopolymers today are in the packaging and food processing industries, but biopolymers could play a significant role in many other industries, including: wastewater treatment, cosmetics, and medical devices. For the most part, biopolymers remain more expensive than synthetic polymers, but their production and use are more environmentally sustainable. The use of biopolymers is already well established in industry, and chemical firms such as BASF and Mitsui Chemical play a significant role as suppliers of biopolymer products for use in applications such as construction and agriculture. Materials such as spider silk, a naturally occurring biopolymer with desirable strength and flexibility characteristics illustrate the potential utility of biopolymer-based materials. Biopolymer-based fibers are an active research topic that could have a significant impact in the materials industry.

[62] www.biorenew.iastate.edu/fileadmin/www.biorenew.iastate.edu/images/research/Biopolymer_Market_Analysis_Final_Report.pdf

Cluster and Technology Foundations

Cluster Fundamentals

Virginia's Chemicals and Materials cluster was selected for inclusion in this analysis due to the sector's significant potential for impact throughout the economy and for its potential for future development in the Commonwealth. Virginia possesses significant R&D assets, in the form of universities and an array of technology-oriented private sector firms, which are strong producers of chemicals and materials-related patents and publications.

Virginia's employment concentration in chemicals and materials sector remains below the national average, but the cluster experienced significant growth between 2003 and 2005. In that time period, the chemicals sub-sector grew by a remarkable 41% measured by employment. Furthermore, there are many new opportunities for growth into promising markets such as nanomaterials and biopolymers, which play on Virginia's competitive advantages such as its proximity to the nation's capital and other regional biotechnology heavyweights and its related expertise in other areas, such as national security and information technology.

Technology Development Assets

There is significant R&D activity in Materials and Chemicals in Virginia, particularly in the private and university R&D laboratories. There are at least twenty private R&D centers. Honeywell focuses on R&D for polyester and high performance fibers. The Degussa Goldschmidt Corporation, the largest private chemicals R&D center in Virginia in terms of number of employees, undertakes R&D for a range of industrial chemicals. University R&D, which comprises at least twelve labs in Virginia, is also thriving. In particular, Virginia Tech has seven of the twelve labs that deal with such varied subjects as geotechnical composite systems, photonics technology, and macromolecular research.

Virginia University Materials and Chemicals R&D Centers		
University	Center	Description
George Mason University	Computational Materials Science Center (CMaSC)	CMaSC's aim is to develop the "next generation of atomistic and quantum mechanical modeling tools for material simulation."
Old Dominion University	Applied Research Center	Conducts research in areas including: thin films, laser and plasma applications, materials technology, nanotechnology, biomedical engineering, sensor technology, and MEMS.
University of Virginia	Institute for Nanoscale & Quantum Engineering, Science & Technology (NanoQuest Institute)	The NanoQuest Institute's research focuses on building the "nano toolbox" by advancing "fabrication, computation and measurement at the nanoscale."
University of Virginia	Center for Electrochemical Science and Engineering (CESE)	Performs mutli-disciplinary research in electrochemical science and engineering.
Virginia Tech	Center for Geotechnical Composite Systems (CGCS)	Advances "understanding, performance, design, construction, and monitoring of geotechnical composite systems."
Virginia Tech	Center for Intelligent Materials Systems and Structures (CIMSS)	Focuses on application and development of smart materials and structures. Also works in

Virginia University Materials and Chemicals R&D Centers		
		area of health monitoring and diagnostics using these materials.
Virginia Tech	Center for Photonics Technology	Conducts research in harsh environment sensors, narrow linewidth laser characterization, and test of physical constants' constancy.
Virginia Tech	Center for Self Assembled Nanostructures and Devices (CSAND)	Nanotechnology research focus is on controlling supramolecular architecture (self-assembly) at the nano/molecular level.
Virginia Tech	Macromolecules and Interfaces Institute (MII)	Macromolecular research focuses on advanced materials and processes for proton exchange membrane (PEM) based fuel cells; high performance adhesives and composites; advanced materials for biomaterials, membranes, etc.; and nanostructured materials for self-organization and solvent-free processing.
Virginia Tech	Sustainable Engineered Materials Institute (SEMI)	SEMI's long-term goal is to "design composite products from the wood of trees grown on intensively managed forest plantations." Research includes simulation modeling, design, manufacturing and performance of wood-based composite products.
Virginia Tech	Wood-Based Composites Center	Supports industry needs for wood-based composite research.
James Madison University	Center for Materials Science	Materials science research includes materials characterization, processing, and applications (e.g., sensors, infrared analysis, and thermal structural-interactions).

Virginia Federal Materials and Chemicals R&D Centers		
Agency	Facility	Description
NASA	Langley Research Center	NASA's Center of Excellence for Structures and Materials. LaRC develops and tests materials and structural designs for airplanes and spacecraft. LaRC's Advanced Materials and Processing Branch focuses on R&D on high-temperature/high-performance materials for aerospace applications.

Research Outputs

Materials and Chemicals R&D organizations in Virginia produced 2,943 publications between 2001 and 2006, with Virginia Tech, the University of Virginia, and Virginia Commonwealth University leading the way. In terms of patent activity in Virginia, apart from the U.S. Navy, the leaders were mainly private sector firms. In 2006 59 patents related to chemicals and materials were granted in Virginia.

Virginia Leading Materials and Chemicals R&D Organizations by Publication Output	
Organization	Publications (2001-2006)
University of Virginia	876
Virginia Tech	1004
Virginia Commonwealth University	442
NASA	152
United States Navy	146
College of William and Mary	107
Philip Morris Inc	71
Old Dominion University	62
George Mason University	57
National Science Foundation	26

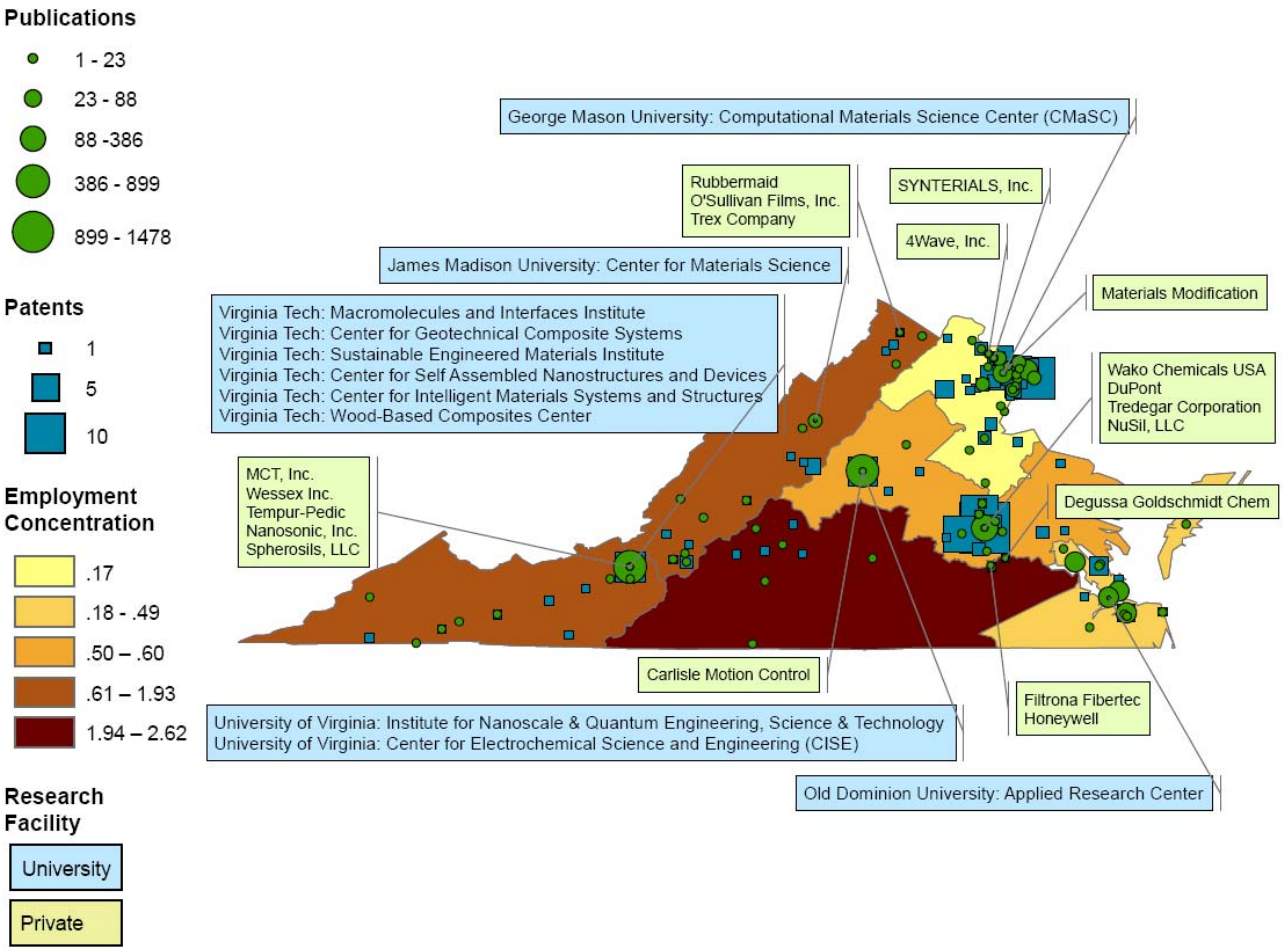
Source: SRI Analysis of ISI Web of Science Data

Patent Assignee Organizations for Virginia Developed Materials and Chemicals Technologies	
Organization	Patents (2006)
United States Navy	24
E. I. du Pont de Nemours and Company	7
ExxonMobil Chemical Patents Inc.	5
ExxonMobil Research and Engineering Company	5
University of Virginia Patent Foundation	5
Virginia Tech Intellectual Properties, Inc.	4
Infilco Degremont, Inc.	3
Aerojet-General Corporation	2
Afton Chemical Corporation	2
Afton Chemical Intangibles LLC	2

Note: Assignee may not be located in Virginia, but at least one inventor listed on the patent is based in Virginia.
Source: SRI Analysis of Delphion Data.

Cluster Map

Publication and patent activity in Virginia tends to be concentrated around the universities, and also in Northern Virginia. The region with the fewest patents and publications, the southside region, surprisingly also has the highest employment concentration in the chemicals and materials field, whereas the northern Virginia region, with its proximity to the federal government, has the lowest employment concentration.



Energy and Environment

Cluster and Technology Overview

Description and Major Subsectors

SRI defines the Energy & Environment sector to encompass a wide variety of products and services, ranging from fuel production & distribution and power generation & technology, to recycling & waste remediation and environmental research & management.

Sub-Sectors Overview		
Sub-Sector	Description	Examples of Large Companies
Coal Production	This sub-sector comprises "firms that mine bituminous and/or anthracite coal (both are types of black coal) and lignite (brown coal). Firms in the industry may also develop coal mine sites and prepare the coal for sale by washing, screening and sizing it."	Peabody Energy Corporation, CONSOL Energy Inc, Arch Coal Inc, Foundation Coal Holdings, Inc., Rio Tinto plc
Petroleum and Gas Extraction	This sub-sector comprises: petroleum refineries ("establishments primarily engaged in refining crude petroleum into refined petroleum"), and firms engaged in oil and gas extraction ("firms that operate and/or develop oil and gas fields and firms that extract liquid hydrocarbons from oil and gas field gases," as well as those that engage "in the mining and extraction of oil from oil shale and oil sands, the production of natural gas and the recovery of hydrocarbon liquids from oil and gas field gases.")	ConocoPhillips, Exxon Mobil Corporation, BP, Chevron Corporation, Marathon Oil Corporation, Royal Dutch/Shell Group
Fossil Fuel Electric Power Generation	This sub-sector consists of: "establishments primarily engaged in operating fossil fuel powered electric power generation facilities. These facilities burn fossil fuels, such as coal, gas and oil in order to generate steam, which in turn is used to power turbines that generate electric power. The establishments in this industry produce electric energy and provide electricity to transmission systems or to electric power distribution systems."	The Southern Company, Duke Energy Company, American Electric Power Company, Inc., Entergy Corporation, Texas Utilities Company
Nuclear Electric Power Generation	This sub-sector includes "establishments primarily engaged in operating nuclear powered electric power generation facilities. These facilities use nuclear fuel to generate steam, which in turn is used to power turbines that generate electric power. The establishments in this industry produce electric energy and provide electricity to transmission systems or to electric power distribution systems."	Exelon Corporation, Entergy Corporation, Dominion Resources Inc., Tennessee Valley Authority, The Southern Company
Hydroelectric and Renewable Power Generation	This sub-sector comprises "establishments primarily engaged in operating hydroelectric and renewable powered electric power generation facilities. Renewable energy sources comprise: wood and wood	Cybex International, Incorporated, Bureau of Reclamation, Power Authority of the State of New York, Duke

Sub-Sectors Overview		
	waste, black liquor, biogenic municipal solid waste, landfill gas, sludge waste, biomass and other agriculture byproducts, geothermal, solar and wind. Firms in this industry may also produce small amounts of electricity using other power sources, including: non-biogenic municipal solid waste, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur and used tires. While water and wind are used to directly power turbines that generate electricity, other facilities typically utilize their fuel to generate steam, which is then used to power turbines and generate electric power. The establishments in this industry produce electric energy and provide electricity to transmission systems or to electric power distribution systems."	Energy Corporation, PG&E Corporation, Tennessee Valley Authority
Waste Disposal and Recycling	This sub-sector includes remediation services (including "(1) remediation and cleanup of contaminated buildings, mine sites, soil, or ground water (2) integrated mine reclamation activities(3) treatment, hazardous material removal, contouring land, and revegetation (4) asbestos, lead paint, and other toxic material abatement"), materials recovery facilities ("for separating and sorting recyclable materials from nonhazardous waste streams"), and recyclable material wholesalers.	The Shaw Group, Inc., Tetra Tech, Inc., CH2M Hill Companies, ARCADIS, Clean Harbors, Inc., Metal Management, Inc., Philip Services Corporation, Aleris International, Inc.
Environmental Research & Management	This sub-sector includes environmental consulting services (firms "primarily engaged in providing advice and assistance to businesses and other organizations on environmental issues, such as the control of environmental contamination from pollutants, toxic substances, and hazardous materials"), and geophysical surveying and mapping (these businesses "often specialize in locating and measuring the extent of subsurface resources, such as oil, gas, and minerals, but they may also conduct surveys for engineering purposes").	CH2M Hill Companies, Weston Solutions, Malcolm Pirnie, AECOM Technology Corporation, Compagnie Generale de Geophysique, Schlumberger, Dawson Geophysical Company

Source: www.ibisworld.com.

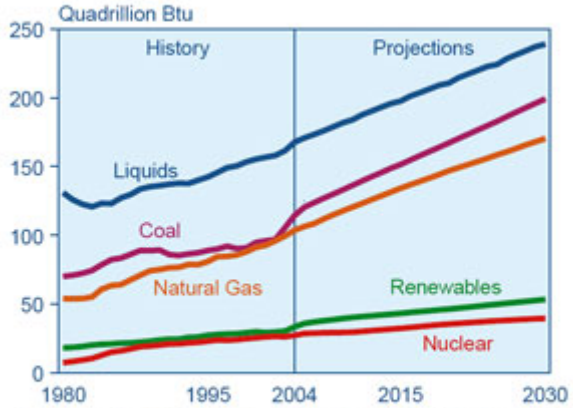
For the purposes of this report, we will limit the scope of the discussion specifically to the nexus of energy and environment: renewable energy production and technologies to reduce fossil-fuel emissions.

Energy sources can be classified in terms of liquids (e.g., petroleum), coal, natural gas, renewables and nuclear. Renewable energy can be broken down further into hydroelectric power and nonhydroelectric renewable energy (e.g., solar, wind, ocean, biomass/biofuel, geothermal).

The U.S. Department of Energy's forecast for the global consumption of energy is projected to increase at a CAGR of 2.0% from 2004 to 2030, with the coal, natural gas and renewables segments

demonstrating the highest compound annual growth rates.[63] The figure below depicts world marketed energy use by fuel type through 2030.

Figure 11. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

Demand for renewable or "clean" energy sources is driven by rising oil and natural gas prices and diminishing supplies of these natural resources, as well as pressures to limit greenhouse gas emissions and to reduce dependence on foreign oil. Investment in the renewable energy market has taken off: in 2002, the estimated value of the U.S. renewable energy investment market was $1.5 billion, and reached $22.5 billion by 2006, which is approximately a third of the worldwide market.[64] The renewable energy market (for biofuels, solar, wind and fuel cells/hydrogen) is forecast to grow from $55.4 billion in 2006 to $226.5 billion in 2016, at a CAGR of 15%, as "NRE [nonrenewable energy] prices are inexorably rising, and RE [renewable energy] prices are almost competitive."[65]

Currently, barriers to the adoption of renewable energy revolve around cost: run-up in production costs for solar photovoltaic (PV) modules, wind turbines and biofuels; the silicon shortage and resulting climbing solar photovoltaics costs; and thin profit margins for ethanol resulting from rising corn prices.[66] Possible solutions to improving cost competitiveness and adoption of renewable energy include: finding alternatives to silicon for photovoltaic cells (e.g., thin film); increasing the energy efficiency of solar cells; commercializing cellulosic biofuel (that is, biofuel that is derived from plant waste, not corn); and directing federal policy and investment (e.g., production and investment tax credits) to support renewable energy. From a consumer perspective, financing options, such as solar home equity loans, may need to be available to make renewable energy technologies affordable. The following table provides an overview of an array of clean energy technologies.

[63] Energy Information Administration, U.S. Department of Energy. International Energy Outlook 2007. http://www.eia.doe.gov/oiaf/ieo/world.html.
[64] Packaged Facts, *Renewable Energy Investment in the U.S.*, November 2007, p. 33.
[65] Ibid., p. 45.
[66] Clean Edge, Clean Energy Trends 2007, March 2007, p. 4. http://www.cleanedge.com/reports/Trends2007.pdf.

Worldwide Energy Technology Market Outlook				
Energy Technology Areas	Description	Estimated Market Size	Estimated Growth Potential (CAGR)	Examples of Large Companies / Key Players
Biofuels (biodiesel and ethanol)	Renewable energy. Liquid and gas fuels derived from plants. Ethanol, a type of biofuel, is derived from corn and sugarcane. Biodiesel is distilled from vegetable oils.	$20.5 billion (2006)	15% (2006-2016)	Archer Daniels Midland, Poet, VeraSun Energy Corp, U.S. BioEnergy,
Wind Power (Installation capital costs)	Renewable energy. Harnesses wind currents to produce electricity.	$17.9 billion (2006)	13% (2006-2016)	Iberdrola (PPM Energy, Community Energy), GE
Solar Power (Modules, systems components, and installation)	Renewable energy. Utilizes radiation from the sun to generate energy. Three main segments: photovoltaic (PV – crystal silicon and thin film), solar thermal, and CSP.	$15.6 billion (2006)	16% (2006-2016)	Sharp, Q-Cells, Suntech, SolarWorld, Kyocera, Mitsubishi
Fuel Cells and Distributed Hydrogen	Renewable energy. Functioning as alternative types of generators and batteries, fuel cells most commonly use hydrogen as an electrical medium. Fuel cells consume hydrogen fuel to produce electricity.	$1.4 billion (2006)	27% (2006-2016)	Ballard, Hydrogenics, Millennium Cell, Plug Power, Magnetek, Bloom Energy
Clean Coal: Coal Gasification	A clean coal technology. Catalytic process for converting coal into natural gas. This is one technique used on coal-to-liquid technology. Gasification is a clean ways to convert the energy content of coal into electricity, hydrogen, etc.	$44 billion (2006, U.S)	N/A	American Electric Power, Sasol, Peabody Energy, Eastman Chemical Company
Clean Coal: Carbon Capture and Storage	A clean coal technology. A type of carbon sequestration, where carbon dioxide is captured at its source and subsequently stored in a non-atmospheric reservoir.	$500 billion (potential; unclear over what time span)	High (with possible future carbon taxes and emissions trading requirements)	NRG Energy Inc., Powerspan Corp, American Electric Power, Luminant, Rentech
Nuclear Energy	Energy released directly from atomic nucleus.	$90.3 billion (2007 – nuclear electric power generation)	4% (2007-2012) (nuclear has stagnated for past 15 years)	Exelon Corp., Entergy, Dominion Resources, Southern Company
Geothermal Energy	Renewable energy. This technology utilizes the internal heat of the earth to produce electricity and regulate water/air temperature.	$1.3-$1.7 billion (2006, U.S. only)	N/A	Calpine Corporation, Santa Clara Electric, CalEnergy,

Sources:
Biofuel, Solar, Wind, Fuel Cell: Clean Edge, Clean Energy Trends 2007, March 2007, http://www.cleanedge.com/reports/Trends2007.pdf. Venture capital investment focus and key player information from

Packaged Facts, *Renewable Energy Investment in the U.S.*, November 2007, pages 88, 91, 92.
Nuclear: Icon Group International, Inc., The 2007-2012 World Outlook for Nuclear Electric Power Generation, May 2006.
Coal Gasification: Industrial Info Resources.
Carbon Capture: http://www.nexant.com/news/releases/07_12_03_carbon_capture.html.
Geothermal: M2 Presswire, *Glitnir Bank Expands into US Geothermal Energy Market*, May 15, 2007.

High Growth Potential Technologies for Virginia

Virginia could pursue any combination of several avenues in the Energy & Environment sector. Highlighted below are two such opportunities that both play on Virginia's strengths and assets, and have strong potential in the energy industry.

Fuel cells and hydrogen, a long-term renewable energy technology, was listed in the Virginia Department of Mines, Minerals and Energy's *2007 Virginia Energy Plan* among "Virginia's research areas with current or potential national prominence."[67] The ten-year state energy plan further recommends that "Virginia should support development of fueling infrastructure as the market develops for hydrogen fuel use."

Carbon capture and storage, a near-term clean coal technology, was deemed by the plan to be a research area which "could be leveraged into [a] position of national leadership."[68] The plan specifically suggested that the state "should support carbon capture and storage projects in unminable coal seams to help support continued markets for Virginia's coal."

These two technologies showcased below complement one another. Hydrogen is an energy source of the future. In contrast, fossil fuels are the current primary energy source, and carbon capture and storage can be employed for reducing carbon dioxide emissions from existing fossil fuel consumption, as well as from hydrogen energy production. (In fact, through the Global Climate Change Initiative, there is a $1.5 billion initiative, FutureGen, to build the "world's first integrated [carbon] sequestration and hydrogen production research plant."[69]) Furthermore, fuel cells can be used for carbon capture, demonstrating another synergy between the two areas.

Fuel Cells and Distributed Hydrogen

One particular area of interest in renewable energy production is fuel cell and distributed hydrogen technology. A fuel cell is an energy conversion device used to convert a fuel (chiefly hydrogen) to energy, and there are four types of fuel cells: portable (e.g., batteries, chargers, mobile generators), stationary, transportation (vehicles), and light mobility (e.g., forklifts). "Fuel cells can potentially achieve the highest fuel to electricity conversion efficiencies of any generating technology available today,"[70] although the adoption today is limited by the high cost. Global market revenues are projected to grow at a very high CAGR of 27% between 2006 and 2016, from $1.4 billion to $15.6 billion (refer to table in previous section). Clean Edge also estimates that there was $175 million of venture capital

[67] Commonwealth of Virginia Department of Mines, Minerals and Energy, *The Virginia Energy Plan,* 2007, p. 117.
[68] Ibid., p. 116.
[69] http://www.fossil.energy.gov/programs/powersystems/futuregen/.
[70] Business Insights, *The Future of Distributed Power Generation: New technologies, changing economics and the impact of fuel cells*, 2007, p. 57.

funding in fuel cells in 2006.[71] To support the development of this technology, the President has championed a five-year, $1.2 billion Hydrogen Fuel Initiative. In FY 2007, the federal budget appropriation for this initiative was $274 million.[72]

Hydrogen is touted as a cleaner, more efficient energy alternative (when burned, its waste by-product is water), and the "high energy content of hydrogen and its abundance in the universe makes hydrogen very attractive as an energy source."[73] Hydrogen offers huge market potential but also high risk because this technology is in early stages of development. Also, due to hydrogen's low energy density, existing hydrogen storage systems are too big, heavy and inefficient for practical use. With current technology, fuel-cell vehicles would not appeal to consumers because they do not have the performance and functionality comparable to traditional vehicles (e.g., fuel-cell vehicles cannot travel as far, given similar constraints in fuel tank volume). However, the "desire to move to hydrogen as an energy source is driving global research to find an effective hydrogen-storage system" by developing efficient hydrogen-storage materials (e.g., chemical or metal hydrides, carbon nanotubes, and metal-organic frameworks).[74]

Furthermore, other outstanding issues with hydrogen include the safe storage and distribution, as well as the clean production of hydrogen. Hydrogen can only be produced using external energy sources, so there are R&D efforts directed towards hydrogen production using renewable energy sources.

In Virginia, there is demonstrated support and a favorable policy environment for hydrogen: in 2005 the Virginia General Assembly passed resolutions expressing support for a Hydrogen Energy Plan. A Virginia Hydrogen Economy Roundtable was created to develop a hydrogen action plan for Virginia, *Building a Hydrogen Economy in Virginia: Suggested Strategies 2006.*[75] This hydrogen educational forum represents over thirty entities from Virginia's public, private and nonprofit sectors. The plan highlighted Virginia's assets which would help position it as a hydrogen economy leader, such as "abundant natural resources, highly skilled technical workforce, world-class research universities already engaged in hydrogen research and development, public-private partnership potential, major interstate thoroughfares, military presence, large population and tourist centers, proximity to the nation's capital, and hydrogen demonstration projects already on the ground."[76]

In terms of university fuel cell research, Virginia Tech is a site of significant activity: it has its Center for Automotive Fuel Cell Systems and Center for Energy Systems Research, both recipients of long-term DOE funding. Virginia Commonwealth University and University of Virginia are also involved in fuel cell research. In Virginia's public sector, fuel cell R&D is undertaken by NASA Langley, which researches "energy sources for aircraft, including hydrogen-fueled combustion, hydrogen fuel-cell electric propulsion, lithium-air fuel-cell electric propulsion, nuclear hybrid systems, and aluminum powder combustion."[77] In terms of Virginia's private sector, H2Gen, based in Alexandria, has received $49 million in venture capital funding for development of its technology to convert "gas traveling through pipes into clean hydrogen, bypassing the need for a new transport system that was needed with [the]

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[71] Clean Edge, Clean Energy Trends 2007, March 2007, p. 5. http://www.cleanedge.com/reports/Trends2007.pdf.
[72] http://www1.eere.energy.gov/hydrogenandfuelcells/presidents_initiative.html.
[73] SRI Consulting Business Intelligence. http://www.sric-bi.com/Explorer/FC/FC-2007-08.shtml.
[74] Ibid.
[75] Report can be found at: http://www.hrccc.org/images/VA_H2planCombined_091206_Web.pdf.
[76] Virginia Hydrogen Economy Roundtable, *Building a Hydrogen Economy in Virginia: Suggested Strategies*, 2006, p. 5. http://www.hrccc.org/images/VA_H2planCombined_091206_Web.pdf.
[77] Commonwealth of Virginia Department of Mines, Minerals and Energy, *The Virginia Energy Plan, 2007*, p. 131.

first-generation of hydrogen-energy technologies."[78] Also, Automated Test Labs, Inc. is involved in research and development of fuel cells and fuel cell components.

Carbon Capture and Storage

Carbon sequestration is "a way to reduce greenhouse gas emissions…. Interest has been increasing in the carbon sequestration option because it is very compatible with the large energy production and delivery infrastructure now in place." A type of carbon sequestration, carbon capture and storage is when "carbon dioxide is captured at its source (e.g., power plants, industrial processes) and subsequently stored in non-atmospheric reservoirs (e.g., depleted oil and gas reservoirs, unminable coal seams, deep saline formations, deep ocean)."[79]

Even with the rise in prominence of renewable energy, carbon dioxide capture and storage technologies are increasingly relevant because "oil, coal, and natural gas still are projected to provide roughly the same 86-percent share of the total U.S. primary energy supply in 2030 that they did in 2005 (assuming no changes in existing laws and regulations)."[80] All of these fossil fuels contribute to climate change, and coal is the worst offender: its consumption "produces 37 percent of the world's fossil-fuel-related emissions of carbon dioxide, the chief greenhouse gas."[81] While there is only 41 years' worth of oil in the ground, there are still 164 years' worth of coal.[82] Southwest Virginia produced almost 27 million short tons of coal in 2005, and coal is Virginia's chief energy export.

Virginia has significant potential to complement and support its coal production activity by sequestering carbon through its unminable coal seams. In particular, "an estimated 7.33 trillion cubic feet of carbon dioxide storage capacity is available in the unminable Lee and Pocahontas formation coals in southwest Virginia."[83] The map below demonstrates the carbon capture potential in Virginia and West Virginia. In terms of financial benefits, carbon capture is costly, but the development of such technology would be invaluable in a possible future regulatory climate with economic incentives, carbon taxes, emissions trading requirements and other mechanisms which assign a financial and societal value to environmental benefits. Business Insights predicts that "[i]f strict control of carbon dioxide emissions into the atmosphere becomes normal, then there is going to be a strong economic case for a renewed nuclear power program. This will, inevitably, lead to a lengthy and acrimonious debate and it does not seem likely that new nuclear power plants will appear in either Europe or North America over the short term…. When nuclear power is eliminated, and even if a new program is implemented it cannot provide the entire world's power, fossil fuel combustion combined with CO2 capture and enhanced oil recovery offer the cheapest option."[84]

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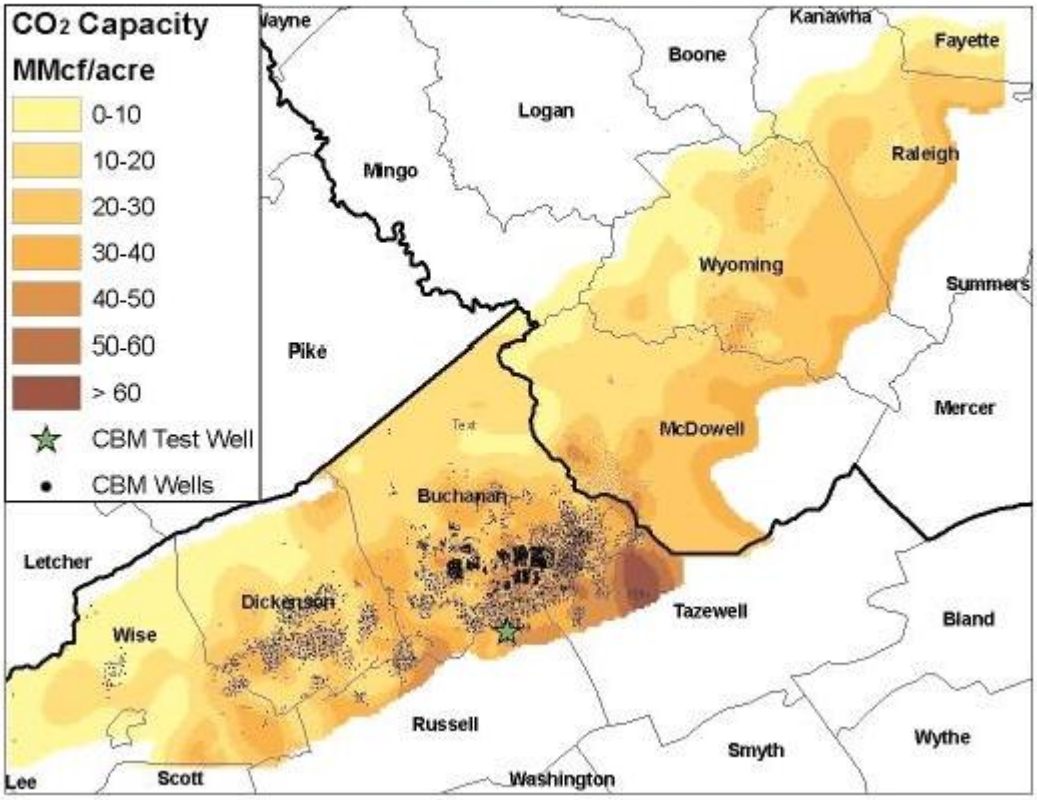
[78] The Washington Post, '*Cleantech' Investing Gets Its Day in the Sun*, November 26, 2007, p. D07. http://www.washingtonpost.com/wp-dyn/content/article/2007/11/25/AR2007112501268.html?wpisrc=newsletter.
[79] MIT Carbon Capture & Sequestration Technologies. http://sequestration.mit.edu/technology_overview/index.html.
[80] U.S. Department of Energy, Annual Energy Outlook 2007, February 2007, p. 2. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2007).pdf.
[81] Talbot, David, "The Dirty Secret," *MIT Technology Review*, July/August 2006, p. 54.
[82] World Coal Institute, qtd. In Talbot, David, "The Dirty Secret," *MIT Technology Review*, July/August 2006, p. 54.
[83] Commonwealth of Virginia Department of Mines, Minerals and Energy, *The Virginia Energy Plan, 2007*, p. 50.
[84] Business Insights, *The Future of Carbon Sequestration: Key drivers and resistors, costs and technologies*, 2006, p. 120.

Figure 6-1 Carbon Capture Potential in Virginia and West Virginia



Source: Commonwealth of Virginia Department of Mines, Minerals and Energy, *The Virginia Energy Plan*, 2007, p. 120.

The Commonwealth is "positioned to be a leader in developing" the carbon capture and storage technology, and, to do so, needs to invest in research facilities in this area as well as "facilities to collect carbon from generating sources, transport it to the areas with available coal seams, and inject into the unminable coal seams."[85]

In terms of university R&D in Virginia, the Virginia Center for Coal and Energy Research (VCCER) and the Center for Advanced Separation Technologies (CAST), both affiliated with Virginia Tech, lead coal-related research. Carbon management and sequestration is among VCCER's research areas, and VCCER is leading a coalition of "universities, industry, and state agencies to identify potential carbon sequestration sinks in central Appalachia, as part of the Southeast Regional Carbon Sequestration Partnership (SECARB)," a partnership created by the DOE to "determine optimum approaches for capturing and storing carbon dioxide."[86] This project has "the potential to implement a ten-year pilot to capture a million tons of carbon dioxide per year in Virginia."[87] SECARB is part of the President's Global Climate Change Initiative, which calls for "an 18% reduction in the carbon intensity of the United States economy by 2012," and an "increased emphasis on carbon sequestration."[88]

[85] Ibid., p. 165.
[86] Ibid., p. 1.
[87] Ibid., p. 112.
[88] USDOE Office of Fossil Energy, National Energy Technology Laboratory, *Carbon Sequestration Technology Roadmap and Program Plan*, 2003.

Cluster and Technology Foundations

Cluster Fundamentals

Virginia's Energy & Environment industry cluster was profiled in this report based on analysis of several factors. First and foremost, the state itself has a policy environment favorable to this industry. Virginia's Senate Bill 262 "established an energy policy for the Commonwealth and directed the Department of Mines, Minerals and Energy (DMME), in consultation with the State Corporation Commission, Department of Environmental Quality, and Virginia Center for Coal and Energy Research, to prepare a ten-year comprehensive Virginia Energy Plan (VEP) to implement the Commonwealth's energy policy."[89] Energy and the environment is at the heart of this plan's purpose, which is to "chart a path forward that will provide for reliable energy supplies at reasonable rates and increase the use of conservation and efficiency measures in Virginia." [90]

From a national perspective, climate change and energy is also at the forefront of public policy issues. As a result, investments in renewable energy and clean technologies are increasing, both in terms of private and federal funds. Virginia can leverage its proximity to the federal government for financing to sponsor research and demonstration projects with the U.S. military and U.S. Departments of Energy and Transportation. In terms of private funding, venture capital firms invested $2.4 billion nationwide in clean energy technology startups in 2006. This constitutes 9.4% of total venture investments, up from 4.2% in 2005.[91] Virginia, with room to grow the meager 2% share of its venture capital directed towards energy in 2006, could potentially harness this trend in VC investing and increase its funding in this area.

Also, based on cluster analysis, Virginia's Energy & Environment industry demonstrates a solid foundation for growth. Its sub-sectors display considerable strength: the environmental research sub-cluster is growing rapidly and has a high employment concentration in Virginia; and the fuel production sub-cluster is especially concentrated in Southwestern Virginia, at over six times the national average. A focus on renewable energy and clean technology is a natural outgrowth from these sub-sector strengths. Virginia also has considerable R&D activity in Energy & Environment in all sectors; one particular asset of note in this area is Virginia Tech.

Technology Development Assets

Virginia Tech is the leader in energy-related university R&D in Virginia, and, along with the University of Virginia, is making energy and the environment a key part of its strategic plan. There are many other energy-related research efforts being undertaken by other universities in Virginia. The major energy-related research centers are outlined in the table below (there is also significant activity in environmental research not listed below).

There are also a number of private sector companies conducting R&D in a wide range of energy-related areas in Virginia, including: Verdant Power, a leading tidal turbine manufacturer; HyperV

http://www.fossil.energy.gov/sequestration/publications/programplans/2003/sequestration_roadmap03-13-03.pdf.

[89] http://www.dmme.virginia.gov/vaenergyplan.shtml.

[90] Commonwealth of Virginia Department of Mines, Minerals and Energy, *The Virginia Energy Plan, 2007*, p. 119.

[91] Clean Edge, Clean Energy Trends 2007, March 2007, p. 4. http://www.cleanedge.com/reports/Trends2007.pdf.

Technologies Corporation, which conducts R&D in plasma jets for alternative energy use; Afton Chemical Corporation, a global petroleum additives supplier; and General Electric's Salem facility, which has expertise in control and power electronics in application areas such as wind energy, solar energy, nuclear energy, coal gasification, gas/steam turbines, and oil and gas.

Virginia University Energy and Environment R&D Centers		
University	Center	Description
George Mason University	National ITS Implementation Research Center	DOT-funded University Transportation Center formed from a consortium with UVA and VT for Intelligent Transportation Systems research.
James Madison University	Center for Energy and Environmental Sustainability	Performs research on energy, economic development, and natural resources social needs. One program focus is alternative fuels, including investigating microalgae as a feedstock for biodiesel. Also works with City of Harrisonburg to develop waste-to-energy facility. Partner of the Virginia Wind Energy Consortium (VWEC).
Old Dominion University	Virginia Coastal Energy Research Consortium (VCERC)	Identifies and develops coastal energy resources (wind/tidal/current/wave/thermal/methane hydrates). Researches algae production for biodiesel. Other university partners include VT, JMU, NSU, UVA, VIMS and VCU.
University of Virginia	Smart Travel Lab	Studies conservation related to transportation energy use.
Virginia Tech	Center for Energy and the Global Environment (CEAGE)	Promotes research and education in issues concerning energy & its role in the global environment. Partner of VWEC.
Virginia Tech	Center for Advanced Separation Technologies (CAST)	Conducts research in clean and efficient technologies to produce coal and mineral concentrates. CAST is a consortium of seven universities.
Virginia Tech	Center for Power Electronics Systems (CPES)	A consortium of five universities, CPES is a National Science Foundation Engineering Research Center to advance vision of making the nation the world leader in power electronics. Conducts research in the integration of power and load management actions to improve power conversion.
Virginia Tech	Center for Power Engineering	Conducts research in power grids and equipment, distributed and alternative power systems, electricity storage, and the improvement of motor efficiency.
Virginia Tech	Center for Energy Systems Research	Performs research on fuel cell systems for stationary power and transportation applications.
Virginia Tech	Future Energy Electronics Center	Promotes and develops energy efficient technologies through the modeling, design and test of power electronics systems, devices, and components.
Virginia Tech	Virginia Center for Coal and Energy Research (VCCER)	Conducts and coordinates coal and energy research including carbon sequestration at Virginia Tech, and disseminates findings.
Virginia Tech	Center for Automotive Fuel Cell Systems	Fosters research and education in systems and components for transportation applications of fuel cell systems.

Virginia Federal Energy and Environment R&D Centers		
Agency	Facility	Description
Department of Defense	Office of Naval Research	Fosters research to promote naval power and national security. Energy-related research for ship systems includes: electrical power generation systems and equipment; energy conversion, distribution, and storage; and thermal energy management.
Department of Defense	Naval Surface Warfare Center, Dahlgren Division	Focuses on weapons and combat systems. Energy research is on gun and weapon energy efficiency.
Department of Energy	Energy Efficiency and Renewable Energy Clearinghouse	Advances energy technologies including biofuels, solar power, wind power and hydrogen fuel cells, through education and coordination efforts.
Department of Energy	Thomas Jefferson National Accelerator Facility	Conducts research on atomic nuclei at quark level. Energy research includes photovoltaics and hardened materials (for use in turbine blades).
NASA	Langley Research Center	Expertise lies in systems analysis, materials and structures, and aerodynamics. Energy research includes energy sources for aircraft (e.g., hydrogen-fueled combustion), hydrogen fuel-cell electric propulsion, lithium-air fuel-cell electric propulsion, nuclear hybrid systems, and aluminum powder combustion.

Research Outputs

Virginia's Energy & Environment R&D organizations produced over 8,400 publications between 2001 and 2006, with Virginia Tech as the leader of the pack. VT also led in terms of patent activity, garnering 9 of the 232 energy-related patents granted in 2006 in Virginia.

Virginia Leading Energy and Environment R&D Organizations by Publication Output	
Organization	Publications (2001-2006)
Virginia Tech	890
University of Virginia	408
U.S. Geological Survey	305
NASA	296
College of William and Mary	271
Old Dominion University	232
Virginia Institute of Marine Science	133
George Mason University	131
United States Navy	89
Virginia Commonwealth University	59

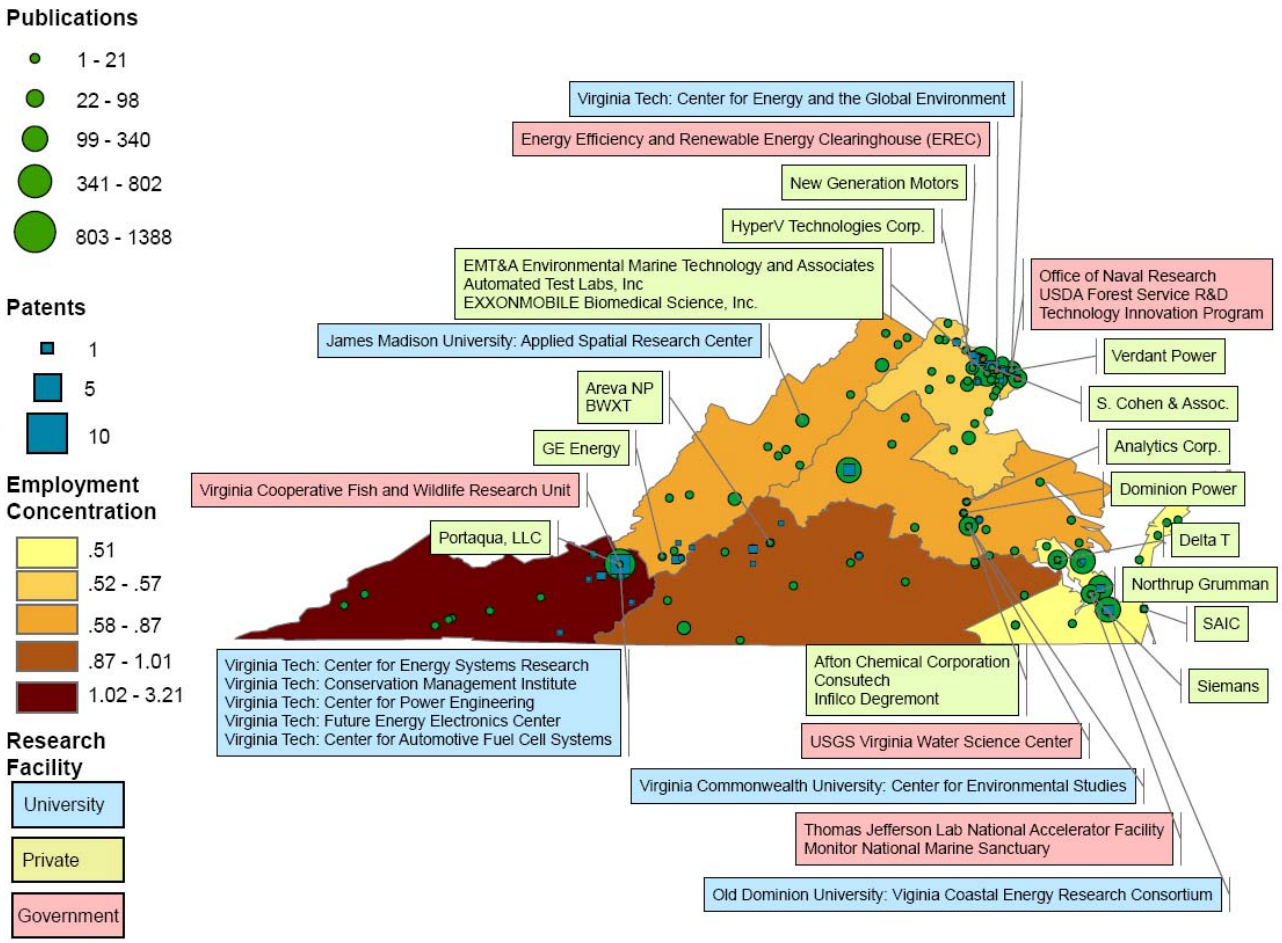
Source: SRI Analysis of ISI Web of Science Data

Patent Assignee Organizations for Virginia Developed Energy and Environment Technologies	
Organization	Patents (2006)
Virginia Tech Intellectual Properties, Inc.	9
Advanced Optical Technologies, LLC	3
Danville Automation Holdings LLC	3
ITT Manufacturing Enterprises, Inc.	3
NASA	3
Thermo Finnigan LLC	3
Face International Corp.	2
Light Engineering, Inc.	2
Southeastern Univ. Research Assn.	2
Vocollect, Inc.	2

Note: Assignee may not be located in Virginia, but at least one inventor listed on the patent is based in Virginia.
Source: SRI Analysis of Delphion Data

Cluster Map

The highest employment concentration of the Energy & Environment cluster is not surprisingly in Southwestern Virginia with its plethora of natural resources, including coal. This region also houses Virginia Tech, which is the state leader in energy-related research. Energy & Environment R&D is also scattered elsewhere in the state, with some concentration in Northern Virginia as well as Hampton Roads.



Transportation and Logistics

Cluster and Technology Overview

Description and Major Subsectors

Today's economic environment requires nimble, seamless global supply chains that enable producers to obtain inputs and retailers to access inventory when and where they are needed. To meet these requirements, the transportation and logistics industry has evolved to focus as much on information as on shipping, handling, and delivery, and information platforms and services that supply data to and permit communication among all partners, from end to end, are critical elements. Indeed, visibility and traceability are the watchwords for the entire transportation and logistics industry.

Transportation and logistics is a mature industry, and recent trends – particularly the need for substantial investment in information technology systems and related infrastructure – have prompted consolidation rather than expansion in the industry's structure. Nonetheless, the industry itself is continuing to grow and in 2006 achieved revenues of $1.6 trillion, with employment of almost 4.5 million workers.[92]

In the next five years, most transportation-based aspects of the industry – that is, movement of goods by truck, rail, express courier, and water – are expected to grow at approximately the same rate as gross domestic product (GDP). The $229 billion[93] truck transportation sub-sector, for example, is expected to grow at about 2.6%, paralleling GDP growth.[94] Rail transportation revenues, which reached $57.4 billion in 2006, are forecast to grow at 2.4% during the next 5 years; however this prediction could change if fuel prices remain high or increase, since rail transportation is more fuel efficient per ton of freight than truck transportation. Courier services, a sector in which 2006 revenues totaled $67.6 billion, also will expand at slightly less than the anticipated GDP growth rate through 2012. The water transportation sub-sector, a $21 billion industry, is expected to grow at slightly lower rates than ground transportation: deep sea and coastal transportation will expand at 2.0% and inland water transportation will grow at only 0.5% through 2012.

Warehousing and storage services (which earned approximately $9.1 billion in revenues in 2006) as well as logistics services (a $42.9 billion industry in 2006) are both relatively mature components of the transportation and logistics industry, and thus both are expected to continue to grow at approximately the rate of GDP growth through at least 2012.

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[92] Plunkett Research Ltd., *Transportation Industry Almanac*, "U.S. Transportation Industry Overview," 2007.
[93] Plunkett Research Ltd., *Transportation Industry Almanac*, "Selected U.S. Transportation & Warehousing Industry Revenue," 2007.
[94] Unless otherwise noted, IBISWorld's Industry Executive Summaries for the related NAICS cods are the sources of all sub-sector growth rates and revenue figures for the transportation and logistics section.

Sub-Sectors Overview		
Sub-Sector	Description	Examples of Large Companies
Ground	Includes transportation of goods by truck and express courier as well as related support activities.	CNF Inc., FedEx Corporation, J.B. Hunt Transportation Services, Schneider National, United Parcel Service (UPS), YRC Worldwide.
Rail	Includes transportation of goods by rail road and related support services.	Burlington Northern Santa Fe, CSX, Norfolk Southern, Union Pacific.
Water	Includes deep sea shipping, inland shipping, and coastal shipping in addition to related support services.	Alexander & Baldwin, American Commercial Lines, Crowley Maritime, Ingram Industries, Kirby, Tidewater.
Information Technology	Includes software, hardware, IT consulting, and systems/services developed for the transportation and logistics industry.	Fittipaldi Logistics, GlobalWare Solutions, TransCore Holdings, WhereNet, Wireless Matrix.*
Logistics	Includes arrangement of services between shippers and carriers (i.e., third party logistics, or 3PL), including freight forwarding, customs, and coordination between transportation modes.	C.H. Robinson Worldwide, EGL Inc., Expeditors International of Washington, Menlo Worldwide, UPS.
Warehousing/Warehouse Management Services	Includes operation and management of warehousing and storage facilities.	DHL, DSC Logistics, Kenco Group, Neptune Orient Lines, UPS.

*** Includes companies engaged only or primarily in information technology activities for the transportation and logistics industry, rather than IT companies with broader focuses.**

Technology needs across the transportation and logistics industry will center on providing greater information about product location; as mentioned above, such information is required in order to meet the demands of today's supply chains. The technologies used in the transportation and logistics cluster are not exclusive to the industry; instead, these technologies are being adapted and customized for use in transportation and logistics. As a result, the technologies listed in the following table are familiar – for example, RFID and GPS – and inherently support capacity in and development of multiple clusters.

For ground freight and rail transportation, GPS and RFID technologies are particularly important, as they can be used to track and trace the goods being transported as well as assets used in the transportation. Security-related technologies, including scanners and sensing devices, are also increasingly important for railroads, which could face threats or disruptions to rail lines and terminals. Likewise, sensors and other monitoring devices are gaining greater attention with respect to their potential applications in traffic management (e.g., "smart" roads).

Because of the complexity of logistics management in today's lean inventory environment, manufacturers and retailers have turned to outsourcing warehousing and warehouse management functions. As a result of this new customer-driven environment, "track and trace" technologies are becoming critical in warehousing and warehouse management as a way to effectively monitor and efficiently organize inventory and thereby minimize disruptions in stock for warehouse customers. Track and trace technologies encompass different combination of technologies, such as RFID, GPS/wireless, and software applications.

Technology Market Outlook			
Technology	Description	Estimated Market Size	Estimated Growth Potential
RFID (radio frequency identification)	Used for: managing and tracking inventory throughout shipping, storage and delivery processes; for monitoring rail and truck assets; for electronic toll collection and other types of automated traffic management systems.	$1.8 billion	$6 billion by 2010
Scanners and other sensing devices	Used to detect explosives, nuclear materials, and other cargo presenting security or other hazards; also may be used to sense transportation of humans in containers.	n/a	n/a
GPS and wireless	Used to track assets and products and to monitor vehicle and driver performance. As air traffic congestion air increases, these technologies also may replace radar use by air traffic controllers.	n/a	n/a
Software	Includes the platforms for use and integration of technologies in transportation, logistics, inventory, and warehouse management systems.	n/a	n/a
"Smart" roads and related devices	Involves use of sensors embedded in roads, cameras, magnetic strips and other devices to monitor vehicle movement and thereby provide real-time traffic information (e.g., roadside signs) or changes (e.g., "smart" traffic signals).	n/a	$430 billion from 1996 to 2016

High Growth Potential Technologies for Virginia

RFID (radio frequency identification)

RFID is "an automated data capture technology that uses low-power radio waves to communicate between readers and tags or contact-less cards."[95] RFID technologies are on the cusp of becoming critical enabling technologies for a wide variety of sectors, such as retail, health care and

[95] SRIC-BI, *RFID Technologies*, 2007, p. 9.

pharmaceuticals, manufacturing, payment systems, and security, identification and authentication. In transportation and logistics, RFID is particularly important for supply chain and logistics management, for tracking and monitoring, and for security and identification purposes. "RFID-system implementation is at an early stage … this nascent market stage resembles the early days of the Internet."[96] The major constraints to expansion of RFID use are privacy issues, costs, and potential conflicts between supply chain partners regarding integration of systems and ownership of data. Despite these obstacles, however, movement forward is already discernible – for example, in light of the current high cost of RFID tags, companies have switched from a product-tagging focus to container or shipment tagging options – and mass use is widely predicted to occur in the next five to ten years. For Virginia, RFID technologies are linked closely to development in several clusters, including life sciences and health care, national security, and information and communication technology, in addition to transportation and logistics.

"Smart" Roads

"Smart" roads are intended to solve or ameliorate the congestion created by the fact that, in the past 20 years, the United States has added only 2% more roadways, while the number of cars has increased by 50% and the number of miles driven by 77%.[97] These technologies also contribute to better understanding of how road materials affect durability and traction under different weather conditions. In fact, Virginia's Department of Transportation and Virginia Tech's Transportation Institute developed one of the nation's first test-beds for examining how vehicle movement is affected by 12 different types of surfaces under a variety of weather conditions (e.g., rain, ice, snow, and fog). The technologies underpinning smart roads are diverse, including embedded sensors and magnetic strips as well as batteries (or other power sources) and transmitters (including wireless devices) to relay information. In Virginia, technology development for smart roads complements potential activities in another important cluster, namely chemicals and materials technology.

The other technologies summarized in the table above – that is, scanners and sensing devices, GPS and wireless, and software – also overlap with technology development needs for other clusters which Virginia is considering as targets of opportunity. For example, scanning and sensing technologies are important for national security as well as life sciences and healthcare, as are wireless technologies and (for national security) GPS. As part of the ICT cluster, an enabling cluster for other industries, software development for the transportation and logistics industry also is beneficial to other Virginia clusters.

Cluster and Technology Foundations

Cluster Fundamentals

Both within Virginia and the United States as a whole, the transportation and logistics services cluster has recently experienced growth in employment, with Virginia's employment increasing by 8.1% from 2003 to 2005, compared to a 4.1% increase for the country as a whole. Rail transportation and ground passenger transit experienced particularly high employment growth in Virginia. Although the cluster overall has a concentration ratio of less than one, both water transportation and logistics and warehousing are more concentrated in Virginia than the national average. Additionally, average pay

[96] SRIC-BI, *RFID Technologies*, 2007, p. 45.
[97] Hampton, Bill, "Smart Roads," *Business Week*, http://www.businessweek.com/adsections/smartcars/smcaroads.htm.

in the cluster is relatively high and, moreover, wages are expected to rise at a rate o between 5% and 10%. In addition to these economic factors, Virginia also hosts several important federally-funded transportation- and logistics-related institutions, and numerous universities conduct research and host specialized centers related to the cluster. All of these factors contribute to the cluster's selection for inclusion in this report.

Technology Development Assets

Virginia's universities and federal facilities located in Virginia offer a variety of specialized research capabilities for the transportation and logistics cluster. For example, transportation safety and management are the focuses of Virginia Commonwealth University's Transportation Safety Training Center, Virginia Tech's Transportation Management Institute, and the Federal Highway Administration's Turner-Fairbank Highway Research Center; together these organizations provide a solid base for technology developments related to, for instance, smart roads. Likewise, the federally-funded Logistics Management Institute provides expertise applicable to managing and developing the information technology supporting today's global supply chains.

Virginia University Transportation and Logistics R&D Centers		
University	Center	Description
George Mason University	Center for Air Transportation Systems Research	The center's objective is air transportation education and research. Research includes analysis of complex adaptive networks, industrial sector economics, innovation and productivity in networked systems, rare-event safety analysis, and simulation of advanced concepts-of-operations and procedures.
Old Dominion University	Center for Advanced Ship Repair and Maintenance	A partnership between the private ship repair yards of Hampton Roads, Old Dominion University, CIT, and the City of Norfolk, the center's goal is to make ship repair operations more cost effective, while meeting or exceeding environmental requirements.
Virginia Commonwealth University	Transportation Safety Training Center	A division of VCU's Center for Public Policy, the center works closely with the Virginia Department of Motor Vehicles to improve transportation safety through training, curriculum development and technical assistance.
Virginia Tech	Center for Turbo-machinery Propulsion & Research	The center's current research includes unsteady stator/rotor interactions in compressors, noise control in turbofans, combustion instabilities and adaptive controls, turbine component heat transfer for realistic flows, analysis methods for controlling performance variability and costs, rotor dynamics, magnetic bearings, and active flow control for reducing high-cycle fatigue.
Virginia Tech	Advanced Vehicle Dynamics Laboratory	This laboratory and its staff offers testing and modeling capabilities to analyze dynamic, noise and vibration problems, and provide the most innovative and cost-effective solutions for these issues.
Virginia Tech	Virginia Tech Transportation Institute	The institute conducts applied research to develop new techniques and technologies to study transportation challenges from various perspectives: vehicle, driver, infrastructure, and environment.

Virginia Federal Transportation and Logistics R&D Centers		
Agency	Facility	Description
Department of Defense	Logistics Management Institute	A not-for-profit entity, the Logistics Management Institute advises government agencies on logistics, focusing on six main areas: acquisition, facilities and asset management, financial management, information and technology, logistics, and organizations and human capital.
Federal Aviation Administration	Center for Advanced Aviation System Development	Operated by MITRE (a nonprofit corporation), the center provides the FAA with technical capabilities in: operations research; computer science; electronic and systems engineering; behavioral science, human performance and air traffic management relevant to the National Airspace System; specialized simulation and computer modeling capabilities; and facilities to model improvements.
Federal Highway Administration	Turner-Fairbank Highway Research Center	The center provides FHWA with advanced R&D related to new highway technologies. The research focuses on development of more economical, environmentally sensitive designs; more efficient, quality controlled constructions practices; and more durable materials. Current research topics include: human centered systems; materials technology; operations and intelligent transportation systems; pavements; safety; and structures.

Research Outputs

As evident in the following table, Virginia Tech produces the greatest volume of transportation and logistics publications, which implies that the university has a relatively advanced degree of expertise in R&D related to the cluster. In addition to the four universities profiled in the previous section, one other university – the University of Virginia – also has substantial research and publications activity in transportation and logistics. Moreover, all of the federally-funded transportation and logistics agencies produced cluster-related publications during the last six years. By contrast, patent activity diverges substantially from publications data: with the exception of the U.S. Navy, no government organizations were awarded patents in Virginia, and private companies account for the remaining transportation- and logistics-related patents awarded in 2006.

Virginia Leading Transportation and Logistics R&D Organizations by Publication Output	
Organization	Publications (2001-2006)
Virginia Tech	216
University of Virginia	118
George Mason University	43
Virginia Transportation Research Council	33
Virginia Commonwealth University	21
Old Dominion University	21
College of William and Mary	11
MITRE Corp.	11
Federal Highway Administration	10
Turner Fairbank Highway Research Center	10

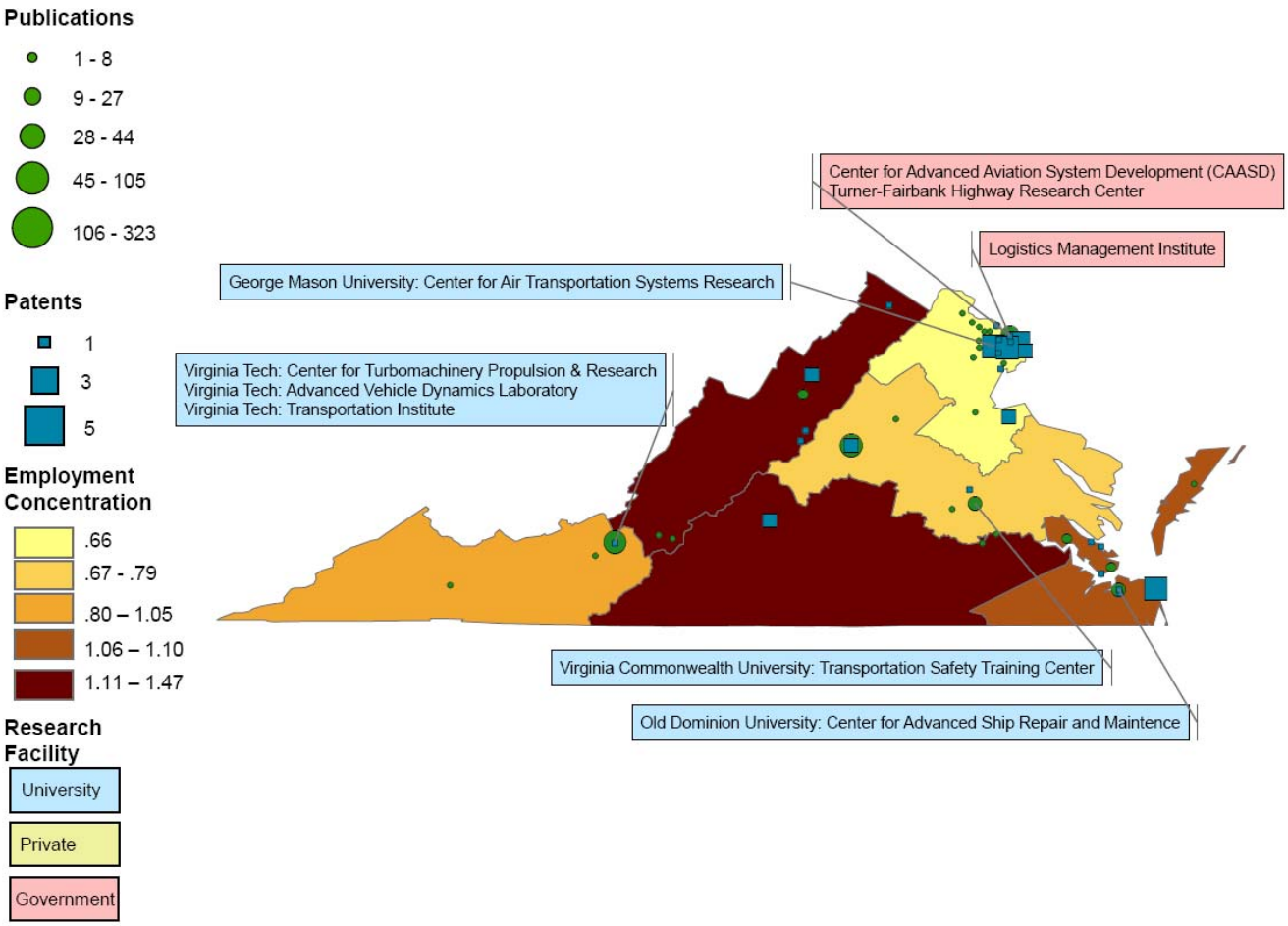
Source: SRI Analysis of ISI Web of Science Data

Patent Assignee Organizations for Virginia Developed Transportation and Logistics Technologies	
Organization	Patents (2006)
United States Navy	4
Allen Engineering Corporation	2
F.R. Drake Company	2
Milwaukee Iron, Inc.	2
AB Volvo	1
Collins & Aikman Products Co.	1
ENSCO, Inc.	1
Ford Global Technologies, LLC	1
Gauge Works, LLC	1
General Dynamics Advanced Information Systems, Inc.	1

Note: Assignee may not be located in Virginia, but at least one inventor listed on the patent is based in Virginia.
Source: SRI Analysis of Delphion Data

Cluster Map

Transportation and logistics publications and patenting activity in Virginia is concentrated around its universities, as well as in Northern Virginia, where all of the state's federally-funded agencies in this cluster are located. Employment, however, is not as concentrated in Northern Virginia as in most of Virginia's other regions, particularly the Valley, Southside, Hampton Roads, and Southwest, all of which have concentration rations above or close to the national average.



Assessing The Technology Industry Potential Of The Commonwealth Of Virginia

January 7, 2008
P18176

Task 4:
State Technology Development Case Studies and Best Practices

Prepared for the Virginia Economic Development Partnership

State Technology Development Case Studies And Best Practices

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I. Introduction and Executive Summary

Introduction

This report presents information on ten case studies of state-level initiatives designed to accelerate technology-led economic development. There are numerous studies on this topic, which provide both in-depth analysis of specific programmatic initiatives, as well as broader analysis of key elements and best practices for successful technology-driven growth. Two notable recent reports include *Investing in Innovation*[1] by the National Governors' Association and the Pew Center on the States, and *A Resource Guide for Technology-based Economic Development*[2] by the State Science and Technology Institute. Rather than duplicate such reports, the SRI team has conducted a thorough review of these and other sources in order to identify successful public-private technology development programs that mirror Virginia's objectives of enhancing innovation capacity, competitiveness, and future economic prospects.

The goal of this report is to:

- Identify relevant case studies on topics/programs identified by the SRI team as worthy of consideration in view of findings drawn from the industry cluster analysis, benchmarking, and technology assessment of the Commonwealth of Virginia;
- Synthesize and condense key findings from the extensive literature that already exists on this topic; and
- Provide expanded information on case studies for programs whose elements could serve as possible models or examples for Virginia to develop its own targeted initiatives and programs.

Readers should keep in mind that the inclusion of programs in this report does not necessarily suggest an endorsement of them. All economic development initiatives encounter problems as well as successes, and it often takes time for practitioners to diagnose and address drawbacks. It is also important to acknowledge that most information about different initiatives comes directly from those with a vested interest in highlighting achievements and downplaying mistakes. As a consequence, the stated impacts and results of programs might be overstated. All such programs have their champions and detractors. Accordingly, the key objective of this report is to distill insights from those examples generally viewed in the literature as meritorious.

[1] National Governors Association and the Pew Center on the States, *Investing in Innovation*, 2007, www.nga.org/Files/pdf/0707INNOVATIONINVEST.PDF. Numerous examples of interventions to stimulate technology-led economic growth are highlighted in this report.

[2] State Science and Technology Institute, *A Resource Guide for Technology-Based Economic Development*, prepared for the U.S. Department of Commerce Economic Development Administration, August 2006. A comprehensive guide covering a wide range of state and regional programs, policies, and practices to promote technology-based development.

Summary of Focal Areas and Case Studies

As noted above, this report explores several case studies in three focal areas of interest to Virginia.

- **Enhancing Research Excellence at Universities.** The first area concentrates on initiatives to strengthen research activities and outputs at universities. Major research universities can serve not only to generate scientific breakthroughs, but also to catalyze regional technology-led development through start-ups, industry linkages, and production of high caliber graduates. In reality, some universities play this role successfully, whereas others contribute little due to a variety of issues and gaps.

- **Enhancing Collaboration Across Sectors and Disciplines.** The second area addresses the challenge of expanding collaboration among institutions, disciplines, and sectors. Experience has clearly shown that active interactions among researchers, entrepreneurs, financiers, businesses, and the public sector can increase levels of innovation and the resulting economic benefits.

- **Enhancing Entrepreneurship and Access to Capital.** The third area examines methods for enhancing levels of start-up activity, as well as access to the finance and capital necessary for entrepreneurs to succeed. World-class research does not translate automatically into new economic activity, and in fact, it most often does not. Regions with climates that nurture and reward entrepreneurs, and which channel appropriate levels of financial support to them, are more likely to outperform regions that ignore or downplay the entrepreneurial environment.

Some of the case studies presented in this report focus on specific, narrowly-articulated programs, while others cover broader-ranging partnership initiatives to support regional economic and technology development. An overview of the case studies is shown in the following table.

Topic Areas	Enhancing Research Excellence At Universities	Enhancing Collaboration Across Sectors And Disciplines	Enhancing Entrepreneurship & Access To Capital
Technical Focuses	■ Creating university-industry research centers or "Centers of Excellence" ■ Creating eminent scholars programs ■ Funding to promote joint university-industry research ■ Promoting technology transfer & commercialization of technologies from universities	■ Facilitating linkages and joint research among universities, industry, federal labs, etc. ■ Promoting cross-discipline research ■ Engaging relevant stakeholder groups in the design and operation of innovation programs	■ Creating a culture of entrepreneurship ■ Assisting entrepreneurs and start-ups to access early-stage financing ■ Increasing the flow of venture/angel capital ■ Other support services for entrepreneurs (such as incubators)
Case Studies	■ Georgia Research Alliance ■ University of Texas System Eminent Scholars Program ■ Ohio Third Frontier Initiative: Wright Mega-Centers of Innovation	■ New York Centers for Advanced Technology ■ Maryland Industrial Partnerships Program ■ California Industry-University Cooperative Research Program (Discovery Grants) ■ North Carolina's Research Triangle	■ Maryland Venture Fund ■ Georgia Advanced Technology Development Center ■ Pennsylvania Ben Franklin Technology Partners

Summary of Best Practices and Lessons Learned for Virginia

A number of overall conclusions and inferences relevant to the Commonwealth of Virginia can be distilled from the case studies examined in this report, as well as from other reports and examples of technology-based economic development initiatives. These lessons provide guidance for discussions on how best to structure efforts to enhance Virginia's innovation capacity, competitiveness, and future prospects.

1) **Highlight collaboration as a central component in programs.** Many technology-based economic development efforts suffer from a "stove pipe" effect, in which research, training, finance, and other programs operate independently and do not cross-fertilize for maximum impact. States in which universities seek to isolate themselves from other institutions, the business community, and regional and state leaders do not generate the environments conducive to innovation. On the other hand, states that enjoy high levels of collaboration reap the benefits of innovation. The successes of states such as Georgia, North Carolina, and Texas in accelerating innovation demonstrate the importance of engaging key players across the academic, public, and private sectors to achieve common goals.

2) **Seek to leverage multiple sources of funding.** Research and innovation, as well as translating research outputs into commercial activities, takes money – a scarce commodity. The most successful programs actively seek to identify and attract multiple funding sources, ranging from public revenues, industry, foundations, universities, etc. In most of the programs highlighted here, state funding is contingent upon academic and/or private sector matching funds. This approach, in turn, encourages funders to become stakeholders and encourages collaboration.

3) **Utilize industry and technology experts as key players in decision-making.** Successful regions and states engage the "experts" in shaping and operating innovation programs. Such efforts may include using a peer review process for selected proposals to be funded, or creating a board of industry experts to provide program oversight. Industry partners can breathe economic reality into initiatives; they help ensure that research activities have real market potential that can lead to economic impacts.

4) **Select and target strategic sectors.** The amount of resources and time required for science-driven innovation are considerable, thus necessitating some form of strategic selection process for funding research. Choosing broad groups of technologies based on their potential for commercialization and competitiveness makes sense in efforts to marshal scarce public sector resources. Successful programs typically focus on a range of 3-6 broadly defined high-technology areas that have real market potential and applications in the state. These technology areas build on existing assets and "anchor" research institutions, and they strive to use new public money to make these technology areas "best-in-class."

5) **Incorporate key economic development objectives and milestones.** Ultimately, public resources allocated to any development effort should yield benefits to the public, mostly in this case in the form of productive employment opportunities. Innovation and technology-based programs should be driven by economic outcomes, and hence should be monitored against economic milestones.

6) **Introduce and maintain strong systems of accountability.** All programs, public or private, need systems to assure accountability and transparency, both financial and operational. For example, those conducting research should accurately report their progress, successes, and failures. Entrepreneurs need to account for the resources they receive. Programs in general should have structures in place to monitor and report performance objectively. Overall, accountability creates and sustains credibility and confidence. Funding should be tied to well-articulated requirements for technology commercialization, sustainability, and/or economic benefits (such as jobs, company creation, etc.).

7) **Include flexibility to allow for corrections and to support longevity.** Nearly all state and regional innovation programs have evolved over time, both to address problems and to accommodate to altered circumstances or needs. Those responsible for authorizing programs need to recognize that for programs to be ultimately effective, they need sufficient time and resources to allow them to incubate, adapt, mature, and perform.

II. Enhancing Research Excellence At Universities

List of Case Studies

- Georgia Research Alliance
- University of Texas System Eminent Scholars Program
- Ohio Third Frontier Initiative: Wright Mega-Centers of Innovation

Georgia Research Alliance

The Georgia Research Alliance (GRA) was founded in 1990 to bring together business, research universities, and the state government to build an innovation- and technology-driven economy fueled by pioneering university research. Since its establishment, it has become one of the country's most successful and highly acclaimed models of public-private-university collaboration.

GRA Mission: *Georgia will be ranked among the top tier of states in the nation with a vibrant, sustainable, technology-rich economy.*

GRA Core Values:[3]

- **Flexibility:** In a rapidly changing environment, agility and flexibility breed success.
- **Sharp Focus and Broad Application:** Focus on the development and application of those technologies that will offer the best opportunity for significant impact on Georgia's economic vitality.
- **World Class Initiatives:** Aspire to excellence.
- **Balanced Interests:** Maintain a balance of interests among partners who must come together to achieve GRA's vision.
- **Collaboration:** Promote collaboration among the business, university, and government sectors, among industries, among universities and across departments and disciplinary lines.

GRA is affiliated with six of the state's universities: The University of Georgia, Medical College of Georgia, Emory University, Clark Atlanta University, the Georgia Institute of Technology, and Georgia State University. The core of GRA's program is to attract pre-eminent scientists (or "Eminent Scholars") to Georgia's universities to lead cutting-edge research and development in areas with the greatest potential for creating and strengthening companies in strategic technology industries. Ultimately, the goal is to help the state to:

- Compete successfully for a larger share of federal and foundation research funds.
- Attract other talented faculty and graduate students to Georgia.
- Foster new companies and create new relationships with industry to commercialize technologies developed through their research, so that more jobs and economic opportunities can be created for Georgia's citizens.

Establishment And Evolution Of The Program

The first major state-supported R&D initiative in Georgia began in 1985, when Governor Harris founded the Governor's Research Consortium, an R&D investment program to establish centers of excellence at Georgia's research universities. The Consortium funded a number of research centers in the state's universities, including a Life Science Center at the University of Georgia (1985-1986), the Manufacturing Research Center at the Georgia Institute of Technology (1988), and the Rollins Research Center at Emory University (1988). Typically, the state provided substantial support for facilities and equipment, with commitments from the universities to attract additional research funding from external sources. However, there was no funding for investment in research personnel, nor did the Consortium foster linkages between university and industry.

[3] www.gra.org

In the late 1990s, a group of business leaders recognized this gap and began to champion for a more comprehensive approach to developing Georgia's research excellence and leveraging it for economic competitiveness. Among these business leaders were real estate developers Lawrence Gellerstedt, Jr. and Thomas G. Cousins, who conceived of the Georgia Research Alliance in 1990, an election year. Realizing the importance of having the state's top universities buy into the idea at an early stage, the business group obtained the support of the presidents of the Georgia Institute of Technology, the University of Georgia, and Emory University (two public and one private institution), with other research universities expected to join the Alliance later. The cooperation of the university presidents was facilitated by the fact that Gellerstedt and Cousins served on the Boards of Trustees of two of the three initial affiliated institutions in the Alliance.

The business leaders who conceived of the GRA lobbied both gubernatorial candidates before the election and secured their support. As potential contributors to both candidates' campaigns, Gellerstedt and Cousins made it clear that their contributions were contingent upon each candidate's support of GRA. As a result, the GRA became part of both candidates' economic development plans. Zell Miller was elected Governor and fulfilled his promise by supporting GRA enthusiastically and guiding the funding initiative through the state legislature.

The Georgia Research Alliance was created as a 501c3 corporation, with the Governor serving as an *ex officio* member of the Board of Trustees. The Medical College of Georgia, Georgia State University, and Clark Atlanta University joined GRA shortly after its creation. The Trustees initially consisted of twelve CEOs of Georgia-based businesses and the presidents of the six affiliated universities, each of whom had one vote.[4] Gellerstedt served as the chair of the first GRA Board of Trustees. The first appropriation (FY 1993) was made for $15 million, to be used to fund three Eminent Scholar positions and to modernize laboratories at the state's research universities.

Concrete evidence that GRA's strategy was paying off began to accumulate beginning in 1994, when the Georgia Institute of Technology won a National Science Foundation Engineering Research Center Award, a first for the state of Georgia. This was soon followed by other prestigious awards won by GRA-affiliated university research centers under the intellectual leadership of Eminent Scholars attracted by the program. Through fiscal year 1999, the state of Georgia had invested $242 million in the GRA, matched by $65 million in private funds. This investment, in turn, had attracted more than $600 million in additional sponsored research. The obvious and tremendous payoffs of GRA to Georgia's economy solidified continuing support and funding for GRA over the following decade.

In fiscal year 2006, the State of Georgia provided $26.8 million in funding to the Georgia Research Alliance. According to GRA, to date the Alliance has invested some $400 million, which has helped to attract more than 55 Eminent Scholars and secured an additional $2 billion in federal and private funding. GRA's investments have also led to the creation of an estimated 4,000+ new technology jobs and 125 new technology companies, and have allowed established Georgia companies to expand into new markets.[5]

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[4] Membership on the Board was later expanded to include representatives from other sectors.

[5] www.gra.org/results.asp, www.gra.org/economicimpact.asp, and GRA, *The Year in Opportunities, A Report to Constituents 2006*, www.gra.org/documents/GRA_AR2006.pdf

How The Program Works

GRA makes strategic investments at the state's leading research universities through three mechanisms: **Eminent Scholars, Research Infrastructure,** and **Technology Transfer and Commercialization Support.** These components work together to attract research talent and additional federal and private research dollars in sharply focused technology research areas. The current areas in which Georgia focuses on developing and enhancing research competitiveness include: advanced communications, computing and content; bioscience; nanoscience and advanced materials; and energy innovation.

GRA Programs and Investments		
Investment Mechanism	**Overview**	**FY 2006 Investment**
Eminent Scholars	Permanent endowments ($1.5 million each) at six universities, funded 50% by GRA and 50% by private sources, to help recruit enterprising scientists to Georgia, as well as funding to equip their start-of-the-art labs.	$7,400,000
Research Infrastructure	Partner with federal sponsors to build Centers of Research Excellence; build one-of-a-kind labs around Eminent Scholars and industry requirements; and invest in start-of-the-art technology.	$14,085,000
Technology Transfer and Commercialization Support	Investment to launch companies out of university research, open university labs to Georgia companies (through partnerships), and acquire technology for university-based incubators.	$5,338,000
Source: Georgia Research Alliance, *The Year in Opportunities, A Report to Constituents 2006*, www.gra.org/documents/GRA_AR2006.pdf		

1. Eminent Scholars

The centerpiece of GRA is its Eminent Scholars Program, a highly successful and emulated model. The program seeks to recruit prominent scholars from around the world, who are leaders in strategic technology fields, to work at GRA member universities. To date, GRA has created 55 Eminent Scholar positions in participating universities. Each position is established with a permanent endowment of $1.5 million, split 50/50 between the state and the university. To establish an Eminent Scholar position, a GRA-affiliated university must identify a strategic research area in which they want to attract a high-profile research scientist and provide the $750,000 in matching funds (often obtained from private sector partners).

The Eminent Scholar can use the income generated by the Endowment as he or she wishes. The University is responsible for creating and funding a salaried position for the Eminent Scholar, and also for providing additional research support positions – such as assistant professors, post-doctoral scientists, and graduate student positions – to support the scholar.

Another important incentive to add to the recruitment package for the Eminent Scholars has been the commitment by GRA to build and equip state-of-the-art laboratories with the sophisticated equipment that the scholars need for research (see *Research Infrastructure* below). This comprehensive recruitment package has been a key success factor for GRA to attract world-class researchers to Georgia.

Selection Criteria for GRA's Eminent Scholars

- Eligible at the rank of professor.
- Grant productivity – Eminent Scholars are expected to generate $1 million or more in R&D awards over a couple of years or be able to bring in major grant for a center or other major effort.
- Well respected in their fields and broadly cited in the literature over a sustained period.
- Working in a field regarded as having strong potential.
- Demonstrate potential for developing a large-scale, comprehensive, well-funded interdisciplinary center.
- Have a track record of building teams and providing mentoring rather than acting primarily in the capacity of an individual investigator.
- Exhibit characteristics that suggest they can interact at a high level with not only academics but with industry and government.
- Have an interest in entrepreneurship, such as interest in creating his/her own company or in working with entrepreneurs or companies interested in commercializing a new technology or discovery.

Source: SSTI, *A Resource Guide for Technology-Based Economic Development*, August 2006

GRA also provides additional incentives for Eminent Scholars to maximize collaboration with outside partners. In fiscal year 2008, *Eminent Scholar Challenge Grants* of up to $50,000 per team will be made to winning teams under a competitive bidding system. The purpose of these investments is to bring together Eminent Scholars from different universities and disciplines to investigate and develop new technologies, and/or to explore opportunities for new federal research funding. To be eligible for an award, the proposing teams must consist of at least two GRA Eminent Scholars from at least two different universities. Applications are evaluated based on technical merit, the potential for future commercial development, or award of a significant federal R&D grant.

2. Research Infrastructure

GRA realizes that world-class scholars require world-class facilities and equipment to facilitate their research and discovery, and that the combination of these factors can attract substantial federal funding and private sector co-investment. Thus, GRA has made enormous investments in research facilities at affiliated universities, ranging from multi-user, multi-purpose centers to highly specialized laboratories and equipment. Among its infrastructure investments are:

- The **Georgia Centers for Advanced Telecommunications Technology** at the Georgia Institute of Technology
- The **Center for Applied Genetic Technologies** at the University of Georgia
- The **Emory Vaccine Center** at Emory University
- The **Center for Biotechnology and Genomic Medicine** at the Medical College of Georgia
- The **Center for Biotechnology and Drug Design** at Georgia State University
- The **Research Center at Clark University**, which facilitates interdisciplinary and collaborative research

In addition, GRA investments have been instrumental in establishing **18 National Centers for Innovation and Research** in Georgia, primarily by providing matching funds to attract federal grants, foundation grants, and private sector funds as the foundation for the Centers' research programs. Many of the Centers are led by GRA Eminent Scholars, some of which are one-of-a-kind laboratories built around Eminent Scholars' and industry requirements. Examples include:

- The NSF-funded **Center for the Engineering of Living Tissues** and **Center for Behavioral Neuroscience**
- The **Southeast Collaboratory for Structural Genomics**, established through a $24 million National Institutes of Health grant
- A $4.5 million grant received by the **Emory Vaccine Center** from the Bill and Melinda Gates Foundation
- A $3 million commitment received by Georgia Tech's **Center for Organic Photonics and Electronics** from the pharmaceutical group Solvay
- The **Microsystems Packaging Research Center**, a collaboration funded by NSF, the State of Georgia, and electronics industry partners.

Eminent Scholar and Research Infrastructure Investments Working Hand in Hand

The successful recruitment of one of GRA's newest Eminent Scholars, Dr. Kapil Bhalla, is an example of how GRA investments in Eminent Scholars and supporting R&D infrastructure work together as a powerful tool for recruiting top research talent in critical technology fields.

In 2006, the Medical College of Georgia gained Dr. Bhalla as a GRA Eminent Scholar and to serve as director of a new $54 million Cancer Research Center at the University. Dr. Bhalla is a prominent cancer researcher who was formerly the scientific director at the H. Lee Moffitt Cancer Center & Research Institute (Florida's only "comprehensive cancer center" as designated by the National Cancer Institute). The new Cancer Research Center facility is a five-story, 167,000 square foot hub of scientific, clinical, and education initiatives. It will explore immunology and immunotherapy, cell signaling, prevention and control, and development therapeutics. GRA helped recruit Dr. Bhalla from Florida to be the founding director of the new Cancer Research Center by co-funding his Eminent Scholar position. GRA is also investing in transforming one of the unfinished floors of the facility into a Cancer Epigenetics Program, which will help to recruit additional top cancer research scientists to the Center.

Source: GRA, The Year in Opportunities, A Report to Constituents 2006, www.gra.org/documents/GRA_AR2006.pdf

3. Technology Transfer and Commercialization

The third component of GRA's program is aimed at nurturing research and emerging technologies into business opportunities, new companies, and high value jobs for Georgia. GRA supports technology transfer and commercialization by making investments to launch companies out of university research, by acquiring technology for university-based incubators, and by opening university labs to Georgia companies through partnerships.

- The **VentureLab Program** was conceived as a "pre-incubator" program, supporting the first step of bringing technology from the university to commercialization, prior to company formation. The program was piloted at Georgia Tech in 2001, then extended to the University of Georgia in 2002, and is now being expanded to other GRA-affiliated universities. Operating out of the individual research universities, VentureLabs offer a suite of services that help entrepreneurial faculty identify laboratory discoveries that have commercial potential and guide faculty during the earliest stage of commercialization, so that their ideas can advance to the stage of company formation. The ***VentureLab Fellows*** program provides seed investments to hire professionals who bring skills in new business and product development, and have a track record in raising venture capital. VentureLab Fellows coach faculty entrepreneurs through the initial phases of the commercialization process. They often serve as the first CEO of the new company, guiding activities that explore the viability and commercial potential of the company technology and seeking private investment capital.

VentureLab commercialization grants also support participating university-based researchers to validate technology and to develop and refine projects. *Phase I* grants provide up to $50,000 to assess market demand for a product or service. *Phase II* grants provide up to $100,000 to develop a working prototype and require equal financial participation from the new company. *Phase III* grants provide up to $250,000. A recent success story of VentureLab investment is the biotech startup Vivonetics. GRA invested $118,000 in Vivontetic through two VentureLab grants. The GRA funding helped attract a $1.65 million grant from the National Institutes of Health in 2006 to develop and commercialize a nano-scale sensor that will help detect and diagnose cancer and other diseases. The company planned to launch a commercial product in 2007.[6]

- **Technology Development Centers (TDCs)** are incubators run as joint ventures between GRA, the host university, and in many cases, the Advanced Technology Development Center (part of the Georgia Tech's Enterprise Innovation Institute). Located at GRA-affiliated universities, the seven TDCs provide resident companies with access the university's specialized equipment and facilities, in addition to affordable space and a menu of comprehensive startup services. GRA estimates that 125 companies have graduated from all of Georgia's university-based technology incubators.[7]

- Through its **Technology Partnerships Fund**, GRA provides matching funds for industry-university partnered research. Grants of up to $100,000 per partnership per fiscal year are given under a competitive bidding process to university-industry teams who are collaborating to investigate and develop new technologies and to improve products/processes of Georgia companies. Industry partners must enter into a sponsored contract agreement with the university and must agree to provide financial support to the project in an amount at least equal to GRA's contribution. This program is open to GRA-affiliated universities as well as research faculty from other Georgia universities who are partnering with faculty from a GRA-affiliated university. The program targets three specific technology areas: advanced computing and communications, bioscience, and nanotechnology/advanced materials.[8]

Program Impact

The Georgia Research Alliance has been recognized nationwide and internationally as a highly effective model of channeling and leveraging state resources for technology development that leads to tangible economic benefits. State government investments are made on the basis of achieving gains for Georgia's economy, and GRA tracks its program results and impact using measurements of economic impact and vitality. Since its inception 16 years ago, GRA has invested some $400 million and has reported the following results, which have moved Georgia from the lower or middle tier states to the top tier states in a number of metrics of economic vitality:

- GRA's $400 million investment has brought $2 billion in new federal and private investment, a return of $5 for every $1 invested by the state of Georgia.
- 125 new start-up companies were spun out of university research, and more than 4,000 new jobs were created in technology fields.

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[6] For more information about the VentureLab program, see: www.edi.gatech.edu/gra-venturelab/index.html
[7] For more information about Technology Development Centers, see: www.gra.org/techincubators.asp. The Georgia Tech Advanced Technology Development Center is also presented as a separate case study in this report.
[8] For more information about the Technology Partnerships Fund, see: www.gra.org/innovationgrants.asp

- More than 100 partnerships have developed between Georgia companies and universities. GRA-affiliated research universities have increased their research collaboration with industry by 800 percent since the early-1990s.
- Georgia ranks 9th in the nation for its number of biotech companies, growing 65 percent between 1995 and 2002, as compared to a 37 percent growth rate nationwide.
- Georgia consistently ranks high for the support infrastructure it provides to start-up companies, including venture capital.
- Georgia is among the small number of states across the country whose government has adopted research enterprise as a cornerstone of its statewide economic development strategy. Collaboration among research universities, state government, and business and industry in Georgia is among the most effective and strongest of any state in the nation. [9]

Success Factors And Lessons Learned

- **Strong vision and leadership.** The founding of GRA was only possible because a strong group of champions, consisting of industry leaders and university presidents, obtained the commitment and support of the highest level of the state government (Governor Miller) to make substantial state investments in achieving a new economic vision based on investment in technology development.

- **Autonomy and the "catalytic role."** GRA's autonomy, rising from its nongovernmental structure, helped it garner initial public support in state where many are suspicious of big government. GRA focuses its role as a catalyst, using its investments as incentives and impetus to bring together resources – public, private, and academic – that collectively will produce higher economic impact for Georgia.

- **Collaboration.** GRA credits much of its success to the ability of the Alliance to encourage and support collaboration. This extends from collaboration among GRA universities and their interdisciplinary teams, to collaboration between universities and the private sector. The ability of GRA to play the important synergistic role in facilitating and enabling these collaborative efforts is an important ingredient of success.

- **Focus.** Focusing investments in specific technology/research areas, as the well as integrating the three GRA pillars – scholars, infrastructure, and commercialization – to support each targeted research area, creates economies of scale that help GRA achieve high returns on its investments.

[9] www.gra.org/results.asp, www.gra.org/economicimpact.asp, and GRA, *The Year in Opportunities, A Report to Constituents 2006*, www.gra.org/documents/GRA_AR2006.pdf

University Of Texas System Eminent Scholars Program

Numerous states have established eminent scholars programs to build their research base by providing their universities with the resources to attract and retain world-class faculty. The University of Texas at Austin pioneered this best practice. In the early 1980s, the university filled 32 endowed positions in engineering and natural sciences, with an emphasis on microelectronics, material sciences, physics, and computer sciences. This initiative was a significant contributor to the ability of Austin to attract the Microelectronic and Computer Technology Corporation (MCC) and SEMATECH, and it spurred rapid growth in the regional economy.

Most eminent scholars programs provide funding for endowed chairs, with endowment income to pay the salary of the researcher, as well as some startup costs to outfit a laboratory, hire research assistants, etc. These are viewed as investments. A current endowed chair might now cost $3-6 million, but can generate between $5-30 million in additional research funding over a ten year period.[10]

Establishment And Evolution Of The Program

Forty years ago, Austin was known largely for being the state capital of Texas and the site of the University of Texas at Austin. Today, Austin is touted in technology circles as "the second Silicon Valley." The city is home to one of the top engineering schools in the country[11] and reads like a *Who's Who* of high-tech computer, semiconductor, and electronic component companies. Motorola, Advanced Micro Devices, Applied Materials, and Samsung, four of the largest semiconductor and semiconductor equipment manufacturers, are all located in Austin, as well as Dell, IBM, and Apple, three of the leading personal computer manufacturers, and the sizeable software company, Tivoli Systems.

The emergence of Austin as an IT cluster was based on strategic decisions, investments, and marketing efforts that took place in the 1980s. Specifically, the establishment of the semiconductor industry in Austin came about largely because of the success of direct efforts taken by the Greater Austin Chamber of Commerce, the local government, and the University of Texas at Austin to attract MCC and International SEMATECH to Austin. The dominance of Austin's IT industry's presence today is a direct consequence of research carried out at UT and at key private sector companies, and in many cases the creation of entire companies can be directly linked to a particular university research effort as well. These synergies have not stopped and continue to support the growth of newer high-tech industries in Austin, such as software development, biotechnology, and multimedia.

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[10] SSTI, *A Resource Guide to Technology-Based Economic Development*, August 2006, p. 18.

[11] University of Texas at Austin ranked 11th in the Top Engineering Schools category in the U.S. News & World Report's *Best Graduate Schools 2008* (grad-schools.usnews.rankingsandreviews.com/usnews/edu/grad/rankings/eng/brief/engrank_brief.php)

The Road to High Tech: Timeline of Key Junctures in Austin's Economic Development	
1957	Austin Chamber of Commerce hires UT Austin's Bureau of Business Research to identify how Austin could diversify its economy. The Bureau recommends that Austin develop its light manufacturing industry with a focus on the electronics industry.
1963	IBM opens a plant to manufacture Selectric typewriters.
1966	Texas Instruments opens a plant to manufacture handheld calculators.
1974	Motorola establishes semiconductor operation.
1979	Advanced Micro Devices (AMD) opens semiconductor facility.
1982	Dell Computer Corporation founded by Michael Dell, a freshman at UT Austin.
1983	Creation of thirty-two $1 million endowed chairs in engineering and natural sciences at UT Austin as part of incentive package to woo MCC.
1983	Microelectronics & Computer Technology Corporation (MCC), a consortium of the world's leading computer, semiconductor, and electronics manufacturers, selects Austin over 53 other cities in 27 states.
1984	Austin Chamber of Commerce commissions SRI International to develop a long-term economic plan for Austin. SRI's report stresses the development of three science and technology-related sectors: (1) research and development, (2) technology manufacturing, and (3) technology-based information. The report also highlights the linkage between quality of life and high-tech economic development.
1988	International SEMATECH, a national consortium of semiconductor manufacturers, chooses to locate in Austin.
1990	Applied Materials locates its manufacturing facility in Austin.
1995	Austin Community College establishes a Semiconductor Technology Program to address a shortage of high-tech technicians. The program was designed in partnership with AMD, Applied Materials, Motorola, SEMATECH, and Texas Instruments and offers two-year associate degrees and one-year certificates.

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

Austin's eminent scholars program had its origins in investment promotion – a regional effort in the early 1980s to attract the Microelectronics & Computer Technology Corporation (MCC). MCC is a consortium of the world's leading computer, semiconductor, and electronics manufacturers, and users and producers of information technology. Created in 1982, it was the first high-tech R&D consortium in the United States financed by private industry.[12] In 1983, MCC was looking for a place to locate, and Austin made it into the final four (down from 53 cities in 27 states), competing against Atlanta, San Diego, and Raleigh-Durham. The city marketed its strong partnership between business, education, and government and its seriousness about turning Austin into a technology-driven economy. The government contributed financial incentives and a business-friendly environment, as well as providing the requisite statesmanship by the governor and the mayor.[13] The University of Texas at Austin, supported by the private sector, offered the following incentives:

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

[12] In June 2000, MCC announced a major restructuring of its business model. Under the new model, MCC is investigating spin-off of all or part of its major projects as separately funded start-ups.
[13] Miller, Jonathon. "Regional Case Study: Austin, Texas, or 'How to Create a Knowledge Economy'" for the European Commission's *The Stories Behind Jobs and Growth: U.S. Regional Economic Development.*

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

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

The creation of the thirty-two $1 million-endowed chairs at UT Austin was a pivotal part of the incentive package offered to MCC. The endowment was raised through an $8 million private gift and subsequent matching funds. Since 1984, more than forty $1 million-endowed chairs have been created to recruit internationally recognized faculty to accelerate research programs in engineering and science.

The endowment of the chairs was also the key turning point for Austin for bolstering its capabilities in advanced information and communications technology research. The endowment allowed the university to attract world-class professors in these fields, who, in turn, attracted top-level students and companies anxious to benefit from the research being undertaken and from the students that began to graduate from these top-level science and engineering programs.

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

How The Program Works

UT Austin's initiative to recruit and retain top researchers in the 1980s was carried out as something of an *ad hoc* activity by a public/private partnership, rather than a fully articulated program. However, the effort has evolved into the UT System's current "Science and Technology Acquisition and Retention" (STARs) Program. The STARs Program was established in 2004 and is funded by bond proceeds from UT's Permanent University Fund. Grants are made available to offer enhanced facilities and state-of-the-art equipment with the aim of attracting and retaining world-class researchers.

The STARs Program, which was funded at $30 million in fiscal year 2007, has three related goals:

- Retaining high quality faculty who have offers from other research institutions or have the potential for leaving because of limited access to quality equipment and/or laboratories.
- Recruiting senior faculty who have "star" quality.
- Improving the quality of new faculty and the research capacity of UT institutions by augmenting start-up packages for tenure-track assistant professors.

The STARs Program consists of two elements:

1. Non-competitive block grants (up to a total of $10 million) to recruit extremely high-potential junior faculty.
2. Competitive grants (up to a total of $20 million) to recruit top-caliber senior faculty.

The competitive grants program provides funds to purchase equipment and renovate facilities to help recruit particularly outstanding faculty. These funds are meant to supplement institutional resources.

Priority is given to recruiting individuals who have national reputations and who are promising candidates for selection to national honor societies such as the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, etc., or who have already been elected to those organizations.

The STARs Program requires a commitment by nominating institutions to match not less than 10 percent of the amount awarded by the UT System. Nominated individuals must show evidence of accomplishment in research, with demonstrated capacity for national competitive extramural research support and graduate student training. There must be clear justification for additional equipment and renovation needs for amounts up to $1 million, the maximum start-up package for recruiting new faculty. The maximum package for recruiting assistant professor level faculty is $500,000. Some faculty recruitments may require substantially more than these amounts, and in such cases the institutions would be expected to provide a higher amount of support for recruitment.

Program Impact

The initial eminent scholars initiative in Austin contributed significantly to the growth of the region's technology sector, which has been the fundamental driver of Austin's economy over the past decade. Three IT industry clusters now exist where previously there were none (semiconductors, computers, and software). The initiative was instrumental in attracting MCC and later SEMATECH, which in turn attracted other companies and triggered Austin's high technology boom.

MCC's critical role in Austin's economic development was in bringing researchers from premier technology-based companies – such as 3M, Hewlett-Packard, Eastman Kodak, Nortel Networks, Motorola, Texas Instruments, and Raytheon – to conduct R&D in Austin over several years. After research projects ended, a few of the more entrepreneurial researchers decided to stay in Austin and started their own companies. In other cases, the member company decided to open an Austin operation. This was the case for Crystal Semiconductor and Silicon Laboratories.[14]

In 1984, utilizing the same business, education, and government partnerships, Austin successfully enticed 3M to relocate five of its R&D and administrative divisions from Minnesota. Then, in 1988, Austin attracted SEMATECH. Originally created as a public-private partnership to reinvigorate the U.S. semiconductor industry, SEMATECH has evolved into the world's premiere research consortium on semiconductor technology. The consortium currently consists of 13 semiconductor manufacturing companies from seven countries that strive to accelerate development of the advanced manufacturing technologies that will be needed to build tomorrow's most powerful semiconductors.

The results of the more recent STARs Program have also been impressive. According to UT System Chancellor Mark Yudof, "The STARs Program has strengthened our recruitment and retention efforts at UT institutions, ultimately translating into keeping the best minds, their research and potential applications here in Texas.[15] Through mid-2007, the 3-year-old program had invested around $86 million to recruit or retain top faculty members and researchers in mathematics, computer sciences, biological sciences, physical sciences, engineering, and liberal arts. The UT System universities have realized a return of more that $202 million in current or future research grants and private gifts.

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[14] Greater Austin Chamber of Commerce, "Austin's Evolution: University Town to High Tech Center."

[15] www.utsystem.edu/news/2007/UTS-STARs-07-24-07.html

More than half of the faculty members nominated to receive STARs awards were successfully recruited or retained. These faculty members have accounted for 88 issued or pending patents, authored or refereed nearly 700 scientific publications, and have or are sponsoring more than 450 graduates and post-doctoral students.

Success Factors And Lessons Learned

Eminent scholars programs have been proven successful in generating research and increasing a region's capacity to attract new funding for research. Successful programs often share the following common elements:

- **Recruiting the right people.** The most obvious key to success is for programs to recruit the right people. Scholars should be broadly cited in the literature, have potential for developing and operating large-scale research centers, and have a proven track record in building teams and mentoring others.

- **Emphasizing technology commercialization.** Assuming that the basic goal is technology-based economic development, in addition to being world-class researchers, the scholars must have a desire to see their discoveries commercialized. This could be based on individual entrepreneurship or willingness to work with outside companies to commercialize technologies.

- **Funding the infrastructure needed to achieve broader goals.** It is critical to provide adequate funding for the infrastructure – laboratories, equipment, supplies, etc. – that are needed to support the scholar's research team.

- **Focusing on strategic sectors.** Scholars should be working in scientific fields that are generally viewed to be strong and productive for at least the next several years. In order to shorten the time between eminent scholar recruitment and ultimate economic payout in terms of new investments and employment, it is preferable to choose technical fields in which the state or region already possesses sizeable assets, such as the presence of large companies (or a group of smaller companies) already operating in those fields. This will provide an environment for immediate interactions and cross-fertilization.

Ohio Third Frontier Initiative: Wright Mega-Centers of Innovation

Initiated in February 2002, the Third Frontier Project is Ohio's largest-ever commitment to expanding the state's high-tech research capabilities, promoting innovation and company formation, and creating high-paying jobs for generations to come. The 10-year, $1.6 billion initiative is designed to:

- Build world-class research capacity.
- Support early-stage capital formation and the development of new products.
- Finance advanced manufacturing technologies to help existing industries become more productive.

Through the Third Frontier Project, additional federal and private sector support is anticipated to boost the total investment to more than $6 billion. The initiative provides a variety of grants that cover all phases of the technology commercialization process. However, this case study focuses on one award area in particular – the Wright Mega-Centers of Innovation – as an example of a program enacted to enhance research excellence and maximize commercialization coming out of this research.[16]

Establishment And Evolution Of The Program

The Third Frontier Project was conceived and launched under former Ohio Governor Bob Taft. The Ohio state legislature created a special commission in 2003 to administer the project and allocate funds. The Commission is comprised of the Ohio Director of Development, the Chancellor of the Ohio Board of Regents, the Science & Technology Advisor to the Governor, and four regional representatives from industry. The Commission is assisted by a 16-member Advisory Board comprised of leaders from industry, academia, and government.

The Commission decided to focus investments in five target high-technology areas: biosciences, power and propulsion, instruments-controls-electronics, information technology, and advanced material technology. The program awards a variety of grants that cover all phases of the technology commercialization framework in four program areas:

- Research and Commercialization Collaborations
- Entrepreneurial Support
- Product Development Assistance
- Company Attraction

Funding for the 10-year, $1.6 billion Third Frontier Project came from a voter-approved "Jobs for Ohio Bond Initiative" placed on the ballot in November 2005, which fully funded the initiative. The initiative had strong bipartisan support in the state legislature. By June 31, 2007, the state had awarded a total of $637 million in Third Frontier Projects since 2002.

The Third Frontier Project adopted the following operating guidelines that provide the framework for awarding grants:

1. Support the best the state has to offer, not just regions of the State.
2. Anticipate and act on market opportunities.

[16] Ohio's Third Frontier Project is noted in the NGA Center for Best Practices and Pew Center on the States report, *Innovation America: Investing in Innovation*,2007, www.nga.org/Files/pdf/0707INNOVATIONINVEST.PDF

3. Demand strong industry involvement.
4. Invest at the intersection of core competency areas.
5. Recruit world-class talent and high growth companies.
6. Engage regional partners.
7. Emphasize accountability and metrics.

How The Program Works

The Wright Mega-Centers of Innovation (WMI) are an important component of the Third Frontier Project's portfolio of programs. The state will provide a $60 million grant for each of the 2-3 centers of excellence planned over the ten-year period. It is intended that these centers will clearly define Ohio as an international leader in research and commercialization for one or more technology platforms in one of the five target technology areas. Each grant is disbursed over five years and requires a two-to-one match of the state dollars awarded (e.g., if an institution is awarded the $60 million grant, it would have to raise a matching $120 million within the five-year period.).

As described by the staff director of the Third Frontier Commission, Dr. Norm Chagnon, "The rationale behind this was: If we take a step up in the magnitude of the investment, could we uncover and support some activities that might be game-changing for the state of Ohio?"[17]

A significant difference between the Wright Mega-Centers and a different group of related Third Frontier grants (called Wright Center of Innovation grants), is that a large portion of the Mega-Centers grants can be used towards operating costs, as opposed to capital acquisition. The intention, here, is that the mega grants can be used to help recruit top researchers from out-of-state.

The first Mega-Center was awarded to a consortium led by the Cleveland Clinic in March 2007 to establish a Global Cardiovascular Innovation Center (GCIC). This consortium also includes the Fairfax Renaissance Development Corporation and over 20 biomedical and academic institutions. Prior to this $60 million award, the single largest grant under the Third Frontier Project was a $28 million grant made in 2004 to the Center for Computational Medicine at Cincinnati Children's Hospital.

The Ohio Department of Development (ODOD) contracted with the National Academy of Sciences to conduct an independent review of the seven proposals (three in physical sciences and four in biomedical sciences) for the WMI program. The National Academies' National Research Council established a committee that was deemed "technically competent and balanced in its perspectives," comprised of two subcommittees, one in physical sciences and one in biosciences. The 17 committee members, all of whom were screened for potential financial or fiduciary interests in the organizations submitting proposals, were experts in the physical sciences or the biosciences and "also had experience in the commercialization of scientific discoveries, venture-capital investment and management, research, and production aspects of pharmaceutical, biotechnology, aerospace, and related industries."[18]

In terms of the review process, 2-3 committee members with relevant expertise initially reviewed each proposal. In discussion with other members, a list of issues and questions was prepared based on the initial review of a proposal, which was then forwarded to the corresponding proposal team. The

[17] Glenn, Brandon, "Hefty tech grants up for grabs; Third Frontier to award 'centers of excellence' up to $60 million," *Crain's Cleveland Business*, 17 April 2006.
[18] The National Academy of Sciences review of 2007 Wright Mega-Centers of Innovation proposals, www.ohiochannel.org/content_files_system/default/your_state/third_frontier_project/rfp_documents/92910.pdf

proposal teams then met with the ODOD and the subcommittees to address the initial issues and questions raised. Based on this additional information, the subcommittees revised and expanded their reviews of the proposals, and assessed which proposals should be funded according to the evaluation criteria listed below. All of the committee members then reviewed all of the proposal assessments, discussed them, and harmonized their findings to select which of the proposals should be recommended for funding.

The evaluation criteria used to select the winning proposal for the first Mega-Center are broken up in five broad categories:[19]

Evaluation Criteria for Wright Mega-Centers of Innovation	
General Center Concept	■ Why the proposed center's activities will be "game-changing" for Ohio's future economy. ■ The proposed center will be competitive compared to international leaders, differentiated, and best in class. ■ Its Board of Directors will be led by members from industry. ■ The center leverages existing resources without duplication of efforts. ■ There is a credible continuation plan for the center beyond five years, demonstrating increasing financial support from sources external to the Third Frontier Program.
Scientific Merit	■ The proposed center's core technologies represent internationally competitive scientific excellence. ■ To enhance the value of its outputs, the center's activities will be integrated, interdisciplinary and collaborative. ■ The center will pursue lines of research that will potentially lead to attraction of future investment. ■ The center will recruit at least three new researchers from outside Ohio, with prominence that will contribute to the technical and commercialization capabilities of the center.
Commercialization Potential	■ The proposed center's technology outputs will result in "significant economic development contributions to Ohio including job creation, business formation, company expansion and company recruitment." ■ The center demonstrates the ability to create "a pipeline of commercially viable products/processes that will be sustained beyond the five-year period with external funding." ■ The center's core technology competencies have marketable competitive advantages over alternatives. ■ To inform its activities, the center will utilize market data by integrating this function into its organizational structure. ■ The proposal demonstrates "technical and commercial excellence, with strategies for short-, mid-, and long-term commercialization outcomes." ■ There is a plan to accelerate the commercialization of outputs, and the proposal identifies resources and partners to implement the plan. ■ To assure that the commercialization will benefit the state, the proposal includes a strong intellectual property plan. ■ The lead institution has access to capital to finance the commercialization of the center's technology outputs.

[19] For more detail on evaluation criteria, please refer to Appendix B (p. 42-43) of The National Academy of Sciences review of 2007 Wright Mega-Centers of Innovation proposals, found at: www.ohiochannel.org/content_files_system/default/your_state/third_frontier_project/rfp_documents/92910.pdf

Economic Development Potential	■ The proposed center's technology platforms support the economic development priorities of at least one region in Ohio, and there is demonstrated evidence that there is regional support of the proposed center. ■ Specific Ohio businesses will directly benefit from the center's activities. ■ The center identifies short-, medium-, and long-term goals in line with its technical and commercialization goals.
Performance History in Prior Third Frontier Program Projects	■ Past performance, expenditure of funds, and provision of cost share are consistent with scope of work/budget plan for previous awards. ■ Positive economic impact results as well as technical and commercial progress were achieved in technology area(s) supported by previous awards.

Source: The National Academy of Sciences review of 2007 Wright Mega-Centers of Innovation proposals, Appendix B (p. 42-43), www.ohiochannel.org/content_files_system/default/your_state/third_frontier_project/rfp_documents/92910.pdf

The winning Global Cardiovascular Innovation Center proposal's major strength was that "it builds on a foundation of cardiovascular excellence at the Cleveland Clinic."[20] Also, the Center is a collaborative effort between a mix of large corporations, small corporations, and universities. In addition, GCIC plans to utilize a proven venture capital model and enlist national VC groups, thereby improving regional access to VC and potential for new company formation in Ohio. Over the five-year grant period, GCIC projects that it will cumulatively raise over $200 million in venture and seed capital, establish 16 VC-backed companies, submit 90 products to the FDA for approval, and create 855 jobs in Ohio.

Below are the committee's general findings from all of the proposal reviews.

National Academy of Sciences Committee:
General Findings of the Wright Mega-Centers of Innovation Proposal Reviews

After reviewing the seven Wright Mega-Centers of Innovation proposals, the general findings of the National Academy of Sciences committee were as follows:

- "To succeed, centers should be established with oversight and management that are independent of the academic and industrial participants and are dedicated to keeping the center focused on their primary mission, long-term job growth and wealth creation in Ohio…. Centers should be established with management teams and business plans that are much stronger than those described in these proposals.
- The state may wish to place greater emphasis on co-investing with experienced venture investors and encourage future proposal teams to include venture capitalists as lead investors. (Most of the proposals reviewed by the committee included no venture capitalists, and the ones that did would have been stronger if the venture capitalists were assigned a larger role and had made a bigger financial investment.)
- The state may also wish to support a mix of economic and technology investments that offer a high rate of return or that pursue strategic and longer term goals."[21]

Source: The National Academy of Sciences review of 2007 Wright Mega-Centers of Innovation proposals, p. 2, www.ohiochannel.org/content_files_system/default/your_state/third_frontier_project/rfp_documents/92910.pdf

[20] Ibid., p. 4
[21] Ibid, p. 2

In addition, after scanning through the individual summary evaluations of the proposals, several recurring themes emerge in terms of what the National Academy of Sciences Committee highlighted as being particularly important for proposed centers and plans:

- A solid technological foundation is essential. The center should focus on building on existing expertise in specific technology platforms that can be applied and commercialized, versus broad application areas requiring expertise in many different technical areas.

- The center should have a deep understanding of the market, technical, and operational requirements for industry success, as well as the process for commercialization. As such, the proposed plan needs to be tactical, extremely detailed in terms of implementation, and well-supported. Essential plan components include: clear mission/focus of the Center, especially in how priorities will be established amongst potential research projects to pursue; a commercialization plan; specific corporate partners and funders; timelines for recruitment; etc. "Proof of concept" proposals that were underdeveloped and merely contained the "germ of an idea" were denied funding.

- The committee emphasized the need for business focus, governance, strong internal authority, accountability and control.
  - The Center should have a strong, business-like management team and solid organizational structure.
  - The CEO should be full-time, business-oriented (versus academic), and independent of any of the business or financial participants in the Center. In general, the committee tended to emphasize the importance of business/industry/private sector practices and partners to the success of a WMI center.
  - The Board of Directors should have a majority of independent members.
  - The Center should be a distinct standalone entity with its own employees and CEO, whose interests should be coupled with the success or failure of the center (versus employees who are part-time at their universities/other organizations and can return to those jobs if the center does not survive).

- The Center should create jobs that will remain in Ohio (and not have high potential of being lured out of state through outsourcing or acquisition by national corporations).

- The scale of the proposed Center needs to large enough to be "game-changing."

- The projections for the economic development potential of the proposed Center (e.g., number of VC-backed companies and number of new jobs) need to be substantiated. In some cases, the proposals estimated these figures without credible market data to back them up.

- The committee placed higher priority on proposed Centers which would not be viable on their own without WMI funding.

Program Impact

While one criterion for the Wright Mega-Center grants is company and job creation, it is too early to gauge the program impact, since the first Mega-Center was just awarded in March 2007. However,

performance statistics for all Third Frontier Project awards are available on the project website (www.ohiochannel.org/your_state/third_frontier_project/performance_statistics.cfm).

Success Factors And Lessons Learned

- **Large magnitude of the grant.** The state is investing $60 million for each of the 2-3 centers it plans on establishing over the next ten years.

- **Leveraging of state funding to attract co-investment.** The state requires a 2-to-1 match for each grant. In the case of the first Wright Mega-Center of Innovation awarded in 2007 – the Global Cardiovascular Innovation Center – a significant share of investment came from companies and venture capitalists, indicating private-sector confidence in the viability of the Center's commercialization aims.

- **Clearly articulated and substantiated economic development and commercialization goals.** A requirement of winning Wright Mega-Centers of Innovation awards is that the proposed Center's technology outputs will result in job creation, business formation, company expansion, and company recruitment. The evaluation criteria include proof that these goals can be attained through market data, past commercialization performance data, and access to finance by the lead institution.

- **Expert reviewers.** The Ohio Department of Development contracted with the National Academy of Sciences (NAS) to review the seven proposals submitted for the 2007 Wright Mega-Centers of Innovation. The NAS established a committee of 17 people with extensive backgrounds in the physical and biosciences. Committee members also had experience in the commercialization of scientific discoveries, venture-capital investment and management, and production aspects of pharmaceutical, biotechnology, aerospace, and related industries.

- **Independence and transparency of the review process.** The NAS review committee is an independent body and located out-of-state. The NAS Committee prepared a written report detailing the review process and the strengths and weaknesses of each proposal with regard to the evaluation criteria. This report is publicly available.[22]

[22] The National Academy of Sciences review of 2007 Wright Mega-Centers of Innovation proposals can be found at: www.ohiochannel.org/content_files_system/default/your_state/third_frontier_project/rfp_documents/92910.pdf

III. Enhancing Collaboration Across Sectors And Disciplines

List of Case Studies

- New York Centers for Advanced Technology
- Maryland Industrial Partnerships Program
- California Industry-University Cooperative Research Program (Discovery Grants)
- North Carolina's Research Triangle

New York Centers for Advanced Technology

The New York Centers for Advanced Technology (CAT) program focuses on developing partnerships between universities and industry to promote technology development and commercialization. Over its nearly 25 year tenure, the program has supported university-industry collaboration across a wide variety of high-tech fields, including electronics, optics, biotechnology and life sciences, telecommunications, robotics and automation, imaging, nanotechnology, and alternative energy.

The ultimate aim of the CAT program is to tap into the state's outstanding university research resources to enhance the competitiveness of the state's businesses and to create high-quality jobs. The New York State Foundation for Science, Technology, and Innovation (NYSTAR), which administers the CAT program, specifies the program's goals as follows:

- To spur technology-based applied research and economic development in New York.
- To encourage applied research collaboration and innovation with industry.
- To promote workforce development.
- To better leverage state funds with investments from the Federal government, industry, foundations, and not-for-profit economic development organizations.
- To increase the competitiveness of New York state companies.[23]

Establishment And Evolution Of The Program

In the early-1980s, an assessment by the New York Science and Technology Foundation recognized that New York's research universities and professors were an important strength for the state, but were not being fully utilized to support economic development and growth. The Centers for Advanced Technology program was established in 1983 to address this gap. Five Centers for Advanced Technology were initially established at the state's major research universities, with the goal of supporting research collaboration by universities and industry in technology areas with commercial potential. The proposals for establishing and selecting the initial CATs were reviewed and selected by the National Research Council.

In 1987, the CAT program was refocused to place greater emphasis on commercialization and economic growth through enhanced monitoring systems. In 1999, the program was again expanded, under the auspices of the New York State Foundation for Sciences, Technology, and Innovation (now called NYSTAR), to focus on targeted technology areas such as integrated electronics, optics, biotechnology, telecommunications, robotics and automation, imaging, and nanotechnology.[24] The CAT Development Program (described in more detail below) was also created in 1999 to provide more resources to successful Centers to expand their work with New York businesses. In 2004, the CAT program was refocused to incorporate more of a market-based business model in CAT operations, including a business development component to enhance the Centers' roles in helping companies solve production challenges through technology.[25]

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[23] www.nystar.state.ny.us/cats.htm
[24] National Governors Association, *Innovation America*.
[25] www.nystar.state.ny.us/sp/06/060227sp.htm

In the state budgets for fiscal years 2006 and 2007, the CAT program was funded at a level of $15 million annually.[26] Historically, funding has averaged $1 million per year per Center. Over the program's 25-year tenure, additional CATs have been funded, and today there are a total of 15 CATs. Several of the original CATs are still operating.

How The Program Works

The Centers for Advanced Technology (CATs) are collaborative university-industry research centers that conduct cutting-edge research with the goal of developing commercial applications. Within each CAT, "leading research universities work side-by-side with their counterparts in large and small companies to develop new technologies and commercialize these developments."[27] A wide variety of company partners are involved, ranging from small start-ups to Fortune 500 companies.

Definition of a Center for Advanced Technology in New York Program Statues
"*A university or university-affiliated research institute or a consortium of such institutions, designated by the foundation, which conducts a continuing program of basic and applied research, development, and technology transfer in one or more technological areas, in collaboration with and through the support of private business and industry.*" www.nystar.state.ny.us/cats/catsstatute.htm

Each CAT focuses on a specialized high-tech area. There are currently 15 CATs operating in 13 different universities spread throughout New York state, as detailed in the table on the following page. The CATs cover a wide range of high-tech fields, and the program statues specify that the technology sectors to be covered by centers should include areas such as "integrated electronics, optics, biotechnology, telecommunications, automation and robotics, electronics packaging, imaging technology and others identified by the foundation as having significant potential for economic growth in New York, or in which the application of new technologies could significantly enhance the productivity and stability of New York businesses."[28]

New York
Centers for Advanced Technology

[26] www.nyu.edu/ogca/state/nyu.analyses.state.html
[27] www.nystar.state.ny.us/research_programs.htm
[28] www.nystar.state.ny.us/cats/catsstatute.htm

New York State Centers for Advanced Technology	
Name of CAT, University, & Date of Designation	**Description**
Center for Advanced Ceramic Technology Alfred University (1988)	Research and development of high technology ceramic materials that possess the potential to benefit both the industrial base of New York state and the scientific community.
Integrated Electronics Engineering Center Binghamton University (1994)	Engaged in the process of bringing a semiconductor chip, with its resident circuitry, to a form that can be integrated effectively into a larger microelectronics assembly.
CAT in Photonics Applications City University of New York (1994)	Research and technology development in select areas of photonics that have applications in optical communications, medical diagnostics, laser development, semiconductors, and optical imaging.
Center for Advanced Materials Processing Clarkson University (Potsdam) (1988)	Research applied to industrial needs in photocopying and imaging, micro-electronics, pharmaceutical, cosmetic, and environmental control industries, among others.
Center for Advanced Information Management Columbia University (1984)	Specializes in bringing cutting-edge information science to industry for product development and enhancement.
Center for Life Science Enterprise Cornell University (1984)	Research and development, education and training, and technology transfer that address the economic development needs of New York industry.
CAT in Telecommunications Polytechnic University (Brooklyn) (1984)	Partnering with both providers and users of telecommunications and information systems to help them turn the latest developments in these technologies into competitive and productive resources.
Center for Automation Technologies and Systems Rensselaer Polytechnic Institute (Troy) (1989)	Micro- and nano-manufacturing with an emphasis on microsystem design; massively parallel micro- and nano-assembly; automated packaging of MEMS; microfluidics and microphotonics; modular packaging, deployment and networking of unattended microsensors.
Future Energy Systems Rensselaer Polytechnic Institute (Troy) (2004)	Focuses on smart lighting, smart displays, hydrogen fuel cells, and emerging renewable energy systems; a consortium of Rensselaer Polytechnic Institute and Cornell University.
Sensor CAT Stony Brook University (1999)	Magnetic, optical, X-ray, and infrared sensors; signal processing and image recognition; superconducting electronics for sensor applications; DNA sequencing devices; and MEMS-based sensors and actuators.
CAT in Medical Biotechnology Stony Brook University (1984)	Discovery, development, translation and commercialization of promising biotechnology resulting from academic research centers around the state of New York.
CASE Center Syracuse University (1984)	Focuses on high-assurance software and systems, distributed networks and data mining, and wireless telecommunications.
Center for Advanced Technology in Nanomaterials and Nanoelectronics University at Albany (1994)	A research, development, education, and economic outreach resource for industries that manufacture, use, or supply micro-electronics, electronics, optoelectronics, bioelectronics, nanotechnology, and telecommunications devices and components.
Center for Advanced Technology in Biomedical and Bioengineering University at Buffalo (1997)	Focuses on biomedical and bioengineering research, including the development of biopharmaceuticals and biomedical devices.
CAT for Electronic Imaging Systems University of Rochester (1994)	Basic research in the field of electronic imaging, leveraging the results for economic advantage to New York state and the nation.
Source: www.nystar.state.ny.us/cats/catsalt.htm; for more information on the activities and operations of each CAT, see: www.nystar.state.ny.us/Assets/pdfs/cbg2007.pdf	

CAT programs are designed to be industry-responsive and to address in the following areas:

- *University-industry collaboration:* CATs are expected to conduct applied research and technology transfer with industry and to help foster an environment that encourages companies to locate in New York state. Research should have a quantifiable economic impact on the state, and especially on small companies, within one to three years of project commencement.
- *Industry-oriented education and training:* CATs are expected to help workers in New York to expand their skills by offering short courses, seminars, and workshops, and by providing industry-driven research assistant opportunities for students. CATs are also expected to assist in the development of undergraduate- and graduate-level courses in areas related to their technology focus (but are not allowed to offer credit-bearing courses themselves or provide tuition assistance).
- *Outreach and networking:* CATs are encouraged to partner with outside organizations to develop outreach networks and to help partner companies access non-research-related assistances (such as general business consulting).[29]

Selection Process

In order to be eligible to apply for CAT designation, a university or university-affiliated research institute must meet the following criteria:

- Have at least one on-site doctoral program in the research field(s) related to the proposed technology focus for the Center.
- Have annual research expenditures of at least $5 million per fiscal year in the three previous years for research conducted in the proposed technology area(s) for the Center.
- Demonstrate ability to meet the matching funds requirements.[30]

CATs are selected through a periodic statewide competition, and proposals are reviewed by a panel of state and national experts in the technological areas and industries related to the proposal. Criteria for selection of CATs include the following:

- An established record of research, development and instruction in the area(s) of technology involved.
- The capacity to conduct research and development activities in collaboration with business and industry.
- The capacity to secure substantial private and other governmental funding for the proposed center, in amounts at least equal to the total of support sought from the state.
- The ability and willingness to cooperate with other institutions in the state in conducting research and development activities, and in disseminating research results; and to work with technical and community colleges in the state to enhance the quality of technical education in the area or areas of technology involved.
- The ability and willingness to cooperate with the foundation and other economic development agencies in promoting the growth and development in New York state of industries based upon or benefiting from the area(s) of technology involved.[31]

[29] www.nystar.state.ny.us/catsrfp.htm
[30] Ibid
[31] www.nystar.state.ny.us/cats/catsstatute.htm

Each selected CAT is designated for a period of up to ten years, subject to annual performance evaluations by NYSTAR. Evaluation methods include site visits, written reports, and peer review evaluations by experts in the Center's technology field. Criteria for annual evaluations include the following:

- Continued demonstration that the Center meets the criteria established by NYSTAR (listed above).
- Demonstration of assistance to small businesses in New York state through research, technology transfer, or other means.
- Compliance with the rules, regulations, and guidelines of NYSTAR.
- Compliance with any contracts between NYSTAR and the Center.[32]

Redesignation is not automatic, and all Centers must re-compete for designation at the end of the ten-year funding cycle. For example, in 2004, ten CATs were up for redesignation. As a result of the re-compete, nine Centers were redesignated, one was not, and one new Center emerged.[33]

Funding Process

Selected CATs are funded with up to $1 million in the first year. Over the 10-year period, there are increasing requirements for matching funds from outside sources. Funds from the state may be used for purchasing equipment and fixtures, employing faculty and support staff, providing graduate fellowships, and other purposes approved by NYSTAR (funds may not be used for capital construction). To ensure that the state funding is invested in areas with the greatest commercial relevance to industry, each CAT must create an Industrial Advisory Board consisting of representatives from companies operating in the technology areas being focused on by the Center. Details about the funding cycle and matching requirements are provided in the table below.

New York Centers for Advanced Technology *Funding Cycle and Matching Requirements*	
Years One to Five	The funding amount provided by NYSTAR must be matched equally by the Center from outside (private or non-state government) sources. Centers can receive up to $1 million in the first year.
Years Six to Ten	Funding from NYSTAR up to $750,000 must be matched equally by the Center. Funding from NYSTAR above $750,000 must be matched by the Center according to the following formula: ■ Year Six: 120% ■ Year Seven: 140% ■ Year Eight: 160% ■ Year Nine: 180% ■ Year Ten: 200% If a Center is NOT redesignated in Year 10, then the Center may receive a maximum of $500,000 in funding from NYSTAR in its tenth and final year.
Subsequent Years	If a Center IS redesignated in Year 10 in the same area of technology, funding in all subsequent years is provided according to the following formula: ■ Funding from NYSTAR of up to $750,000 must be matched equally by the Center. ■ Funding from NYSTAR in excess of $750,000 must be matched by the Center in amounts of at least 200%.
Source: www.nystar.state.ny.us/cats/catsstatute.htm	

[32] Ibid

[33] www.ssti.org/Digest/2004/071204.htm#CATs

CAT Development Program

In 1999, NYSTAR created the CAT Development Program, which provides one-time investments to successful CATs to significantly expand their work with businesses in the state. The program is designed to "enhance and expand the capabilities of existing Centers for Advanced Technology that have achieved a record of success and demonstrate significant potential to increase the economic impact generated by the CAT."[34] Only existing CATs are eligible to apply for the awards, and one proposal may be made for each CAT at the institution. Criteria for selection include:

- The economic development potential of the research being undertaking at the CAT.
- The amount of funding leveraged from outside sources.
- The potential of revenues accruing to the institution from licensing of products developed and research conducted at the CAT.
- The interaction of the CAT with private industry.[35]

While CATs receiving awards are not required to match NYSTAR funding (except for funds used to support specific applied research projects with industry), proposals are partly judged on their level of matching funds. CAT Development Program award funds may be used for the following activities:

- Compensation of faculty, support staff, and graduate and undergraduate students, including fellowships.
- Purchase of equipment, fixtures, materials, and supplies.
- Travel directly related to the activities proposed.
- Costs associated with developing real property.
- Services subcontracted to partner organizations or other entities to assist the institution in conducting the proposed activities.
- Other purposes explicitly approved by NYSTAR prior to being incurred.[36]

CATs holding these awards are given the designation of "Enhanced CATs." From 2000-2006, NYSTAR made 12 CAT Development Program Awards, totaling $21 million.

Other Related University-Industry Research Enhancement Programs

While the Centers for Advanced Technology comprise its longest-running program, NYSTAR also operates several other related programs that are aimed at enhancing technology research and university-industry collaboration. While these programs are not described in this case study, more information can be found on the program websites.

- *College Applied Research & Technology Centers (CARTs):* Similar to the CAT program, but designed for colleges (non-doctoral institutions) and college-related research centers. Launched in 2004, the program provides 5-year awards, with matching fund requirements, to develop applied research and development and collaborative programs with industry in specific technology focus areas.[37]

[34] www.nystar.state.ny.us/cats.htm
[35] www.nystar.state.ny.us/cdp/cdpstatute.htm
[36] www.nystar.state.ny.us/cdprfp.htm
[37] For more information, see: www.nystar.state.ny.us/cart.htm

- *Centers of Excellence:* Supports major upgrades of research facilities and other high-technology and biotechnology capital projects, allowing academic and research institutions to secure research funding that will lead to new job creation. Operated in conjunction with the state economic development agency, with funds leveraged from the private sector. There are currently five Centers of Excellence specializing in nanoelectronics, bioinformatics, photonics, environmental systems, wireless applications, and information technology.[38]

- *Strategically Targeted Academic Research Centers (STARs) and Advanced Research Centers (ARCs):* Provides awards for capital facilities development at academic institutions (including construction, rehabilitation, and improvement of R&D and laboratory facilities), with the goal of developing world-class academic research centers with state-of-the-art facilities in targeted technology areas.[39]

- *Gen*NY*sis Centers:* Provides $225 million in funding to support the construction of high-tech and biotech facilities at New York's public, not-for-profit, and private academic research institutions, with the goal of making New York a leader in life sciences and biotech R&D.[40]

Program Impact

The success of the CAT program, in addition to other programs, has made NYSTAR a recognized national leader in developing state-sponsored frameworks for university-industry research collaboration. The CAT program and CAT development awards generated the following impacts over the period 2000-2006:

- $90.3 million in state funds were expended, resulting in a credited impact of $3.2 billion – a return on investment of over $34 for every state dollar invested.
- Companies working with CATs gained over $1.2 billion in increased revenues and $452 million in cost savings.
- Partner companies received $318 million in outside funding, through research grants or venture capital investments.
- Partner companies also made capital improvements totaling $778 million.
- Universities hosting CATs received royalty and licensing revenues of over $21 million.
- 29 new companies were created.
- 3,042 new jobs were created, and 1,240 jobs were retained.[41]

New York's CATs have supported ground-breaking research in significant technologies for the future, and have fueled the growth of major technology industries in the state. Some of the impacts highlighted by NYSTAR in the *2006 Annual Report* include:

- The Center for Advanced Technology in Nanomaterials and Nanoelectronics at the University at Albany lead to the establishment of the Center of Excellence in Nanosciences, which hosts the only university-based 300-millimeter computer wafer pilot prototyping facility in the world. The Center also helped attract AMD to build a fabrication facility in upstate New York.

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[38] For more information, see: www.nystar.state.ny.us/coes.htm and www.empire.state.ny.us/High_Tech_Research_and_Development/centers_for_excellence.asp
[39] For more information, see: www.nystar.state.ny.us/stars.htm and www.nystar.state.ny.us/arcs.htm
[40] For more information, see: www.nystar.state.ny.us/gennysis.htm
[41] *NYSTAR 2006 Annual Report*, www.nystar.state.ny.us/Assets/pdfs/annualreport.pdf

- The Center of Electronics Imaging Systems at the University of Rochester worked with Bausch and Lomb to develop customized contact lenses to provide improved eyesight to those with severe eye aberrations.
- The Center for Advanced Technology Materials Processing at Clarkson University worked with NanoDynamics to develop nanosized copper powder technology, allowing the company to begin commercial production of electronic-grade copper nanopowders and to raise over $16 million in private equity funding.
- The CASE Center at Syracuse University worked with Welch Allyn to improve blood pressure monitors and thermometers. Welch Allyn launched a next-generation thermometry device in 2003, and the company estimates incremental revenues of around $10.5 million for fiscal year 2004-2005, with total sales several times that amount.[42]

Success Factors And Lessons Learned

- **Industry collaboration as a key component.** The CAT program was one of the pioneers among state technology-based economic development programs in requiring university-industry collaboration as a key component. Its emphasis on developing working relationships between academic researchers and private companies has helped bring widespread economic impacts from the state's strong research universities.

- **Strong emphasis on economic results and accountability.** The program places stringent requirements on CATs to demonstrate commercial "results" for their technologies within the first three years of funding, to ensure that the program supports NYSTAR's overarching economic development goals. Continued funding is contingent upon annual evaluations that measure economic results and impact. By also requiring Centers to re-compete for their designation as CATs after ten years, the program has built-in measures to ensure that the research being undertaken is of continued relevance in the marketplace and is meeting program goals.

- **Funding leveraged from non-state sources.** The state gets more mileage for its funding to CATs by requiring Centers to obtain an equal or greater amount of funds from private or non-state sources. By demonstrating that outside funders are willing to invest in their research programs, Centers also demonstrate that their area(s) of focus are of interest and relevance to the market. In addition, the program's increasing requirements for matching funds ensures program accountability and works toward sustainability.

[42] Ibid

Maryland Industrial Partnerships Program

The Maryland Industrial Partnerships (MIPS) program provides funding, matched by participating companies, for university-based research projects that help companies develop new products. The program funds collaborative R&D projects between companies and University System of Maryland faculty; consequently, projects are conducted by university faculty and graduate students in conjunction with company researchers. MIPS projects help companies find solutions to technical challenges, as well as develop products, processes, or training materials. More than 800 projects worth over $140 million have received awards since the program began twenty years ago.[43]

MIPS espouses the benefits of its program as follows:[44]

Benefits to Maryland businesses:

- Cost-effective research through university partnering.
- Companies can select research capabilities to meet specific requirements.
- Easier access and more efficient transfer of technology from university to industry.
- Student participants are potential future employees.
- Makes companies more competitive, domestically and internationally.

Benefits to the State of Maryland:

- Helps create and retain jobs.
- Helps to diversify and strengthen the state economy.
- Helps to improve the state's business climate and to enhance its reputation.
- Makes Maryland more attractive to firms outside the state.

Benefits to University System of Maryland:

- Provides faculty with the opportunity to perform research leading to new products and processes.
- Helps to improve university research facilities.
- Improves university academic programs to meet industry needs.
- Students gain experience in industrial environments.

Establishment And Evolution Of The Program

The MIPS program was created in 1987 under the auspices of the Maryland Technology Enterprise Institute (MTECH). MTECH is a unit of the University of Maryland's A. James Clark School of Engineering. Its goals are to "accelerate new ventures, spur economic growth, and bring university innovation to Maryland companies through technology entrepreneurship and partnership programs."[45] MIPS is just one of several programs operated by MTECH to encourage research and partnership development (other programs include a technology extension service for manufacturing companies, funding for undergraduate research projects, a biotechnology-focused program, and venture incubator and accelerator programs).

In 2006, the MIPS program received a $1 million funding increase from the state of Maryland – the first funding increase in the program's history. This increase almost doubles the program's previous operating

[43] Maryland Industrial Partnerships, www.mips.umd.edu
[44] www.mips.umd.edu/overview.html
[45] www.mtech.umd.edu

budget of $1.35 million. The increase will enable up to 22 additional projects each year, bringing the annual total to about 54 projects per year.

How The Program Works

The MIPS program pairs private sector companies with university-based researchers to conduct product-oriented research and development within the University of Maryland system. MIPS does not provide any funding directly to private companies. Instead, MIPS program funding, together with a substantial matching contribution from the private sector participants, supports research carried out by university-based researchers with the goal of creating technologies that will later be transferred back to private industry and commercialized.

Selection Process

The selection process begins when a proposal is screened by a MIPS program staff member. Then, a small group of technical experts in the subject area rates the project on its technical merits. Third, a small group of business experts evaluates the business, cost, and economic development aspects of the proposed project. Finally, an Evaluation Board considers the input from the technical and business experts and recommends projects for MIPS program funding awards.

Projects are mainly chosen for selection based on technical feasibility and economic development factors. A project should also have the ability to create or help retain jobs in Maryland, improve the company's competitive position, or help the state's economy in some other way. Other factors that are considered include whether or not companies exceed their required minimum contribution, the level of commitment by the company, contribution to the goals of the university, and any enhancements to university/industry interaction.

To be eligible for funding, four basic criteria must be met:

- **Maryland Companies:** The business must have a manufacturing, service, or research and development operations within the state or it must set up operations in Maryland within the year in which an award is received.
- **University Participation:** Each proposal must be co-authored by a faculty member from any of the institutions of the University System of Maryland, and the university researcher must be the Principal Investigator. MIPS funds will be applied only toward work performed by university researchers.
- **Technology-Based Projects:** The proposed research projects must deal with innovative technological or scientific concepts, whether it be traditional or high-technology end products and processes.
- **Matching Funds:** Company matching funds include both "cash" paid toward the university's project budget, and "in-kind" which is the company's effort on the project.

Funding Process

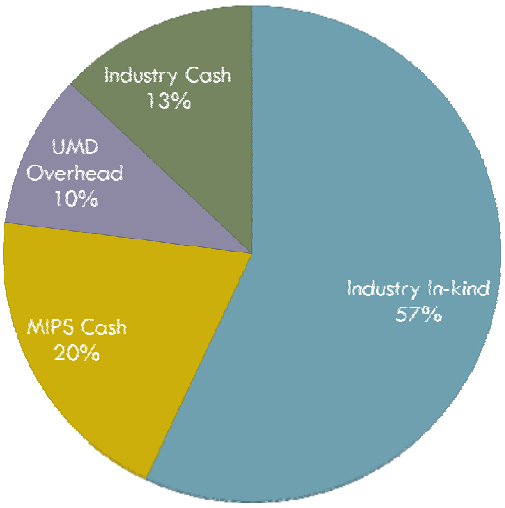
MIPS program awards are limited to $100,000 per project per year for large, medium, and small companies and $90,000 for start-up firms. The minimum is $5,000 per project per year. Multi-year projects of up to two or three years are allowed in extraordinary circumstances within the MIPS program framework; however, these awards require the submission of a follow-on proposal following the successful completion of a project status review.

Participating firms provide industry matching funds based on the company size and type (i.e., large, medium, small, or start-up). Matching fund requirements are described in the table below.

MIPS Program *Company Matching Fund Requirements*		
Company Type	**Definition**	**Matching Fund Requirements**
Large Firms	More than 1,000 full-time employees	Company cash contribution is at least 50% of the University Budget. Company's in-kind requirement is at least equivalent to 25% of the University Budget.
Medium Firms	100 to 1,000 full-time employees	Company cash contribution is at least 50% of the University Budget. Company's in-kind requirement is at least equivalent to 25% of the University Budget.
Small Firms	Fewer than 100 full-time employees	Company cash contribution is at least 35% of the University Budget. Company's in-kind requirement is at least equivalent to 30% of the University Budget.
Start-Up Firms	A new company with one to twelve full-time employees in product development mode, with no public offering, whose time in business does not exceed four years, and whose annual sales do not exceed $1,000,000.	Company cash contribution is at least 10% of the University Budget. Company's in-kind requirement is at least equivalent to 35% of the University Budget. In lieu of a matching cash contribution, start-up firms have the option of offering an equity contribution.
Source: www.mips.umd.edu/applying_funding.html		

MIPS program funding represents only a small fraction of the total cash and in-kind services leveraged by the initiative. As shown in the chart below, private sector in-kind and cash contributions together account for approximately 70% of MIPS project funding.

MIPS Total Project Funding Sources



Source: MIPS

Program Impact

The MIPS program boasts several success stories that demonstrate the program's positive impact:

- **MedImmune:** The developer of Synagis, the 10th best selling biotech drug in the world, asserts that its MIPS project "improved [our] knowledge of carbohydrate analysis…and helped in structural testing of Synagis."[46]
- **Martek Biosciences:** Assisted by the MIPS program, this company produced omega-3 infant food and nutritional additives, which it licensed to infant formula and nutritional product manufacturers such as Kellogg, Mead Johnson Nutritionals, Abbott Laboratories, and Nestlé.
- **Quantum Sail:** This number two sail maker in the world received technological contributions to their entire sail line from the MIPS program.

The MIPS program appears to have had a positive economic impact in Maryland. Products developed from MIPS-supported research have generated more that $12.1 billion in sales and revenues. Combined with more than $142 million in R&D expenditures, the total economic impact of the MIPS program exceeds $12.2 billion. Looking forward, the program is anticipated to continue to have a significant impact; future sales projections for commercial products created by 2006-funded projects are $4.89 billion.

The MIPS program has also been linked to job creation throughout the state of Maryland. In 2006, the MIPS program supported 25 university-based jobs and 16 company-based jobs to conduct supported projects. The MIPS program estimates that its investment of $1.85 million in 2006 will create 2,645 future jobs in the state.

In 2005, the MIPS program won the national "Best Practice" award for technology transfer programs from the U.S. Small Business Administration's Office of Advocacy.[47] In October 2007, the MIPS program won the National Excellence in Technology-Based Economic Development Award from the State Science and Technology Institute, an award given in the category of "improving competitiveness of existing industry."[48]

Success Factors And Lessons Learned

- **Leveraged funding.** The MIPS program leverages substantial private sector funding by requiring that participating companies provide a significant share of total project funding. Participants are required to contribute from 10 to 50 percent of project funding, depending on firm size, as well as in-kind contributions. Of the total $142 million in R&D expenditures related to MIPS projects, more than $115 million was provided by participating firms. In other words, each dollar invested in the MIPS program generates more than five additional dollars in university research activity. This leveraged funding assures that participant firms are committed to the effort and also provides a valuable influx of funding for university R&D activities.

- **Focused and rapid review process.** MIPS approves fewer than 40% of applicants. In its first forty application rounds, the program reviewed 1,521 applications, but approved only 577

[46] www.kyepscor.org/Conferences/2007_Oct2_Lexington/4_Connolly.ppt
[47] www.mtech.umd.edu/news/press_releases/MIPS_SBA_award.html
[48] www.mtech.umd.edu/news/press_releases/MIPS_SSTI.html

projects.[49] Applications are evaluated on a variety of criteria, but two core criteria drive the selection process: technical feasibility and economic development factors. To assure robust evaluation of the economic and technical feasibility of applications, MIPS employs targeted review panels with relevant expertise. To assure that the program is responsive to the fast-moving needs of the private sector, MIPS runs a rapid evaluation process with a 60 day turn-around time from application to award, and it runs two application rounds per year.

- **Shared incentives.** MIPS offers strong incentives for both private sector and university participants. Companies leverage their R&D funding with matching funds, but more importantly, gain access to university faculty expertise and facilities. From the university perspective, faculty gain a rich source of R&D funding, insights into current commercial technology needs, and opportunities for their students to engage in practical research.

[49] www.kyepscor.org/Conferences/2007_Oct2_Lexington/4_Connolly.ppt

California Industry-University Cooperative Research Program (Discovery Grants)

California's Industry-University Cooperative Research Program (IUCRP) was established in 1996 to increase the flow of creative ideas and people between the University of California system and the private sector, thereby enhancing the state's competitive advantage. The program identifies the state's best opportunities for expansion of high-technology sectors, and then provides targeted incentives for universities and industry to work together to accelerate the innovation needed to maintain competitiveness.

IUCRP's major activity is the Discovery Grants program, which provides matching grants for collaborative university-industry research projects in science and technology fields that are deemed strategic for the state. Funding for the grants is leveraged from the state, university, and industry sources, effectively forming a three-way partnership between the University of California, the State of California, and the state's businesses.

The aim of IUCRP is to develop strong working relationships between industry and academic researchers, promote innovation, and speed the process of technology transfer and commercialization. It helps expand private sector funding for strategic academic research projects, while simultaneously providing California's businesses with access to the world-class research resources at the University of California.

Goals of UC Discovery Grants[50]

- To promote and support high quality, early stage research with grants funded by UC and the State, with matching support by California businesses.
- To speed the utilization of research discoveries for public benefit, by facilitating technology transfer.
- To support the training environment that prepares California's future workforce and industry leaders.
- To advance understanding of the role of science and technology in California's increasingly knowledge-based economy.
- To assess and communicate the social and economic impact of research and education.

Establishment And Evolution Of The Program

California's Industry-University Cooperative Research Program (IUCRP) was originally established at UC-Berkeley in 1996 by University of California President Richard Atkinson. The program initially focused on two sectors, biotechnology and microelectronics:

- ***Biotechnology STAR Project ("Strategic Targets for Alliances in Research").*** The biotechnology program had an initial funding level of $3 million from UC, and a $5 million contribution from the State of California came soon after the program's establishment. Within 3 months, project applications from biotechnology firms offered additional funding commitments of nearly $8 million.

[50] ucdiscoverygrant.org/about/goals.htm

- ***MICRO Project ("Microelectronics Innovation and Computer Research Opportunities").*** At its establishment, IUCRP also consolidated under its structure an existing, highly-successful program known as MICRO, which was founded in 1981. The program provides collaborative research funding for the microelectronics sector.

In subsequent years, funding levels for the IUCRP program continued to grow. By 1998-1999, total funding from state and private sources exceeded $30 million annually, and by 1999-2000, it exceeded $60 million per year (nearly $25 million from the state and UC, and the remainder from private commitments).

Based on the program's initial successes, its scope was expanded over its first three years to include four additional target sectors: digital media; electronics manufacturing and new materials; information technology for life sciences; and communications and networking. The key criterion for selecting the fields that were added to the program was that "California must have a growing knowledge-based economy in that field that increasingly depends upon innovations from basic research and highly skilled personnel to create product and market opportunities."

In 2002, IUCRP began accepting multi-field research proposals, which have interdisciplinary research themes that incorporate two or more of the program's five target fields. It also launched a Major Program Grants initiative, which provides larger award sizes for teams from two or more UC campuses to undertake interdisciplinary projects with a significant scale and impact.

Over time, IUCRP has also introduced new initiatives to streamline program management. In 2000, it launched an online proposal system, allowing principal investigators and private sponsors to submit research proposals online. In 2002, the "UC Discovery Grant" brand name was officially adopted, replacing the sector-specific grant names that had been used previously.

From the start, IUCRP has been guided by a Steering Committee consisting of representatives from all UC institutions, as well as advisory board, made up of leaders from business and industry, economic development organizations, as well as the UC institutions. The advisory board provides a market-based perspective on the long-term needs of California's industries and how those needs might best be addressed by the IUCRP program. In addition, there are five Executive Committees, one for each of the target fields, consisting of representatives from each UC institution, the three UC-managed national laboratories, and the UC agriculture experiment station. These committees help promote the program, provide peer review for proposals, and make the final decisions on grant awards.[51]

How The Program Works

IUCRP provides matching grants, known as "Discovery Grants," that help California companies and University of California researchers to develop collaborative research projects. Grants are provided in five high-technology sectors that have been deemed as strategic to the California economy. IUCRP also operates a separate but similar grant program, known as MICRO, that focuses on the microelectronics industry. The program encourages multidisciplinary projects that span two or more of the target sectors.

[51] Information in this section was adapted from ucdiscoverygrant.org/about/history.htm; ucdiscoverygrant.org/about/governance.htm; and www.ucop.edu/pres/industryinit.html

IUCRP and UC Discovery Grants *Target Sectors*		
Sector	**Focus Areas**	**Sample Projects**
Biotechnology	Agriculture; biomaterials; engineering; environmental sciences; marine sciences; medicine; veterinary sciences; stem cell research	■ *Fragile X and Ampakines*, UCI, $252,564 ■ *Heart failure and improvement in calcium flux*, UCSD, $139,304 ■ *Human Embryonic Stem Cells for the Treatment of Spinal Cord Injury*, UCI, $366,797 ■ *Microbial Biopolymer Factories*, UCSF, $285,566
Communications and Networking	Communications systems and networks; wired, wireless, and Internet research; broadband access; multimedia applications; nomadic and agent-based computing; battery-conserving protocols; satellite system overlays; wireline and optical fiber networks; hardware components; communication protocols; computer aided design tools	■ *Control Components for Next Generation Wireless Base Station Applications*, UCSD, $154,872 ■ *Mesh Networks: Ad Hoc Backbone Design and Management*, UCLA, $50,848 ■ *High Performance Transpacific Transport of Text and Continuous Media*, UCLA, $84,270 ■ *Failure Management in Service-Oriented Automotive Software*, UCSD, $172,870
Digital Media	Library science; music; journalism; education; physical sciences; psychology; agriculture; life science; pharmacology; visual arts; medicine; architecture; astronomy; public health; dentistry; theater; film; television; law; humanities; social science; cognitive science; veterinary medicine; environmental science; business & management	■ *The Design of Digital Hearing Aids that Provide Satisfying Music Listening Experience*, UCB, $224,588 ■ *Implementing Cell Processor Engines for Resolving Constraints in Real-time Graphic Environments*, UCSD, $222,161, 2006-2007 ■ *Ubiquitous RFID*, UCSC, $64,530 ■ *Applications of Personal Robots to Learning and Education*, UCSD, $277,597
Electronics Manufacturing and New Materials	Vacuum electronics (e.g., high power tubes, CRTs); electromagnetic devices and subsystems, e.g., antennas, data storage; system interconnection materials and manufacturing processes; component and system packaging and production testing; quality assurance in electronics manufacturing; electronics production planning and scheduling tools; novel materials and thin film structures; Innovative processing for integrated circuits, MEMS, flat panel displays, storage media, optoelectronics; advanced equipment design; process integration; sensors, metrology, and control; physics and chemistry of electronics processes; signal processing, modeling and innovative software techniques; environmentally clean manufacturing; nanotechnology related to electronics manufacturing and new materials; smart energy sources; micro-instrumentation platforms for biomedical applications; microsystems packaging for MEMS and electronics manufacturing	■ *Electromigration and drop test of Pb-free solder joints in mobile electronic devices*, UCLA, $269,235 ■ *Engineering MOS Interfaces with Hf based Dielectrics and Metals*, UCLA, $165,961 ■ *An On-Chip Protein Array with Multiplexed Electrical Detection*, UCI, $87,104 ■ *High Performance Ambipolar Vertical Organic Transistors*, UCLA, $207,200

Information Technology for Life Sciences	Agricultural sciences; animal sciences; chemistry; biological sciences; engineering; environmental sciences; medicine; veterinary medicine; zoology; other life sciences	■ *High Throughput, Low-Latency, Low-Power, Reliable Wireless Communication in Compact Sensors for Medical Applications*, UCI, $121,288 ■ *Computational Model of Protein Stabilities and Solubilities*, UCSF, $83,003 ■ *A whole-genome approach to marker discovery in lettuce*, UCD, $879,741 ■ *Analysis and Optimization of Blood Circuit Components Using Adaptive CFD*, UCI, $188,048
Microelectronics	Coding and modulation; electronic devices; optoelectronics; materials and processing; micro mechanical devices; circuit design simulation; signal processing; CAD/CAM; networking; computer systems and architecture; software; computer science; information technology; hardware/software collaboration; internet computing	■ *Enhanced Coding Techniques Exploiting Nonlinear System Theory*, UCSD ■ *Analog Circuits for Wireless Communications and Signal Processing*, UCLA ■ *Integrated Electrothermal Modeling and Analysis of Nanometer Scale High-Performance IC's*, UCSB ■ *Design and Application of Network Processors*, UCR

Source: ucdiscoverygrant.org/fields.htm and www.ucop.edu/research/micro/

In 2006, IUCRP added three new "Pilot Project" fields: energy and environment, health and wellness, and rapid application of nanotechnologies. The application cycle for these fields is offered in addition to the funding cycle for the five primary focus areas. This program is intended to complement and extend the five focus areas and provide greater breadth and flexibility in project scope.

All ten University of California campuses participate in IUCRP, in addition to three UC-managed National Laboratories and its Agriculture Experiment Station. All grants require participation and matching funds from industry sponsors. For-profit businesses that have R&D operations in California (or an alliance with a firm in California) in a field related to the research proposal are eligible to participate. Typical funding levels range from $50,000 to $2 million per year for four years.

Grant Process

For most fields, research proposals are accepted three times per year using an online proposal submission system. The MICRO program has one round per year.[52] The application and selection process is described below. The application requirements and peer review process are modeled on systems used by the National Institutes of Health and National Science Foundation.

1. **Proposal Generation and Submission.** A UC researcher (the "Principal Investigator") and an industry partner prepare a proposal that addresses a topic of mutual interest. The industry partner must provide at least half of the direct costs and all of the indirect/overhead costs for the project. Application requirements include detailed research plans, detailed budgets, etc. All proposals are submitted using an online proposal submission system.
2. **Peer Review and Funding Decisions.** All proposals are rigorously reviewed during a one-day session by expert scientists and engineers. Proposals are judged according to scientific and technical merit, budget, and the relevance of the study to the State of California. The Executive Committee makes recommendations for conditional funding on the day of the review meeting. Unsuccessful applicants are provided with comments and are encouraged to improve and resubmit their proposals in the next funding cycle.

[52] ucdiscoverygrant.org/about/glance.htm

3. **Conflict of Interest Review and Research Agreement.** Conditionally-approved applications must meet certain conditions within 100 days of the submission deadline (no extensions are granted). Conditions include a conflict of interest review and submission of a formal research agreement between the participating UC campus and the industry partner. An application receives final funding approval when all conditions are met. The proposal approval rate varies from field to field, ranging from 40% to 70% per round.
4. **Grant Initiation.** The entire process, from the proposal submission deadline to funding, is completed within 100 days. Upon final approval, an award letter and the initial funding allocation are issued so that research may commence. Any project modifications during the grant period must have written approval.
5. **Annual Reviews.** Annual progress reports must be submitted by the university principal investigator throughout the grant term, using an online system. Inadequate progress reports or failure to submit reports results in project termination. Annual industry partner surveys are also conducted. Annual funding allocations are made after progress reports are approved.
6. **Final Reports.** University principal investigators are required to submit a final report one month before their project's end-date. The final 10% of funding is allocated upon approval of the final report.[53]

Program Impact

IUCRP has expanded significantly since its initial $3 million investment by UC in 1996. By 2003, it had grown to a level of $281 million in investments by UC ($21 million), industry partners ($147.5 million), and the state of California ($112 million), with the capacity to grow at a rate of $60 million annually.

From 1996 to 2003, IUCRP's Discovery Grants program funded nearly 600 research projects and engaged 353 private companies to collaborate with UC researchers. The industry partners reflect a broad cross section of California's technology sector, including start-up firms and industry leaders such as Intel and Chiron.

A research survey conducted by IUCRP showed that nearly half of the participating companies had never sponsored collaborative research with UC before participating in the program. Industry partners reported that the program had the following impacts on their companies:

- Companies stated that participation enabled them to do something they could not undertake in-house (96% of survey respondents) and that participation led to new collaborations with other firms (33%).
- Participation helped companies accelerate R&D (86%) and recruit key personnel (49%).
- Out of 156 industry partner firms at a start-up stage, 41 firms raised at combined total of $1.4 billion in venture capital after their first participation in IUCRP matching grants.
- 5,000 net new California jobs were created by firms that had fewer than 500 employees at the time of their first IUCRP matching grant.
- IUCRP's 595 Discovery Grants resulted in 103 formal invention disclosures and 22 licenses by UC researchers.[54]

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[53] Information in this section was adapted from ucdiscoverygrant.org/apply/stages.htm and www.research.ucsf.edu/icd/icdIUCRP.asp

[54] Information in this section was adapted from *IUCRP Annual Report 2003*, ucdiscoverygrant.org/AnnualReport.pdf; ucdiscoverygrant.org/about/introduction.htm; and www.research.ucsf.edu/icd/icdIUCRP.asp

Success Factors And Lessons Learned

- **Emphasis on collaboration.** Rather than the traditional view of research being conducted in the university, and then being "spun-off" to the private sector, IUCRP requires university-industry collaboration throughout the research process.

- **Strong leveraging of private funding.** IUCRP's required 1:1 match of industry funding provides a major boost to program funding provided by the state and UC, and it strengthens the stake of the industry partners in the successful outcome of research projects.

- **Tightly-managed application process.** IUCRP has developed an efficient application process that allows for several funding cycles per year and ensures that all funding decisions are made quickly (within 100 days). Peer review of research proposals by industry and scientific experts, as well as expert participation in program oversight, ensures that the research undertaken is of relevance to the market.

- **Focus on early-stage investigations.** IUCRP's research areas emphasize early-stage investigations of emerging technologies in critical technology fields, which have the potential to become new products that can boost the state's economy. With this focus, IUCRP provides an important funding boost for research in high-potential areas that may not be feasible or immediately profitable for participating companies working on their own.

North Carolina's Research Triangle

This case study differs from the others presented in this report in that it examines the overall development of one of the nation's leading examples of technology-led economic growth, rather than assessing a specific state program or intervention. In addition, this case study covers a region within a state rather than a whole state. However, Research Triangle serves as an important case study indicating how sustained public/private/university collaboration can lead to significant technology-led economic development.

Although less well known than Silicon Valley, Research Triangle in North Carolina is one of the oldest technology clusters in North America and provides a prime illustration of a world-class research and industrial park and industry cluster being created "from scratch." Research Triangle is a product of deliberate planning by the region's visionaries. The philanthropic activities of early entrepreneurs provided the foundation for the region's transition from agriculture to manufacturing to a knowledge-based economy. Land and money grants provided the underpinnings for the region's institutions.

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

Establishment And Evolution

The concept of using the research strengths of North Carolina's three major universities – Duke, North Carolina State, and the University of North Carolina at Chapel Hill – to promote the state's economic growth and stem the migration of university graduates to other states originated in the 1950s. It was stimulated by the recognition that North Carolina had one of the lowest per capita incomes among all states, and that its three major industries were all low-wage employers and in decline. In 1955, Governor Luther Hodges created a committee of business and university leaders to examine how university-based research could restructure the state's economy. The report produced by the committee envisioned using faculty expertise in selected fields of research to attract industrial R&D labs to the region. The committee predicted that economic development would occur as firms located their production facilities near their research facilities, thus stimulating employment. Interestingly, the report did not envision a research park as part of the plan.

Two years after the committee's report was completed, Karl Robbins, a retired industrialist, was recruited to invest in the concept. Robbins proposed a private research park located within the triangle formed by the three universities, but was not able to attract additional investors. In part, fundraising was slow because the idea of a research park was as yet untried, but the idea received mixed support because it involved public universities and state agencies in promoting a private real estate deal. After some delay, a group of private citizens and corporations bought the stock of the park and formed the Research Triangle Committee, Inc., which later became the Research Triangle Foundation. Under the leadership of George Simpson, Jr., a faculty member at the University of North Carolina, the Foundation raised funds, promoted the idea that the Research Triangle Park (RTP) would be a desirable location for corporate R&D facilities, and created the Research Triangle Institute (RTI). The Institute, a non-profit contract research organization, was initiated by a $500,000 cash grant and gift of 157 acres in the middle of RTP.

RTP was built in 1959 around the three universities located in the cities of Raleigh, Durham, and Chapel Hill. The initiative has been extremely successful, and by the year 2000, over 50,000 people worked at 136 research and development, office, and high tech manufacturing facilities in RTP. RTP has evolved into an international research and development center, bringing high-paying jobs and attracting other industries and facilities to the region. The result is booming growth and urbanization, particularly around Raleigh in Wake County.

Development And Key Assets

Research Triangle essentially sprang from the academic and research assets surrounding it. However, government support provided a strong stimulus to development. Catalytic government activities have had a tremendous influence on Research Triangle, and the efforts of local and state institutions were key in bringing information technology and bioscience research and training facilities to the area. Coupled with the state and federal government funded R&D programs, these actions have been, and continue to be, critical to Research Triangle's success.

The wide range of incentives and services, provided primarily by the state government, are outlined in the table below.

Research Triangle Incentives and Services	
Tax Incentives (North Carolina William S. Lee Quality Jobs and Expansion Act) ■ Corporate income tax reduction ■ Investment tax credit ■ Job creation tax credit ■ Worker training tax credit ■ Research and development tax credit ■ Business property tax credit	**Site Selection Services** ■ Employee relocation assistance ■ Community orientation briefing and tour ■ Assistance with visitation itineraries ■ Liaison with service providers ■ Liaison with public officials ■ Available site and building inventory ■ Statistics and research information
Financing ■ Industrial revenue bonds (for manufacturing only) ■ SBA loans ■ Community development bock grants (low/moderate income employment opportunities required) ■ Venture capital funds ■ State technology based equity funds ■ Manufacturer's incentive tax formula	**Infrastructure Programs** ■ Utility extensions ■ Raleigh-Durham International Airport ■ Moor County Commercial Airport ■ Industrial access roads
Employee Screening, Placement and Training ■ Free customized pre-employment job training through area community colleges ■ Screening and placement services through Employment Security Commission's Job Service ■ On-the-job training/youth summer project	**Higher Education-Based Support Programs** ■ MCNC, North Carolina's microelectronics, computing, and networking center ■ Industrial Extension Service ■ Kenan Institute of Private Enterprises ■ Small Business and Technology Development Center

Key Research Institutions

As noted above, Research Triangle exists because of the region's market magnets and critical assets. Key among these are cutting edge research institutions. Three educational institutions form the pillars of the region's knowledge-based economy, providing world-class research facilities as well as critical mass of scientists, researchers, and technicians.

- **Duke University.** Duke University is regarded as one of Research Triangle's most valuable assets one of the South's premier private research institutions. Duke is known for the quality of its faculty, as well as its academic and research programs.

- **North Carolina State University (NCSU).** NCSU is the largest of the universities in the University of North Carolina System. Since its founding in 1887, NCSU has become one of the nation's leading institutions for science, engineering, and technology research. The University is ranked among the top schools nationally for industry-sponsored research and for licensing revenues and patents.

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

In addition to these large universities, the Research Triangle region benefits from a number of other key assets, including specific university and independent research centers and public/private partnerships, such as the following:

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

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

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

- **Research Triangle Foundation of North Carolina (RTF).** RTF is a non-profit foundation that operates and governs the Research Triangle Park. RTF has been extremely successful in steering the growth of RTP through its two-pronged approach to growth: 1) attracting prominent R&D entities into RTP, and 2) nurturing new firms springing from the universities and other research efforts. The early attraction of IBM as one of its tenants dramatically increased the visibility of RTP to other IT firms. At the same time, the nurturing of new start-ups helped build the critical mass of R&D activity that in turn facilitated the attraction of larger companies.

  The planners of RTF also aggressively promoted RTP's image. They consciously decided to sacrifice the total amount of building space that could be used in order to create a high quality environment for workers. This low-density approach was made possible by the inexpensive land costs in North Carolina at the time. In addition, development standards were strictly enforced, with an architectural review board working closely with tenants and developers. The relationship was ideal, as it created a working environment that serves firms and employees in the park well, provided a positive setting for marketing to new tenants, and generated an attractive image in the media, thereby creating "free" promotion.

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

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

Other Key Innovation Assets

Strong Anchor Firms. The region has benefited from strong anchor firms, especially information and communications technology powerhouses. IBM was the first to establish a major research facility in RTP. Other big IT players, such as Nortel Networks and Cisco systems, followed suit. By the mid-1990s, the cluster began to achieve a critical mass that propelled it to become a world-class networking and telecommunications center.

High Levels of R&D. A key component to continued discovery and innovation is the amount of investment poured into research and development efforts. Research Triangle receives more than six to seven times the national average amount of federal expenditures for university R&D.

Skilled Workforce. Graduates from local colleges and universities have provided the region with a steady supply of specially trained scientists and engineers. The large labor pool has been a source of attraction for firms to the RTP.

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

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

Success Factors And Lessons Learned

The emergence of Research Triangle was based on strategic decisions, investments, and marketing efforts that took place from the late-1950s through the early-1980s. The strong IT industry presence in the Research Triangle region is a direct consequence building an ideal research park, closely linked with the research capabilities of the three regional universities.

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

- **Build the research infrastructure to attract knowledge companies.** The key turning points in Research Triangle's development were the construction of Research Triangle Park, the ability to obtain the cooperation of the three regional universities, and the marketing of the region as a major metropolitan area. Setting up a quasi-independent private non-profit foundation was also a critical step to run RTP.

- **Recruit well-known technology companies as anchor firms.** Marketing personnel at RTP utilized prominent companies such as such as IBM and Cisco Systems as anchor firms, which established a reputation for the region and in turn attracted other world-class firms.

- **Nurture home-grown firms with entrepreneurial assistance.** This mission was achieved through the creation of CED, which provides a variety of programs and services to entrepreneurs throughout the region. Through these efforts, CED supports the growth and success of local start-up technology companies.

- **Capitalize on synergy between IT and other high-tech sectors.** Research Triangle houses a variety of other internationally competitive industry clusters that have strong synergies with IT, including: biopharmaceuticals, clinical research, and venture capital. Clustering of these industries create synergy and stimulate cross-disciplinary innovation and discovery.

IV. Enhancing Entrepreneurship & Access To Capital

List of Case Studies

- Maryland Venture Fund
- Georgia Advanced Technology Development Center
- Pennsylvania Ben Franklin Technology Partners

Maryland Venture Fund

The Maryland Venture Fund (MVF) was founded in 1994 by the Maryland State Legislature as an evergreen fund that would receive a funding allocation each year. According to Maryland's Governor Martin O'Malley, the Fund "is a regionally recognized leader in seed and early-stage investing and a national model for state-run investment programs."[55] The Fund makes direct investments in technology and life science companies, as well as indirect investments through venture capital firms. MVF currently invests 60% of its portfolio in the ICT sector (software, communications, and IT security) and 40% of its portfolio in life sciences companies (therapeutics, medical devices, and diagnostics). The Fund has also established with nine venture funds since its inception.[56]

Establishment And Evolution Of The Program

The Maryland General Assembly authorized the establishment of the Enterprise Fund in fiscal year 1993, leading to the creation of the Maryland Venture Fund (MVF) in 1994. Originally created to make equity investments in "new" Maryland enterprises, MVF has since narrowed its focus to target "investments in early stage and high technology companies experiencing difficulties attracting private sector investment dollars."[57]

The overall structure of the Fund has changed very little over the past decade. Recent additions to its activities include two new initiatives – the Maryland/Israel Development Fund and the FIPS Certification Grant Program, which are detailed in the following section. Based on economic circumstances and state funding allocations, MVF has been operating within annual investment budgets that fluctuate between $2 million to $6.5 million annually.

How The Program Works[58]

MVF makes strategic investments through its five programs:

1. The Enterprise Investment Fund
2. The Challenge Investment Program
3. The Enterprise VCLP Fund
4. The Maryland/Israel Development Fund
5. The FIPS Certification Grant Program

1. The Enterprise Investment Fund (EIF)

This fund targets early-stage, high technology firms that are seeking venture capital as their first meaningful source of investment funding. The EIF requires a three-to-one ratio of investment matching by a private investor, with a maximum EIF equity not to exceed 25%. Most EIF investments do not exceed $500,000; however, some single portfolio companies have received over $500,000 for a number of years in order to protect Maryland's investment.

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[55] Maryland Venture Fund, *Annual Report 2006*, www.choosemaryland.org/Resources/pdffiles/performancereporting/06reports/FY%202006%20MD%20Venture%20Fund%20Annual%20Report.pdf
[56] www.choosemaryland.org/businessservices/marylandventurefund/mvf.html
[57] Division of Finance Programs Investment Finance Group, *Annual Financial Status Report Fiscal Year 2007*, www.choosemaryland.org/Resources/pdffiles/performancereporting/07reports/FY07%20IFG%20Annual%20Report.pdf
[58] Ibid

Investment choices under EIF are made by a ten-member Advisory Board, who sends recommendations to Maryland's Secretary of the Department of Business and Economic Development (DBED) for final approval. Subsequent investments must retain their principal place of business within Maryland for no less than five years, and the investments can last up to a maximum of fifteen years.

Through June 30, 2007, the EIF has invested in 82 ventures at a cumulative cost of about $35.4 million. By the end of fiscal year 2007, twenty-one of those ventures went public or were acquired by a larger privately-held firm or a publicly traded firm.

Investment Examples of the Enterprise Investment Fund, 2005-2006

- ***$250,000 investment in Jackbe Corp***, a leader in AJAX (Asynchronous JavaScript and XML)-based solutions. The company's main product is a set of development tools that allows rapid development of sophisticated, rich-client applications using AJAX. In November 2005, Jackbe Corp. brought in its lead co-investor, Blue Chip Capital Company.
- ***$600,000 investment in Cardiocore Lab***, whose clinical operations organization provides centralized cardiac testing services, including ECG analysis and Holter monitoring. Cardiocore is the only provider with exclusively U.S. board certified cardiologists to interpret ECG results. In March 2006, Cardiocore raised an additional, outside $8 million.

2. The Challenge Investment Program (CIP)

The Challenge Investment Program (CIP) provides seed funding to high-technology start-up firms. Initially established as an exclusive grant program in 1989, CIP was modified into an investment program and incorporated as part of MVF after its inception in 1994. CIP has a less stringent requirement than the EIF in terms of recipients' place of business, requiring firms to stay in Maryland for no less than three years. The Program also requires a minimum of one-to-one private investor matching.

CIP's target firms are those that have the potential to be an EIP candidate or an attractive equity investment in the private sector within two years. CIP investments are ten-year agreements with two methods for eventual repayment: (1) 2% royalty on revenues in excess of $500,000; and (2) If a recipient receives outside equity funding, the recipient will repay DBED 1% of the equity raised in excess of $500,000, with a maximum payment of three times the original investment. A recipient may receive as much as $50,000 as an initial investment, based on his/her business plan and presentation. The investment amount can be increased in increments of $50,000, up to a maximum of $150,000, based on mutually agreed milestones for the recipient company.

Through June 30, 2007, CIP has invested in 156 ventures at a cumulative cost of about $9.8 million. Around forty of those ventures have either received investment from EIF, transitioned to the EIF through conversion into stock, traded publicly, or been acquired by other investors.

Investment Examples of the Challenge Investment Program, 2006

- ***$50,000 investment in 3CLogic, Inc.***, which enables real-time, peer-to-peer communications for business applications.
- ***$100,000 investment in CollectiveX, Inc.***, a web-based service that enables members of organized groups to maximize return on involvement through private, secure communication and social networking.
- ***$50,000 investment in Message Level***, the only e-mail authentication solution that prevents impersonation of legitimate e-mail addresses.

3. The Enterprise VCLP Fund

The Enterprise VCLP Fund invests in venture funds "selected based on their investment philosophy and performance as well as a commitment to consider investments in the State of Maryland."[59] Targeted funds typically provide early stage financing, especially in high-technology and life sciences companies, which complements the EIP's initiatives and allows the public and private sectors to co-invest. The Enterprise VCLP Fund has invested $11.5 million in nine venture funds, or Venture Capital Limited Partnerships (VCLPs), since 1994.

Examples of VLCP Investments

- The ***Meridian Management Group (MMG)*** was founded as a spin-off from DBED in 1998 to create a minority private sector fund. DBED initially committed $5 million to invest in minority businesses in economically challenged parts of Maryland.
- In 1998, MVF committed $1.5 million to ***Boulder Ventures III, LP***, an $85 million fund based in the Baltimore region that seeks opportunities in enterprise software, internet-based business applications and services, communications infrastructure and services, and life sciences tools and services.
- In 2000, MVF invested $1.5 million in ***Grotech Partners V, LP***, a $287 million fund that originates and leads investments in emerging and traditional industries, including communications, technology and consumer, healthcare, and business products and services.

4. The Maryland/Israel Development Fund (MIDF)

In November 2004, Maryland and Israel entered a Memorandum of Understanding to establish the Maryland/Israel international research and development fund (MIDF). The mission of the MIDF is to encourage collaboration between Maryland and Israeli companies to create high technology companies. Investments range from $100,000 to $300,000, with half from DBED for the Maryland company and the other half from Israel's Ministry of Industry, Trade, and Labor for the Israeli firm. The funds may only be used for the R&D expenses of the project, and company matching funds are required equal at least half of the project's costs. The MIDF program will last five years and would ideally have a budget of $500,000, with repayments made after the joint-effort yields revenues.

5. The Federal Information Processing Standards (FIPS) Certification Grant Program

In 2005, DBED started the Federal Information Processing Standards (FIPS) program to provide small grants to technology companies that need proper security certification to do business with the Federal Government. Specifically, the program assists companies in obtaining FIPS 140-1 and FIPS 140-2 for certification. In order to be eligible to apply, the company must be based in Maryland, have no more than thirty full-time employees, and have annual revenues that do not exceed $5 million. If approved for the grant, the company can receive up to 40% of the eligible costs involved in FIPS certification (not to exceed $50,000). The first grant for the program was given to a company in 2006.

Program Impact[60]

Since 1994, MVF has invested over $45 million in more than 175 companies. For that investment, the Fund has returned over $57 million to DBED in the sale of securities held by EIF. This is translated into an annual rate of return of 20%. Companies in the MVF portfolio have attracted more than $1 billion in

[59] Information in this section adapted from: Maryland Venture Fund, *Annual Report 2006*, www.choosemaryland.org/Resources/pdffiles/performancereporting/06reports/FY%202006%20MD%20Venture%20Fund%20Annual%20Report.pdf

[60] Program impact figures adapted from the source in Footnote 3.

equity investments and have created an estimated 1,500 new jobs with average salaries of $70,000, almost twice the state average of $36,000.

In 2005, *Entrepreneur* magazine ranked the Maryland Technology Development Corporation (TEDCO) and the Maryland Department of Business and Economic Development (DBED), under which the MVF operates, as two of the most active seed fund investors in the nation.[61] In 2006, the MVF earned the "Excellence in Economic Development Award" from the U.S. Department of Commerce for its innovative strategies in economic development, an award presented each year to showcase best practices, highlight outstanding results, and honor innovative economic development strategies of national significance.[62]

As a measure of recent success, several companies in the MVF portfolio began trading on listed exchanges in fiscal year 2007:

- ***Solution Technology International***, a company based in Western Maryland, began trading on the NASDAQ over-the-counter market in July 2006.
- ***Osiris Therapeutics***, which develops and commercializes cellular therapies based on stem cells isolated from readily available adult bone marrow, began trading on the NASDAQ market in August 2006.
- ***Neuralstem***, which is applying stem cell research and its patented human neural stem cell technology to treat diseases of the central nervous system, began trading on the NASDAQ market in December 2006.
- ***Sourcefire***, which offers a suite of network intrusion prevention products, including open source software, began trading on the NASDAQ market in March 2007.

Although it is challenging to determine "Fair Market Value" (FMV) for the balance of DBED's holdings in the EIF since the firms are still privately held, using typical venture capital valuation methods yields an FMV of $25.5 million as of June 30, 2007. In fiscal year 2007, the EIF liquidated 18 investments worth $2,945,800.

Of the 156 investments made by CIP, 98 are still in business or have had some successful exit from the program. This 63% success rate is considered quite high given the typical high risks associated with start-up financing. In fiscal year 2007, the CIP liquidated 25 investments worth $1,500,000, of which 3 CIPs worth $200,000 were converted to EIF.

DBED has received $616,531 in distributions and interest from the partnerships of the Enterprise VCLP Fund. In fiscal 2007, $206,935 was distributed to DBED by its investments.

Success Factors And Lessons Learned

- **Broadly Written Statute.** The Maryland Venture Fund is unique among state-sponsored venture capital funds in that it is not prohibited from owning stocks in private companies. MVF's ownership stake is restricted to 25%. The MVF statute also does not preclude the Fund from investing in new industries and/or technologies that may be considered risky, such as biotechnology.

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[61] Maryland Programs Recognized by Entrepreneur Magazine as Two of Nation's Most Active Early Stage Investors: http://www.marylandtedco.org/tedco/docs/TEDCOEntrepreneur2006.pdf
[62] Blue Chip Director Named to State of Maryland Venture Fund Board: http://findarticles.com/p/articles/mi_pwwi/is_200605/ai_n16409018

- **Partnership with the Private Sector.** Another factor for MVF's success has been its active collaboration and partnership with the private sector. The Challenge Investment Program began in 1989 as a grant program with no real measures of accountability. From the time it was merged into MVF, investment in companies was more active and collaborative. For example, although Maryland State employees are prohibited from acting as board members of private companies, MVF employees often attend board meetings on an observation basis, to monitor whether milestones are being met.

- **Tech-Savvy Fund Managers.** MVF leadership rotates between leaders who specialize in technology and biotech. The current managing director, Ray Dizon, specializes in technology, while the former managing director, Elizabeth Good, came from the biotech field. Having tech-savvy fund managers is a logical and vital component of MVF's success rate, as it lends a more discerning eye to judge the business plans of technology and life-sciences companies applying for investment dollars.

- **Calculated Risk Taking.** Throughout its nearly fifteen years of operation, MVF has expanded upon its initial investment base by being able to take calculated risks on promising first-time entrepreneurs or entrepreneurs who are having difficulty finding funding elsewhere. The general void in seed funding and "early stage" capital opens up a niche for MVF to fill. The high success rates of their investments demonstrate the ability of MVF to mitigate risks based on their industry knowledge and careful selection of venture investments.

Georgia Advanced Technology Development Center

Founded in 1980, Georgia's Advanced Technology Development Center (ATDC) is a nationally recognized science and technology incubator that helps Georgia entrepreneurs launch bioscience and technology companies. ATDC is part of the Enterprise Innovation Institute of the Georgia Institute of Technology (Georgia Tech), the university's economic development and technology commercialization entity. ATDC provides its tenant companies with practical business advice, flexible lease terms on its facilities, turnkey services, and connections to valuable resources such as Georgia Tech faculty, students, facilities, venture capital firms, etc. Since its inception in 1980, over 100 companies have graduated from ATDC, including MindSpring Enterprises, which is now part of EarthLink. ATDC now has locations in Atlanta, Savannah, and Warner Robins.

ATDC Mission: *To increase the technology business base in Georgia by helping entrepreneurs launch and build successful companies.*

ATDC Goal: *To put top research faculty together with entrepreneurs to form new research-driven enterprises.*[63]

Establishment And Evolution Of The Program

ATDC traces its origins to almost thirty years ago, when concerns about potential erosion of Georgia's industrial base due to increased off-shoring brought together stakeholders to explore strategies that would strengthen the state's high-technology sector. The Committee of Twenty, comprised of influential Georgia Tech alumni, organized the Technology Business Development Project, whose objective was to bolster the university's capabilities to promote high-tech businesses in Georgia. In 1979, the Committee proposed the creation of a Technology Business Development Center.

This proposal was also supported by findings from a subsequent study of the state's science, engineering, and technology programs commissioned by Governor George Busbee and conducted by the Georgia Tech Engineering Experiment Station. This study suggested that the university should establish an "advanced technology development service" with state support.

In 1980, ATDC was established with legislative and financial support from the General Assembly and the Governor. Housed in an old high school building, ATDC's earliest incubator admitted its first tenant company in 1981 and produced its first graduate in 1983. ATDC started with four staff members, one for each of its major programs: entrepreneurial development, industrial recruitment, venture capital, and education. In 1985, ATDC opened its new headquarters on the Georgia Tech campus.

In 2003, ATDC moved its headquarters to Georgia Tech's Technology Square. The new, 83,000 sq. ft. facility takes advantage of the proximity of the Georgia Tech Hotel and Conference Center, as well as the faculty and students at the College of Management, the classrooms and technical capabilities of the Global Learning and Conference Center, and the retail establishments and restaurants at Technology Square. ATDC also has a 22,000 sq. ft. incubator with wet labs and office space for startups, located within the Georgia Tech Ford Environmental Science & Technology Building, to promote the university's research in life sciences and environmental engineering (e.g., clean energy, the environment, sustainable

[63] www.atdc.org/locations.asp

technologies, biomedical engineering, earth and atmospheric sciences, chemical engineering, and biological sciences).

To promote entrepreneurial efforts in multimedia, software, and other communications technologies, ATDC used state and private funds to open a new branch facility in 1996, located in the Georgia Center for Advanced Telecommunications Technologies (GCATT) building near Georgia Tech's main campus. Over time, ATDC has also expanded its technology incubation services to other parts of the state, with additional state support. In 1987, ATDC opened up an Augusta center to promote start-up efforts in health science technologies, leveraging the center's proximity to the Medical College of Georgia. However, this center was closed a few years later because the clinical nature of the College led to few marketable health-science products or services for startups.

In 1991, ATDC opened the Middle Georgia Technology Development Center (MGTDC) in Warner Robins to serve the high-tech growth opportunities in aerospace and defense in middle Georgia. This initiative was driven in part by the technology needs of the Warner Robins Air Logistics Center, which is Georgia's largest industrial complex. More recently, ATDC expanded its operations to Savannah in 2002 by establishing the Chatham Center, in partnership with the Georgia Tech Regional Engineering Program; Georgia Tech Economic Development Institute; the Georgia Department of Industry, Trade, and Tourism; Savannah Economic Development Authority; and Coastal BETA. This new initiative serves new ventures from Savannah's technology community, including academic institutions such as the Savannah College of Art and Design, start-ups, and established companies.

Today ATDC employs 16 staff members, including successful entrepreneurs, technology specialists, and former venture capitalists.

How The Program Works

ATDC's core offerings are their "5 C's," which stand for Centre, Consulting, Community, Credibility, and Connections:[64]

- **Centre:** Office and laboratory space designed for startups is available at ATDC's facilities. ATDC subsidizes rent and offers 90-day flexible lease terms, varied furnished suite sizes, and access to shared services. Member companies may stay up to 3 years in ATDC's facilities. The physical facilities also fosters peer-to-peer learning between startups. There are now five ATDC facilities located in Atlanta, Savannah, and Warner Robins.

- **Consulting:** ATDC employs full-time business advisors – known as "venture catalysts"- who have significant start-up experience and are available to provide practical consultation for tenant companies. They support member companies in key business activities, devise fundraising plans, and serve as sounding boards for strategic direction. ATDC also provides training and technical assistance through its Entrepreneur-in-Residence program, which invites "successful company founders to share their wisdom and experience"[65]; runs a CapVenture Program (a six-week fundraising bootcamp); and pulls together staff and outsiders to review the startups' fundraising pitches.

[64] www.atdc.org
[65] www.atdc.org/erc.asp

- **Community:** ATDC encourages community within its members through activities such as CEO & CTO roundtables, brown bag lunches, and other informal activities that encourage community learning experiences.

- **Credibility:** ATDC's reputation and affiliation with Georgia Tech provide credibility to its member companies.

- **Connections:** ATDC's reputation enables member companies to gain access to people and resources at Georgia Tech, as well as potential investors, business partners, customers, service providers, etc. For example, its ATDC Technology Showcase is an annual networking celebration to attract prominent entrepreneurs, investors, and business authorities to showcase ATDC's members, in particular the new graduate companies. Its Georgia Tech Innovation Experience is a "speed dating" event for entrepreneurs, facilitating 20 entrepreneurs and 20 investors in three-minute rotations to pitch their ventures.

Along with the core offerings described above, ATDC also operates an Entrepreneurship Resource Center (library and website), as well as an official weblog (Peachseedz.com), which intends to virtualize the ATDC community and serve as a resource for:

- Tips and advice on angel investors, building teams, business development, fundraising, legal issues, management, marketing, product development, sales, and venture capital.
- Information on upcoming key events for technology entrepreneurs.
- Updates on startups in Georgia.
- Videos of ATDC events, speakers, and panels.
- Links to other blog postings, podcasts, and websites.
- Other news on Atlanta and Georgia entrepreneurship.[66]

ATDC members are often graduates of VentureLab, Georgia Tech's one-stop shop to assist its faculty, staff members, and graduate students in technology commercialization. In addition, ATDC is part of an incubator network for national security – the Technology Acceleration for National Security (TANS) Network. Other partners in TANS include the Chesapeake Innovation Center, Colorado Springs Technology Incubator, Harrisonburg Innovation Center, Northeast Alabama Entrepreneurial System, Texas Research & Technology Foundation, and Watervliet Innovation Center. TANS will offer a way for government agencies and corporations to identify and foster innovative security technologies.

Over 130 companies apply for ATDC membership every year. Applicants are required to submit a development plan and strategy, and admission criteria include:[67]

- An innovative science or technology based product or business concept.
- A strong and committed management team.
- A business plan that generates significant revenue and many technology jobs.
- Participation in the ATDC community.
- Be based in Georgia, but a connection with Georgia Tech is not a requirement. (Although one-third of ATDC companies have connections to Georgia Tech or VentureLab, no priority is given to Georgia Tech-related companies.)

[66] www.atdc.org/news_details.asp?NewsID=738
[67] www.atdc.org/applicant_criteria.asp

ATDC member companies operate in many areas of technology and bioscience, including: biomedical technology, computers and electronics, engineering and technology services, energy, environmental technology, gaming, Internet applications, manufacturing, new media, optical technology, software, and telecommunications.

To graduate from the ATDC program, member companies must demonstrate sustainability by achieving at least one of the following:

- One million dollars or more annual sales.
- More than 10 employees.
- More than 5000 square feet of space needed.
- Acquisition by a larger company.
- Consistent profitability.[68]

ATDC does not receive equity shares in the companies it assists. ATDC is mostly funded through appropriations from the state legislature. To promote ventures in biosciences and other technology areas, ATDC also coordinated a matching grant program where it raised $3 in private funds for every $1 in state funds to provide seed funding to startups. Under this program, the state provided $5 million in fiscal year 2000 and $3 million in fiscal 2003 in seed capital.

Program Impact

The key impact measurements used by ATDC are the amount of revenue generated by its companies and the number of jobs created by these companies. ATDC has tabulated that, since 1987, member companies have generated more than $12.7 billion in revenues and created approximately 51,000 man-years of employment.[69] According to a recent economic analysis, ATDC member companies have contributed over $100 million in profits to the state.

Other highlighted impacts include:

- 75 ATDC member companies have raised a cumulative amount of $1 billion in venture capital since 1999. The average deal size is $6.7 million. In 2006, 21% of venture investments in Georgia went to ATDC companies, and 10 of the 25 largest VC deals in the state were awarded to ATDC companies.[70]

- ATDC companies have a strong survival rate. 75% of companies who have been a part of ATDC since 1995 are still in business or had a successful exit (e.g., acquisition), as compared to the industry failure rate of 80% for startups nationally.

- 30 ATDC member companies "have been represented on the public markets via either acquisitions or IPO."[71]

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[68] Culp, Rhonda and Philip Shapira, *Georgia's Advanced Technology Development Center: An Assessment*, 1997, www.cherry.gatech.edu/mod/pubs/atdc.pdf
[69] www.atdc.org/success.asp
[70] www.atdc.org/billion/default.asp
[71] www.atdc.org/success.asp

ATDC's awards and recognitions include:

- Recognized by *BusinessWeek* magazine as one of the top incubators in the country.
- Received the 2004 EDA Excellence in Technology-led Economic Development Award.
- Recognized as the model university incubator by Southern Growth Policies Board.
- Named one the "Nation's Eight Most Admired Nonprofit Business Incubators" by *Inc. Magazine* (2000).
- Received the 1996 "Incubator of the Year Award" by the National Incubation Association.[72]

Success Factors And Lessons Learned

- **Heightened credibility through association with a major technological university.** A 1997 survey of ATDC member companies found that the "primary positive impact of ATDC membership on member companies was the heightened credibility factor generated by the association with a major technological university, sometimes but not always in conjunction with business development services, lenient rental terms, and access to facilities, expertise and students." [73] The survey noted a strong "halo effect" through ATDC's affiliation with Georgia Tech. This affiliation is presumed to be helpful in gaining access to venture capital, esteemed faculty, and other vital resources for success.

- **Physical proximity to a major technological university.** Although the primary motivation for membership is typically to receive business development assistance, many member companies, especially those with faculty members, seek ATDC membership to be in close physical proximity to Georgia Tech. Benefits of proximity include: facilitating technology transfer and technology licensing agreements between Georgia Tech and ATDC companies, as well as access to faculty, student labor, and other university resources. Also, as demonstrated by the failure of the Augusta ATDC branch, it is important that the partnering, proximate university have a research program conducive to producing marketable discoveries that can be commercialized.

- **"Feeder" program connects university faculty with the incubator.** The VentureLab program is one effective means of preparing and screening faculty, staff, and students at Georgia Tech for membership in ATDC.

- **State funding used to successfully attract private funding.** The ATDC matching grant program was very successful in leveraging state funds. In fiscal year 2000, the $5 million seed capital fund from the state attracted $145 million in capital investment, helped 11 companies get off the ground, and created 270 jobs with an average salary of $98,000. The state appropriated another $3 million in fiscal year 2003 for a bio-science seed fund, which "has helped 3 companies attract $7.5 million in private capital."[74]

- **Incubator service offerings tailored through member feedback.** In a recent interview, ATDC attributed its success to consulting with its members to gauge what services they value, and then tailored its offerings (the "5 C's") around the survey results.[75]

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[72] www.atdc.org/success.asp
[73] Culp, Rhonda and Philip Shapira, *Georgia's Advanced Technology Development Center: An Assessment*, 1997, www.cherry.gatech.edu/mod/pubs/atdc.pdf
[74] www.usg.edu/chancellor/budget/fy07presentation.phtml
[75] www.startuplounge.com/sl7-inside-atlantas-technology-incubator/

Pennsylvania Ben Franklin Technology Partners

Established in 1982 by the Pennsylvania General Assembly, Ben Franklin Technology Partners (BFTP) is one of the longest running regional technology-based economic development programs in the country. BFTP defines its mission and goals as follows:

BFTP Mission: *To invest in the transformation of the Pennsylvania economy through technology, innovation, and strategic partnerships that fosters a favorable business environment for high-growth companies.*

BFTP Goal: *To ensure that the state's emerging and growing technology enterprises have access to the resources they need to become more efficient, more competitive, and more successful in the global marketplace.*[76]

BFTP's programs focus on both entrepreneurial development and technological innovation as key engines of growth and diversification in the state economy. Its programs serve entrepreneurs, early stage businesses, and established enterprises across a wide variety of technology sectors, including information technology, life sciences, communications, advanced manufacturing, advanced materials, and environmental technology. BFTP also views partnerships and networks as a key component of innovation, and its programs work to facilitate linkages across various stakeholders throughout the state, including industry, higher education, government, associations, entrepreneurs, and others.

Establishment And Evolution Of The Program

BFTP was originally proposed in February 1981 by Governor Richard Thornburgh as the "Ben Franklin Partnership Challenge Grant Program for Technological Innovation." The Pennsylvania General Assembly appropriated $1 million to start up the program in fiscal year 1982-1983. Legislation was also passed to establish the Ben Franklin Program and the Ben Franklin Partnership Board (which replaced the Pennsylvania Science and Engineering Foundation). In February 1982, the Ben Franklin Partnership Board evaluated applications from 7 proposed consortiums to establish regional Advanced Technology Centers and selected 4 consortiums to set up the regional Technology Centers and a series of satellite offices.

From its inception, the Ben Franklin program's main focus was on developing technology and bringing it to the market. The view of the program's key architects and funders was that there was "a significant amount of developed, but unused, technology held 'on the shelf' in many universities." In the early years, program staff spent a significant amount of time developing relationships with university researchers, learning about their expertise, and finding Pennsylvania companies able to utilize university-developed technologies. In support of this aim, BFTP programs initially focused on four key areas:

- ***Research and development:*** supporting development of new products/processes or improvement of existing products/processes, typically involving a university partner performing researching and transferring the knowledge or prototype to a company for application.
- ***Entrepreneurial development:*** supporting small business incubators, especially in rural areas, to help start and grow new technology-based companies.

[76] www.benfranklin.org

- ***Workforce training:*** creating a self-supporting training infrastructure for small- and medium-sized businesses.
- ***University-based centers of excellence:*** developing multi-company partnerships with university research groups that had extensive experience in target technologies, such as nanotechnology or dielectrics.

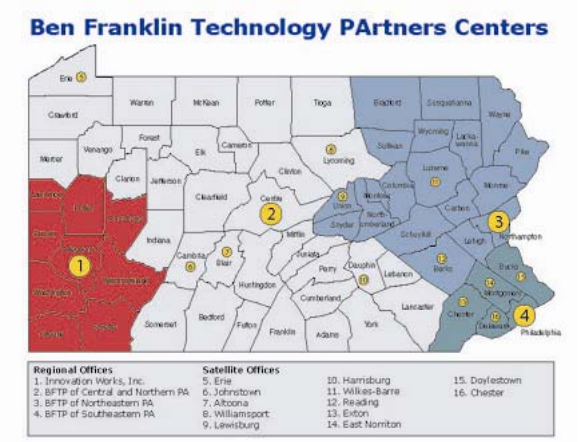
Forging relationships between universities and industry was challenging in the program's early years. Businesspeople often resisted the involvement of universities or the state in their R&D projects; university researchers found it challenging to work within tight business timelines and deadlines. However, over time, strong university-industry partnerships began to develop, helping to grow new businesses and create new jobs in companies such as Lee Industries, Minitab, Centre Analytical Labs, and Zetachron.

In 1985, the Ben Franklin Partnership Board required that the regional Advanced Technology Centers be incorporated as private, non-profit, independent corporations governed by a Board of Directors. Board membership would include institutions of higher education and at least 50 percent private participation. In the Central and Northern Pennsylvania region, for example, the regional center was incorporated as a subsidiary corporation of the Corporation of Penn State University. An 11 member Board of Directors was developed, with 8 private sector members and 3 university members.[77] In 2001, the state passed the "Ben Franklin Technology Development Authority Act." This legislation "established the Ben Franklin Technology Development Authority and charged it with central coordination of BFTP programs and investments that advance the competitiveness of Commonwealth companies in the global economy."[78]

In fiscal year 2007-2008, the funding level for BFTP is $51.7 million, housed within the budget of the Pennsylvania Department of Community and Economic Development. Over time, the activities, programs, and partnerships of each of the regional centers have evolved and expanded, but have also maintained the central mission of technology-based economic development. The current activities of the BFTP program are described in more detail below.

How The Program Works

BFTP currently operates through a network of four regional headquarters (located in Pittsburgh, State College, Bethlehem, and Philadelphia), supported by 12 satellite locations scattered throughout the four regions. Each regional center serves a specific set of counties. In order to qualify for assistance, an individual or company:



- Must be located within the regional center's defined service area.
- Must be a technology-based start-up or established manufacturing firm. Retail and service companies are not eligible for assistance.
- Must offer significant potential for future growth through the development of an innovative technology or technology application. Participation is competitive, and companies must demonstrate potential to commercialize technology and create high-paid, sustainable jobs.

[77] Information in this section was adapted from: www.cnp.benfranklin.org/about/history-of-bftpcnp/
[78] www.sep.benfranklin.org/who/overview.html

The program's specific activities vary across each regional center. However, there are several common themes that all initiatives seek to address:

1. Providing access to risk capital for emerging and established technology businesses

BFTP seeks to "fill a fundamental gap in the lifecycle of startup companies by providing a financial bridge between the personal assets of entrepreneurs and capital funding from third-party investors. The program makes investments in companies that cannot obtain seed capital through conventional mechanisms. Investments may range from $30,000 to $500,000 (maximum amounts vary by region). The program uses a phased, milestone-driven approach, assisting firms as they grow to graduate to conventional debt or equity financing. The following table provides a sample of the financing programs offered by the Central and Northern Pennsylvania regional center.

BFTP Of Central And Northern Pennsylvania *Financial Assistance Programs*		
Who is eligible	**Early-stage companies**	**Established manufacturing companies**
Type of financing	Subordinated debt	Subordinated debt
Amounts	Typically $50,000 to $150,000 per year for up to 3 years	Up to $250,000
Loan terms	Investment payback consists of a 10-year amortized loan at a rate of prime plus 2% with BF having the option to convert unpaid principal to equity. Company payback does not begin until BF funding ends. Interest does not accrue during the initial funding period or any subsequent funding periods that may occur.	Investment payback consists of a 5-year amortized loan at the prime rate on the date of funding approval. Interest does not accrue during the initial funding period or any subsequent funding periods that may occur.
Details about investment phases	**Phase One:** Company proposals address the technical feasibility and product development risks associated with starting the company. A typical Phase One investment would be for prototype development or for fees associated with protecting the intellectual property and would not exceed $100,000. **Phase Two:** Proposals focus on market feasibility and acceptance which includes the introduction of beta sites and proof-of-concept installations. A typical Phase Two investment would be in the $150,000 range. **Phase Three:** Investments are made when a business achieves revenues of $50,000 per month. The loan, for approximately $200,000, is intended to ramp-up sales efforts and encourage overall business growth.	**Phase Four:** Funding up to $250,000, is made to existing manufacturing-based businesses that need to develop a product or process for entry into a new market. Because the risks associated with an established business are less, the payback is structured differently from that of an emerging business and the loan will be repaid regardless of project success.
Competitive application process	**Step One:** Entrepreneur or company seeking financing holds a meeting with the regional center to discuss the technology under development, financing needs, programs available, and terms. **Step Two:** Entrepreneur or company seeking financing makes a 60 minute presentation to BFTP regional staff to explain the project, introduce the management team, describe market potential for the product/process under development, discuss the business development and marketing plan, and discuss the amount of financing needed to complete at least the prototype stage. **Step Three:** Entrepreneur or company submits a formal, written proposal, which is evaluated by BFTP regional staff for technical merit, product marketability, likelihood of near-term completion, and impact on job creation or retention.	

	Step Four: The proposal is presented to the regional Board of Directors at a quarterly meeting for final approval. The applicant is notified of acceptance, and a contract is issued. The entire process typically takes 2-4 months from start to finish. **Ongoing:** Regional BFTP staff maintain regular contact with the company to check on project milestones, deal with issues that arise, and identify appropriate resources to solve problems. The company must submit formal mid-year and end-of-year project reports. Based on individual company needs and progress achieved, a company can receive funding and assistance for up to three years.

Source: Ben Franklin Technology Partners of Central and Northern Pennsylvania, www.cnp.benfranklin.org

The terms of financing programs in other regional centers vary. For example, in the Northeastern region, payback terms are 8 years for early stage companies and 5 years for established companies. In the Southeastern region, initial funding amounts range from $100,000-500,000, and the program focuses on three industries – biotechnology and life sciences, information technology, and physical sciences. In the Southwestern region, there is an additional program, the *University Innovation Grant Fund*, which provides grants to regional universities for technology validation, market research, prototype development, and intellectual property evaluation.[79]

As the loans are repaid, the proceeds are reinvested by BFTP in providing financing to new clients. As companies grow, build their management teams, and begin marketing their product, BFTP then prepares them to raise additional growth capital from private or institutional investors. BFTP maintains relationships with angels, venture capitalists, other financial institutions, and government and economic development partners, and it provides endorsements for companies to ensure they can identify and access the ongoing capital they need to be successful.

2. Providing mentoring and technical assistance for entrepreneurs and start-ups

Entrepreneurs and start-up companies participating in BFTP's financing programs have access to ongoing support and mentoring from the program's network of seasoned business professionals, including both in-house expertise and an outside network of advisors, service providers, and investors. This support team helps companies to identify and address issues and problems, refine their strategies, and grow their businesses.

The specifics of assistance and mentoring programs vary from region-to-region. Some of the services available include:

- One-on-one assistance with developing a business plan, preparing for investor presentations.
- Personal introductions to angels and venture capitalists.
- A mentor network of leaders of successful technology companies who provide advice to start-ups.
- An Emerging CEO Institute, which provides formal leadership training for small company CEOs.
- A program to match start-ups with major corporations who could become customers or business partners.
- Workshops to assist companies applying for SBIR and STTR grants.
- Referrals to legal and accounting specialists who have proven expertise dealing with the issues of early stage firms.

[79] For details on the financing programs available in each region, see the websites for the regional headquarters: www.nep.benfranklin.org, www.sep.benfranklin.org, www.cnp.benfranklin.org, and www.innovationworks.org

BFTP taps into a wide-ranging network of experts to implement these programs, including economic development experts, educational institutions, community leaders, corporate leaders and CEOs, researchers and inventors, and investors and venture capitalists.

The following table provides a specific example of the mentoring and technical assistance services provided in the Central and Northern Pennsylvania region.

BFTP Of Central And Northern Pennsylvania ***Transformation Business Services Network***
The Transformation Business Services Network (TBSN) program was launched 10 years ago to provide ongoing, no-cost mentoring to past, current, and future BFTP portfolio companies in the Central and Northern Pennsylvania region. TBSN is staffed through a contract with a non-profit organization that provides a staff of experts located in the regional headquarters in State College and two satellite offices in Erie and Harrisburg. Assistance is provided in areas such as: ■ Market research ■ Feasibility studies ■ Hiring strategies ■ Pricing ■ Test marketing ■ Accounting systems ■ Analysis of marketplace trends The program's four field officers have a portfolio of about 12 companies each and spend 75 percent of their time directly with the companies. About one-third of the participating companies each year are classified as manufacturing firms. Assistance and mentoring strategies are tailored to the individual needs of each company.
Source: Ben Franklin Technology Partners of Central and Northern Pennsylvania, www.cnp.benfranklin.org; SSTI, *A Resource Guide for Technology-based Economic Development*, August 2006

3. Building partnerships between PA universities and industry

All of the BFTP regional centers work to develop long-term working relationships between their clients and professors/researchers at the state's colleges and universities. In the early years of the program, BFTP programs typically required all client entrepreneurs or companies to work with a university partner. While this is no longer the case, the regional centers now offer a variety of programs to assist and encourage clients to tap into the knowledge, facilities, and manpower of academia. On a case-by-case basis, BFTP may work with companies to identify academic specialists working in a related technology field, gain access to university laboratories or equipment, or utilize graduate student researchers with specialized technical capabilities. These contacts often develop into long-term company-university relationships that span multiple projects. University professors may have the opportunity to work on projects with several different companies over a span of several years.

The following table provides a specific example of a university-industry partnership program in the Southeastern Pennsylvania region.

BFTP Of Southeastern Pennsylvania Technology Commercialization Network
The Technology Commercialization Network (TCN) is comprised of 21 member colleges, universities, and research institutions in the Greater Philadelphia region, including the University of Pennsylvania, Pennsylvania College of Technology, Villanova University, Drexel University, Lehigh University, Temple University, and many others. BFTP staff assist client entrepreneurs and companies to tap into the resources of TCN members in order to address specific technical needs. The network provides advisory and consulting services in areas such as strategic product planning, design, manufacturing, marketing, and testing. The network also provides use of laboratory facilities for analysis, experimentation, and prototyping. BFTP will co-fund an engagement between a TCN Service Network Provider and a client company. The program receives funding support from the U.S. Economic Development Administration (a three-year, $900,000 grant was won in Fall 2007 to support expansion of TCN and related technology commercialization programs).
Source: Ben Franklin Technology Partners of Southeastern Pennsylvania, www.sep.benfranklin.org

BFTP of Southeastern Pennsylvania also works through a wide variety of other programs to build research and technology-based partnerships and networks between industry, universities, and other partners. The table below provides some examples of some of the partnerships that have been developed in the region:

BFTP Of Southeastern Pennsylvania *Examples of Partnerships Developed*
■ Partnered with the **New Jersey Commission on Science and Technology** and the **Delaware Technology Park** to launch in 2004 (with funding from the U.S. EDA) the **Mid-Atlantic Nanotechnology Alliance**. As the nation's first tri-state nanotechnology collaborative, MANA positions the tri-state area as a global hub for expanded research, development, application, and commercialization of nanotechnology. ■ Partnering with the **Delaware Valley Industrial Resource Center** on technology-based education and workforce issues and on the development of a next generation commercialization center at the **Philadelphia Navy Yard**. ■ Partnered with **Thomas Jefferson University** and the **Hepatitis B Foundation** to establish the Ben Franklin Innovation Center – a unique collaboration among complementing nonprofit organizations – to nurture agri-based bio-technology development in the southeast Pennsylvania region. ■ Partnered with **Villanova University** and the **National Science Foundation Partnership for Innovation (PFI)** in Broadband Wireless Communications to obtain federal funds for an agreement to create a Ben Franklin Innovation Center for radio frequency identification (RFID) technology. ■ Partnered with the **Eastern Technology Council** and the **Pennsylvania Biotechnology Association** to create regional Nano Business Forums. ■ Led negotiations with the U.S. Commerce Department's **National Institute of Standards and Technology (NIST)** to develop a partnership among NIST, **Pennsylvania's Department of Community and Economic Development** and BFTP/SEP to establish a broad framework for cooperation to help promote research, technology transfer and commercialization in nanotechnology. ■ Partnered with Philadelphia University, Temple University, Villanova University, and the Delaware Valley Green Building Council to form the Consortium for Sustainable Design and Research of Southeastern Pennsylvania, a collaborative effort to support technology-focused green initiatives.
Source: keynotes.benfranklin.org/archives/SEP_networking_02.html

4. Supporting the development of Centers of Excellence at PA universities

Beyond the services targeted specifically at client entrepreneurs and companies, BFTP also works with the broader community of stakeholders in Pennsylvania to build a favorable environment for technology-based economic growth. One major initiative among the regional BFTP centers is providing funding for the development of Centers of Excellence at Pennsylvania colleges and universities.

A Center of Excellence is defined as "an entity that focuses on a specific technology area and conducts both basic and applied research and development." The goal is to "inspire and nourish ideas that have commercial benefit for an entire industry within the state."[80]

The following table provides an example of the Centers of Excellence that are supported in the Central and Northern Pennsylvania region.

BFTP Of Central And Northern Pennsylvania ***Centers of Excellence at Penn State University***
■ Center for Food Innovation ■ Center of Excellence in Dielectric Studies ■ Radio Frequency Identification (RFID) Center of Excellence ■ The Center of Excellence in Piezoelectric Materials and Devices ■ Center of Excellence for Signal Integrity Applications and Technology Transfer ■ Structural Health Monitoring Center of Excellence ■ Networking and Security Research Center of Excellence ■ Center of Excellence in Nanoscale Lignocellulosic Materials ■ Center for Nanoparticulate Science & Engineering ■ Center for Manufacturing Enterprise Integration
Source: Ben Franklin Technology Partners of Central and Northern Pennsylvania, www.cnp.benfranklin.org

5. Creating targeted support infrastructure for technology firms

BFTP also works to develop the underlying infrastructure that is critical to support emerging technology businesses in the state. One key initiative in this area is providing funding and support for the development of business incubators. The Central and Northern region, for example, has developed close relationships with three regional incubators that emerged through partnerships with regional universities and economic development organizations. The Northeastern region is especially active in this area, and has created a 10-member Business Incubator Network in its 19-county region (profiled in the table below).

BFTP Of Northeastern Pennsylvania ***Business Incubator Network and Ben Franklin TechVentures***
Since 1983, BFTP of Northeastern Pennsylvania has collaborated with regional economic development organizations to establish and support a ten-member incubator network. The incubators provide reduced operating costs for early-stage companies, along with a host of other benefits: ■ Business support services and resources tailored to early-stage firms, including management guidance, business planning, strategic planning, and marketing counsel

[80] www.cnp.benfranklin.org/programs-services/centers-of-excellence/

- Connections to angel investors and venture capitalists
- Assistance in preparing and perfecting funding presentations
- An entrepreneurial culture that fuels innovation
- Below-market rental space rates with flexible leases
- Shared basic office services and access to equipment, conference rooms, high-speed Internet, and other amenities

BFTP regional staff meet with network incubator managers regularly to exchange ideas and information, work collaboratively, and provide guidelines that are in accordance with National Business Incubator Association (NBIA) standards. Collectively the member incubators have graduated more than 80 successful companies.

BFTP of Northeastern Pennsylvania actually founded the very first incubator in Pennsylvania in 1983. That incubator, which has been operating at capacity for a couple of decades, has recently moved to a new facility and is now known as *Ben Franklin TechVentures*. Its new, 62,000 square foot facility is located in the former Bethlehem Steel Homer Research Labs, which was reclaimed and renovated by BFTP. The new space meets critical needs of technology businesses, and especially life sciences businesses, by doubling available wet lab space and tripling office and dry laboratory space available.

Key features of the Ben Franklin TechVentures facility include:

- 35,000 square feet of rentable space, including more than 11,000 square feet of dedicated wet lab space
- Full safety and environmental compliance for all facilities
- Flexible floor planning to accommodate specific needs
- 24/7 secured access and video surveillance
- Innovative use of technology to foster community among tenants
- Rental rates substantially lower than market rates
- State-of-the art high-speed Internet and telephone facilities
- Energy-saving automatic lighting system
- Men's and women's shower facilities
- Ample parking and full loading dock with a heavy-duty five-ton crane
- Large elevator with four-ton capacity
- Access to the facilities, equipment, staff, and students of Lehigh University

Source: Ben Franklin Technology Partners of Northeastern Pennsylvania, www.nep.benfranklin.org

Program Impact

BFTP's positive impact on the Pennsylvania economy is demonstrated by the program's longevity – it has been embraced by five different governors and the state General Assembly over its 25 year life span, at increasing levels of funding.

BFTP periodically conducts program impact assessments. The most recent assessment covers the period 1989-2001. Key program impacts measured include the following:

- The state's $311 million investment in BFTP boosted Pennsylvania's economy by $7.9 billion (in constant 1996 dollars), a return on investment of 23 to 1. Every public dollar invested in BFTP yielded nearly $23 of additional income in the state.
- BFTP directly or indirectly generated 93,105 job-years at a cost to the state of $3,342 per job-year. [Job years are defined as the number of jobs created that lasted a full year or more, multiplied by the number of years they have existed to date.]

- The state gained more than $400 million in additional tax revenue as a direct result of the program, which more than covered the operating costs of the program over the same period.
- BFTP has invested in more than 2,500 companies since its first direct equity placement in 1989; 76 percent of the deals were with companies employing less than 50 people at the time of the initial BFTP investment.
- Average annual salaries at BFTP client companies are 28 percent higher than the average annual salary for all private, nonfarm industries in Pennsylvania.
- BFTP supported the development of hundreds of innovative technologies and scientific discoveries, including: process control systems used in the U.S. Navy's defense operations; anti-viral agents for treating HIV/AIDS; pioneering medical devices; advanced automated microstructure metrology tools for the semi-conductor industry; proprietary software products that accelerate the pace of scientific research and discovery; state-of-the-art training tools for new drivers; and enhanced recycling processes and systems.[81]

Success Factors And Lessons Learned

- **Not a "one size fits all approach."** Pennsylvania is a large state, and the regionalization of the BFTP program allows it to adapt its activities and services to the specific needs of each of the four regions. The one-on-one nature of services provided to client entrepreneurs and companies also allows BFTP staff to customize the assistance provided to address individual client needs and problems.

- **Partnerships and networks as a central component.** While BFTP offers many "in-house" assistance programs for entrepreneurs and companies, a key component of its success is that it constantly builds relationships with service providers and stakeholders throughout the state to bring clients the specific assistance they need. Over time, BFTP has built lasting partnerships with universities, researchers, local and state agencies, investors, technology companies, and many others, and these networks have endured beyond the auspices of specific BFTP programs.

- **Program scope and flexibility.** While BFTP focuses on "technology" development in the general sense, the program does not limit its activities within a very narrow set of industries or sectors. Instead, it offers support to any companies or researchers who have the capability to generate original, technology-based ideas and bring them to the market. This flexible, market-based approach has enabled BFTP to nurture and "launch" a host of successful high-tech businesses across a wide range of sectors.

- **Program longevity and respect.** BFTP's 25-year tenure, and its many successes over this time period, have earned the program a high level of respect from stakeholders across industry, academia, and the public sector, both within Pennsylvania and across the country. This success and longevity has not only ensured a secure stream of funding from the state, but it also has earned BFTP a role as a key facilitator and integrator of relationships across the public, private, and academic sectors.

[81] Nexus Associates, *A Continuing Record of Achievement: The Economic Impact of the Ben Franklin Technology Partners*, March 2003, www.benfranklin.org/our_impact/index.asp; and *SSTI Weekly Digest*, April 11, 2003, www.ssti.org/Digest/2003/041103.htm#PA

Virginia's Technology Industry Potential:

Catalyzing Innovation in the Commonwealth

SRI International

Prepared for the Virginia Economic Development Partnership

February 2008

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Introduction

In an increasingly connected, technology-driven world, many states are seeking to improve their economic competitiveness and growth prospects. Public policy initiatives to spur innovation and support the development of existing and new high-technology industries can be a critical catalyst for growth. However, to be successful, any such initiative must be based on a clear understanding of a state's current capabilities and weaknesses, as well as its future opportunities.

The Commonwealth of Virginia is considering an array of such initiatives to enhance its innovative capacity. In order to provide an objective appraisal of the issues involved, the Virginia Economic Development Partnership (VEDP) requested SRI International's Center for Science, Technology, and Economic Development to carry out a comprehensive, independent assessment of Virginia's current technology and research and development (R&D) situation from the perspective of economic development.

The purpose of this assignment has been to obtain, analyze, and present information that can inform public and private leaders in the Commonwealth as they consider different options associated with innovation and technology development. The research was not directed toward duplicating or replacing any specific initiatives currently being implemented or discussed in the Commonwealth,[1] but rather to lay down a strong foundation of information and analysis that can guide long-term strategies that hold up over time and transcend administrations. The goal is to provide Commonwealth stakeholders with a solid groundwork for crafting both individual programs and overall plans.

A VEDP counterpart team was established to liaise with the SRI project team, and the VEDP team offered thoughtful and productive comments throughout the course of the investigation. However, the VEDP team in no way sought to influence the outcome of the assignment, other than to insist that research findings be "robust, objective, defensible, and trackable."

The overall study was divided into five research tasks, as noted in the following figure. This report addresses the fifth and final task, which is to draw strategic inferences for the Commonwealth from all of the project analyses. Since this report distills implications from the four preceding tasks, it also serves as an executive summary of the overall assignment. Separate, full reports have been prepared for each of the first four tasks.

As noted above, this assignment was organized around a logical sequence of tasks. The goal was for each task to provide a useful body of information and analysis in its own right, but also to guide and focus subsequent tasks.

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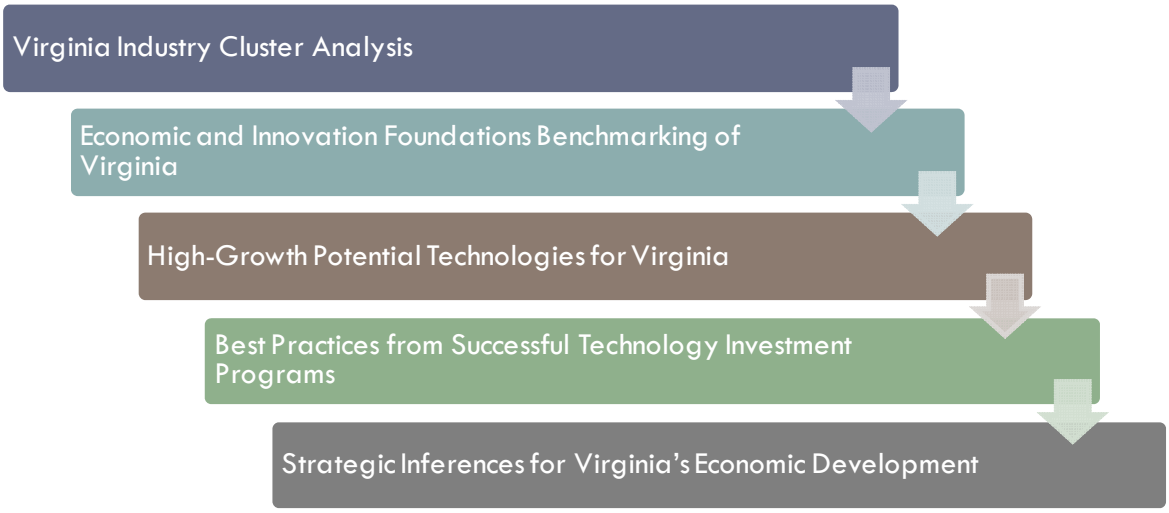
[1] Examples include the Commonwealth Technology Research Fund, the CIT's seed-stage GAP Funds, the recently announced program to support the attraction of Rolls Royce, the R&D investment strategy proposed by the VRTAC Research and Development Committee, plans to develop biotechnology and hydrogen economy activities in Virginia, and the Chesapeake Crescent Innovation Economy. Expanded and integrated versions of some of these initiatives are recommended for further consideration.

Virginia Assessment Project Tasking



- **Task 1** was devoted to establishing a comprehensive understanding of Virginia's economic landscape—specifically the industry clusters that make up and drive the Commonwealth's economy. To accomplish this task, the SRI team carried out an assessment of 25 industry clusters that comprise Virginia's economy, with an emphasis on those clusters that contain a strong technology component.
- **Task 2** consisted of a robust examination of Virginia's economic and innovation foundations and competitiveness, benchmarking the Commonwealth against nine other states (and national averages where applicable). The nine states benchmarked included: California, Florida, Georgia, Maryland, Massachusetts, New York, North Carolina, Pennsylvania, and Washington. This exercise provided insights into Virginia's strengths and weaknesses relevant to innovation and technology industry growth.
- **Task 3** looked over the technology horizon, focusing on the growth potential of different strategic technology areas and their potential industry applications. SRI identified five technology-based industry clusters in which Virginia possesses some competitive advantage and profiled high-potential technologies in each of these clusters for the Commonwealth's consideration.
- **Task 4** provided case studies in three focal areas that address the innovation foundation challenges highlighted in the benchmarking analysis. The focal areas were identified on the basis of needs and opportunities that emerged from the outcomes of preceding tasks.
- **Task 5** represents the culmination of the overall study. It draws strategic inferences from all preceding project components; identifies potential targets for public investments to catalyze strategic technology sectors and enhance Virginia's industrial and academic R&D competitiveness; and highlights a series of guidelines for the consideration of programs and overall strategy building in Virginia.

The inferences that emerged from these analytical tasks are summarized below. Collectively, they build a logical and compelling case for a comprehensive Virginia initiative to spur technology and innovation-based growth.

Global and national economic trends and realities point to the need for forward-looking states to expand industries driven by technology and innovation

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Many of Virginia's high-tech industries serve the Federal market. While an important market, this narrow focus may limit the outward orientation of Virginia firms making them less competitive in the global marketplace.

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The Commonwealth's economic and innovation foundations display some strengths, but do not generate the scientific, R&D, and economic outputs that position Virginia as an innovation leader.

↓

Virginia possesses research and industry assets that could propel state activities in high potential technology arenas.

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Lessons can be drawn from successful state and regional initiatives to inform the design of an innovative Virginia initiative.

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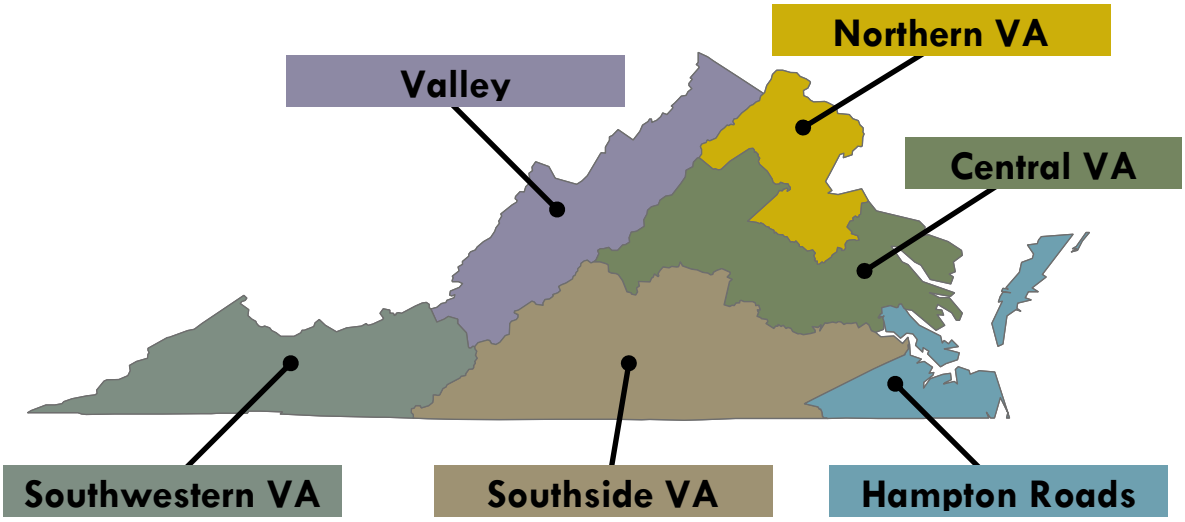
If Virginia can develop and implement an initiative to stimulate innovation and catalyze collaboration among industries, universities, laboratories, and other stakeholders, the Commonwealth can become a model innovation economy.

Task 1: Virginia's Industry Cluster Structure

The desired outcome of technology-focused policies is ultimately new jobs, companies, and industries that will support livelihoods in the Commonwealth of Virginia. Therefore, the economic context in which such initiatives are crafted is important. To provide this context, the SRI team performed an industry cluster analysis for the time period 2003-2005. The first part of this analysis was an assessment of Virginia's overall economic structure in terms of major industries, and the second part drilled down to identify high-potential industries that have significant technology components.

Like many other states, the Commonwealth's overall industry structure is dominated by service sector activities. Measured by employment, Virginia's top six industry clusters in 2005 were: (1) Education and Government, (2) Retail Trade, (3) Construction and Real Estate, (4) Tourism, (5) Life Sciences and Medicine, and (6) Business Services. These six labor-intensive industries accounted for 60 percent of total employment in the Commonwealth in 2005.

SRI also performed an industry cluster analysis for Virginia's six regional economies (see map below). Certain economic characteristics are held in common. Mirroring the state-level economy, Virginia's regional economies are all led by service industries, with Retail Trade, Tourism, and Construction and Real Estate included in the top five employment-generating industries across all regions in 2005. Life Sciences and Medicine is also an important employment cluster, ranking among the top three in every region except Northern Virginia (where Information Technology Services prevailed).



The regions also display important variations:

- In **Northern Virginia and Hampton Roads**, Research and Engineering; IT Services; and Aerospace, Defense, and National Security are significant clusters, owing to the concentration of government agencies, military, and federal and academic research facilities in these regions.

- Several of the more rural regions (**Southwestern, Valley, and Southside)** have high employment concentrations in natural resources-based industries (e.g., Materials and Chemicals, Energy and Environment) and traditional industries (e.g., Wood and Furniture, Textiles and Apparel). However, overall employment levels in traditional industry clusters are relatively low compared to other clusters.

- The **Central Region** is fairly diversified across industry sectors, and Financial Services stands out as being especially strong in both employment concentration and overall employment levels.

An important goal of this task was to identify existing or emerging industries in the state that have a strong technology component. The SRI team analyzed industry data in terms of gross employment, employment growth rates, and employment concentration in industries relative to the national average to identify high-potential technology industries. We identified the following technology-driven industries as fitting one or more of these criteria:

- Health Care and Biomedical Sciences
- IT Services
- Transportation and Logistics
- Research and Engineering Services
- Telecommunications
- Aerospace, Defense, and National Security

To this list, we added four other high-potential industry clusters based on the fact that they encompass strategic technologies expected to have high-growth potential over the short-, medium-, or long-term, and they offer high average wages:

- Electronics
- Materials and Chemicals
- Clean Energy and Environment
- Media and Design Services

In subsequent research tasks, this list was further refined by analyzing these clusters against global and national industry trends, as well as Virginia's competitive R&D and other innovation foundation assets.

Task 2: Benchmarking Virginia's Economic and Innovation Foundations

An objective assessment of Virginia's technology industry competitiveness offers policymakers insights into the strengths and weaknesses in Virginia's economic and innovation foundations and may suggest possible intervention areas. SRI examined the Commonwealth's current economic and innovation foundations and its position for growth relative to other states. In collaboration with VEDP, SRI selected nine benchmark states for analysis—California, Florida, Georgia, Maryland, Massachusetts, New York, North Carolina, Pennsylvania, and Washington—based on their possessing one or more of the following characteristics: (1) a similarly sized economy in terms of gross state product (GSP); (2) a similar high-tech focus or profile; and/or (3) the state being a traditional regional competitor.

SRI benchmarked Virginia against these nine states (and the national average, where applicable) in four competitiveness areas: (1) financial resources, (2) human resources, (3) innovation resources, and (4) innovation economy performance. The benchmarking analysis identified several strengths, but also several challenges for policymakers to address. These are summarized in the table below.

Benchmarking Virginia's Innovation Foundations				Summary Results
	Financial Resources	Human Resources	Innovation Resources	Innovation Economy Outcomes
Strength	SBIR awards STTR awards	Labor force growth AP exams S&E degrees NAEP Science & Math Scores	Federal R&D	Real GSP growth Tech Fast 500 companies
Average	Small business loans	Young adult population growth Advanced S&E degrees	R&D productivity	R&D to GSP
Weakness	VC investment Micro loans		Industrial R&D Academic R&D Patents Publications	Exports Entrepreneurs Business Start-Ups

Technology-based industries rely first and foremost on human capital, and here Virginia is in an enviable position. While many states—including Massachusetts and New York—have seen population growth level off in recent years, Virginia has experienced both positive population growth and strong labor force growth. The Commonwealth's K-12 students have shown solid achievements on national math and science tests and an appetite for rigorous coursework in the form of Advanced Placement courses and exams. This bodes well for Virginia's future high-tech and knowledge-based workforce. The analysis also identified several areas for improvement:

- Looking at Virginia's total R&D enterprise, the Federal government performs a significant share of R&D (34%) and is a major source of funding (45%) for industrial R&D in Virginia—much more so than in other benchmark states.[2] On the one hand, it is a positive sign that Virginia's companies are able to attract and leverage Federal R&D dollars. On the other hand, Federally-funded R&D is not market-driven and may not lead to new products and services competitive in the global market place.
- The Federal government is also a major purchaser of goods and services in the state. Virginia's reliance on a single (albeit important) customer has shifted the focus of Virginia companies away from global markets. As a consequence, exports account for a very small share of GSP relative to other benchmark states and the U.S. average.[3]
- Virginia ranks near the bottom of the benchmark states in both total academic R&D expenditures and per capita R&D expenditures.[4] This indicates that there is room to expand graduate level R&D activities in strategic S&E fields.
- Virginia's share of total U.S. venture capital (VC) investment declined from 3.4% to 1.5% over 1996-2005. In addition, VC funding in Virginia (at all stages) is skewed towards three industry sectors: IT services, software, and telecommunications.[5] Sectors such as biotech, medical devices, and energy receive a lower-than-average share of VC investment in the state.[6]
- Virginia does not rate highly against its peer and competitor states, or against the national average, on indicators of entrepreneurial activity. In 2005, Virginia ranked second from last among nine benchmark states in both the number of entrepreneurs per capita and new firm births per capita.[7] One strategy for enhancing the environment for technology-based entrepreneurship and startups in a state is to ensure there is a critical mass of talented university faculty with commercialization experience and interest in strategic technology fields.

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[2] National Science Foundation, 2003.
[3] According to U.S. International Trade Administration data, Virginia's exports accounted for 3.8% of GSP in 2006 compared to 7.9% for the entire United States.
[4] According to NSF data, Virginia spent $121 per 1,000 population in 2005, as compared to $422 in Maryland, $323 in Massachusetts, and $190 in North Carolina.
[5] According to Pricewaterhouse Coopers/National Venture Capital Association/Thomson Financial *MoneyTree™ Survey* data, IT services, software, and telecommunications received 73.5% of total VC investment in Virginia in 2006.
[6] Biotech, medical devices, and industry/energy received 6.6% of total VC investment in VA in 2006 versus 35.4% in the United States as a whole.
[7] These numbers refer to all types of entrepreneurs and new firms, not only technology-based ones. According to Kauffman Foundation data, in 2005, Virginia had an estimated 220 entrepreneurs per 100,000 population compared to 420 in Maryland, 330 in Georgia, and 320 in California. U.S. Small Business Administration data show that Virginia had 102 new firms per 1,000 establishments in 2005 compared to 154 in California, 148 in Florida, and 141 in Georgia.

Task 3: Potential Technology Areas

Resources available for R&D and technology development are limited in any company, university, state, or region. Therefore, determining where scarce resources should be deployed is a critically important task. To identify an initial list of technology fields for further exploration, the SRI team designed a methodology driven by economic development factors to identify "over the horizon" technology opportunities for Virginia.

The team first identified several industry clusters that rely heavily on technology and that generate new technologies in Virginia. Two to three sub-clusters were identified for each. The team then screened each cluster based on the following economic development and technology criteria:

- ✓ Have a solid or established economic base in Virginia;
- ✓ Are high-growth industries, nationally and globally; utilize technologies; and have the potential for being transformed by critical emerging technologies globally;
- ✓ Can draw on Virginia's existing or emerging industrial, university, or Federal R&D assets;
- ✓ Are subject to other unique factors, such as proximity to Federal government markets, current or potential economic development impact on regions in the state outside of Northern Virginia, etc.; and
- ✓ Can benefit from targeted policy interventions.

The SRI team selected the following five technology-oriented industry clusters as a best fit for Virginia in terms of the aforementioned selection criteria:

- Health Care and Biomedical Sciences
- IT Services
- Materials and Chemicals
- Clean Energy and Environment
- Transportation and Logistics

The SRI team then conducted research to specify a well-grounded cross-section of relevant technologies for each of the five industry sectors selected. Since the list of technologies associated with any one industry is almost endless, and it was beyond the scope of the project to cover all technologies, the SRI team identified two technologies per industry that are characterized by: (1) strong market demand in numerous application areas; (2) early stage of development—indicating there is still time for Virginia actors to enter and become prominent players in this field; and (3) existing R&D assets on which Virginia can build.

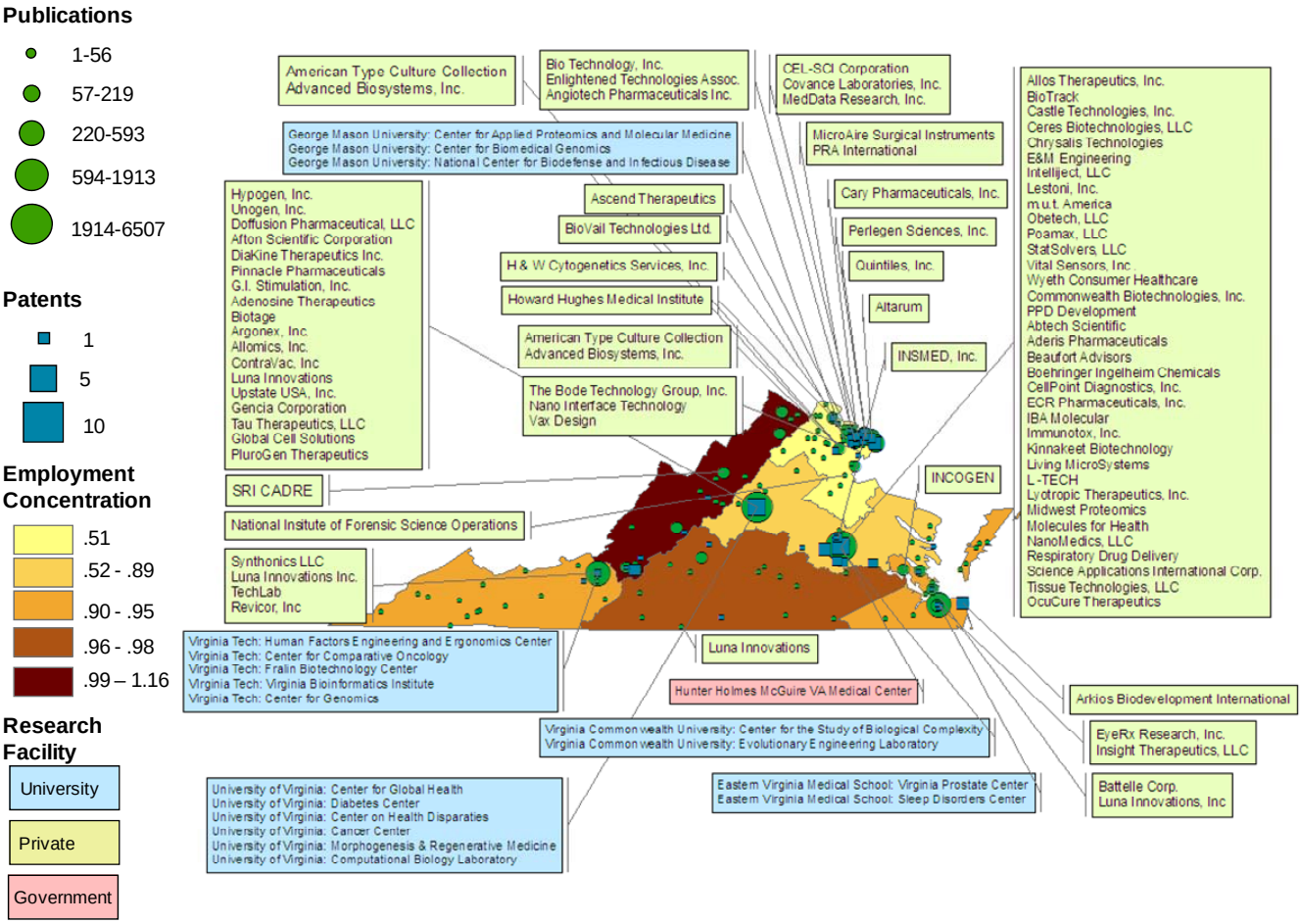
The tables below present five high-potential, technology-based industries for possible development in the Commonwealth of Virginia. SRI identified two technology opportunities per industry and summarized Virginia's key assets in each industry.

Health Care and Biomedical Sciences Technology Opportunities

Technology-Based Industry Cluster	Technology	Description	Virginia's R&D Assets
Health Care and Biomedical Sciences	Point-Of-Care (POC) Diagnostics	Diagnostic tests are important in accurately diagnosing disease, but also in monitoring blood sugar, cholesterol, hormone levels, and other indicators of a patient's response to treatments. A new generation of diagnostics technologies based on advances in nanotechnology, microsystems, biotechnology and information technology could significantly reshape modern health care.	Virginia has a number of university research centers focusing on POC diagnostics and related technologies (e.g., Center for Comparative Oncology at Virginia Tech and the Center for Applied Proteomics and Molecular Research at George Mason University). On the clinical side, assets include research-oriented healthcare systems, such as the INOVA Health System and the University of Virginia Health System. Small biomedical and diagnostic companies are clustered around the state's major universities. Two Department of Defense biomedical R&D centers are located in Virginia.
	Computational Technologies	Bioinformatics and computational biology provide a research platform to acquire, manage, analyze, and display large amounts of data. Both draw on analytical methods borrowed from computer science, mathematics, statistics, and the physical sciences. The promise of bioinformatics and computational biology is to reduce the volumes of genomic and proteomic data being generated to a usable form for researchers, so they may make predictions and test biological and biomedical hypotheses.	Many of Virginia's universities have centers dedicated to bioinformatics and computational biology research pursuits (e.g., Virginia Commonwealth University's Center for the Study of Biological Complexity, Virginia Tech's Bioinformatics Institute, etc.). In addition, the new Howard Hughes Medical Institute campus in Loudon County and the new SRI Center for Advanced Drug Research in Rockingham County will also advance biomedical research activity in the state. In the private sector, companies such as life sciences informatics company, INCOGEN, are collaborating with universities and medical schools to create new computational research platforms.

The maps below present an integrated view of Virginia's economic activity (employment concentration by region), research activities (publications and patents), and research assets (private, university, and government R&D facilities) in five of the Commonwealth's high-potential, technology-based industries. These maps are intended to provide an "at a glance" visualization of Virginia's assets in five key industry areas. The R&D facilities included in these maps are only examples of Virginia's R&D assets and do not comprise a comprehensive list. The keys at the left hand side describe the distribution of scientific publications, patents, industry employment concentration, and key research facilities located throughout the Commonwealth.

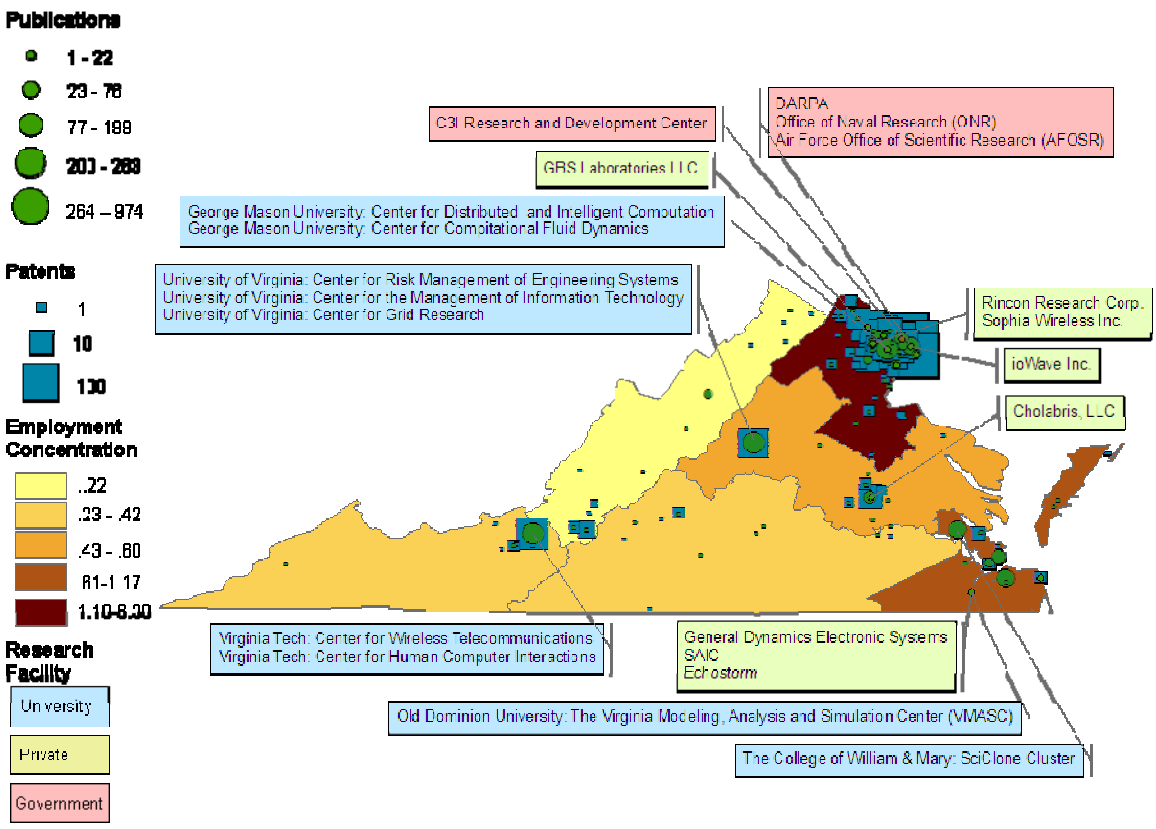
Virginia's Innovation Assets: Health Care and Biomedical Sciences



IT Services Technology Opportunities

Technology-Based Industry Cluster	Technology	Description	Virginia's R&D Assets
Information Technology Services	Health IT	Health information technology (IT) enables comprehensive management of medical information and its secure exchange between health care consumers and providers. With low adoption rates, health IT is a relatively nascent market, which would indicate that there is much potential for market growth and penetration.	There is significant R&D activity in IT Services in Virginia, particularly in private and university R&D laboratories. There are at least twenty private R&D centers. For example, Insight Therapeutics is a company focusing on health IT R&D. Virginia's strong Health Care & Biomedical Sciences cluster and its vibrant IT Services clusters position the state to take the lead as both an early adopter and a developer in this new field of health IT.
	Cybersecurity	Cybersecurity is the use of information technology to protect information against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. According to Business Insights, the global cybersecurity market was $13.8 billion in 2006, and will grow to $20.6 billion in 2010, with a CAGR of 13%.	Virginia's cybersecurity R&D assets include: George Mason University's Center for Secure Information Systems (the nation's first university center dedicated to cybersecurity R&D) and C4I Center; the DoD's Command, Control, Communications, and Intelligence Research and Development Center at MITRE (C3I FFRDC); and R&D efforts at private companies, such as GBS Laboratories and Smart Technology.

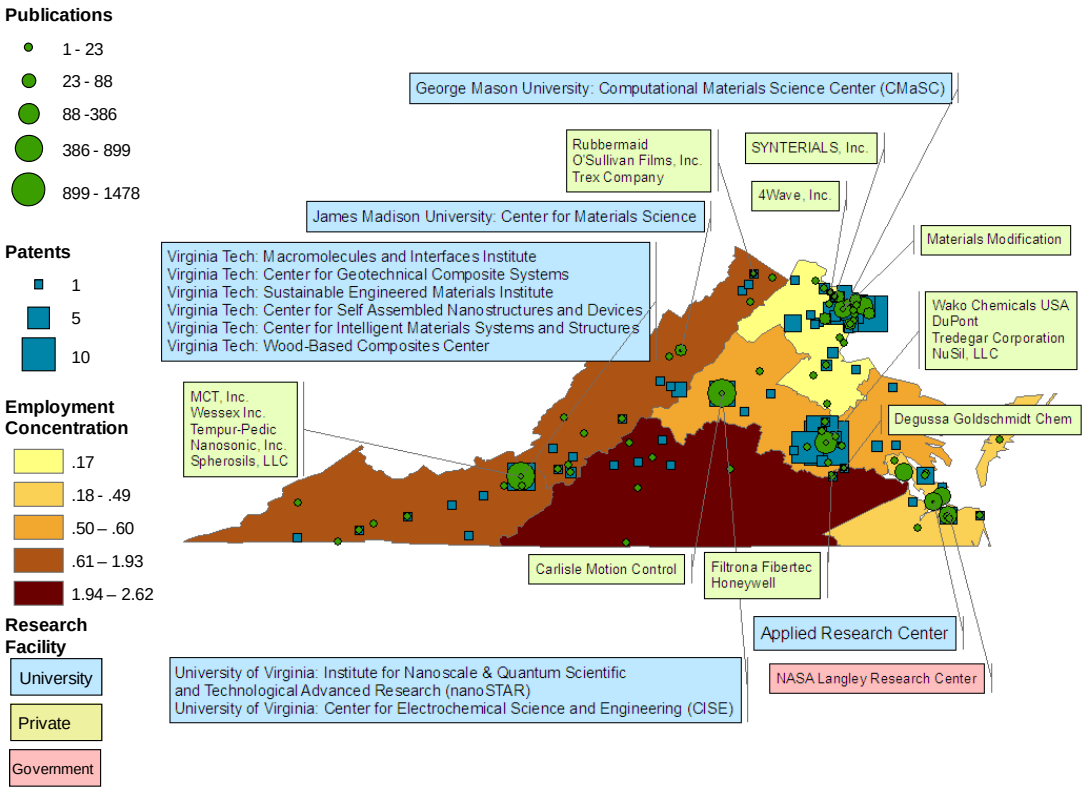
Virginia's Innovation Assets: IT Services



Materials and Chemicals Technology Opportunities

Technology-Based Industry Cluster	Technology	Description	Virginia's R&D Assets
Materials and Chemicals	Nanomaterials	Nanotechnology involves objects generally less than 100 nanometers in size and exploits the unique properties of materials at this scale. Nanomaterials are made from variety of raw materials (e.g., carbon or silver) and come in a variety of shapes and sizes with unique and interesting properties. Some estimates suggest that the "nanotechnology market" will be worth more than $1 trillion by 2015.	Virginia hosts a number of nanotech-focused research facilities at its universities (e.g., University of Virginia's NanoQuest Institute) and in the private sector (e.g., Luna Innovations, Nano Interface Technology Inc., 4Wave Inc., etc.) The Virginia Nanotechnology Initiative identified several areas of strength for nanotechnology development in Virginia, including: nano biomedicine, functional nanomaterials, carbonaceous nanomaterials, and functional coatings.
	Biopolymers	Biopolymers, or "bioplastics," are biologically-derived polymers with a variety of functional uses, e.g., as stabilizers, thickeners, binders, dispersants, lubricants, drug-delivery agents, etc. Concerns about plastics waste, increasing cost, and demand for healthier processed foods are some of the factors driving increased adoption of biopolymers, which could account for 5% of the global plastics market by 2010.	Virginia hosts significant private and university R&D activities in materials and chemicals. There are at least 20 private R&D centers in the state (e.g., Honeywell focuses on polyester and high performance fibers; Degussa Goldschmidt is directing R&D to industrial chemicals.) University chemicals and materials R&D, which comprises At least 12 university labs in Virginia are also conducting materials and chemicals R&D.

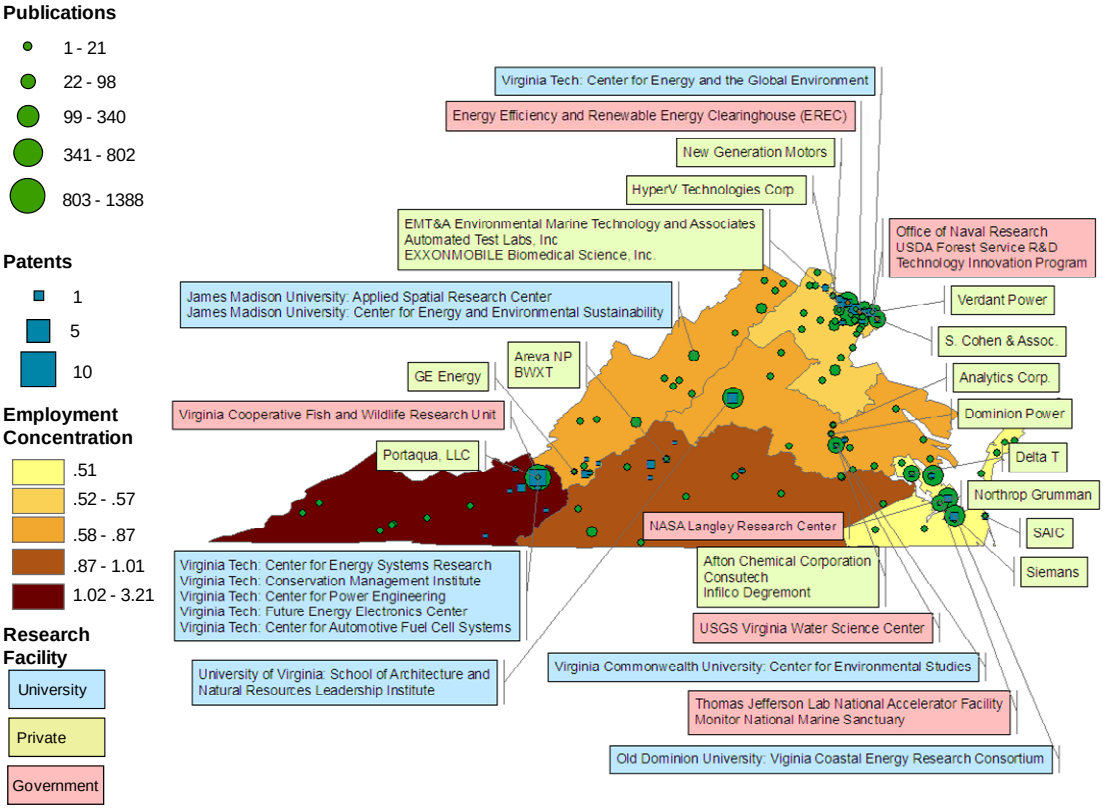
Virginia's Innovation Assets: Materials and Chemicals



Clean Energy and Environment Technology Opportunities

Technology-Based Industry Cluster	Technology	Description	Virginia's R&D Assets
Clean Energy and Environment	Fuel Cells and Distributed Hydrogen	A fuel cell is an energy conversion device that transforms a fuel (chiefly hydrogen) to energy. It is believed that fuel cells could soon yield the highest fuel-to-electricity conversion efficiency available today, although the adoption rate is limited by the high cost. Global market revenues are projected to grow from $1.4 billion to $15.6 billion between 2006 and 2016. Hydrogen offers huge market potential but also high risk, because this technology is in early stages of development.	There is considerable R&D activity in Virginia. Universities involved in fuel cell research include Virginia Tech's Center for Automotive Fuel Cell Systems and Center for Energy Systems Research, Virginia Commonwealth University and University of Virginia. Fuel cell R&D is also undertaken by NASA Langley, a Federal lab. In the private sector, companies such as Automated Test Labs, Inc., and H2Gen (which received $49 million in VC funding) are active in fuel cell and fuel cell component R&D.
	Carbon Capture and Storage	Carbon sequestration is a way to reduce greenhouse gas emission. Interest in carbon sequestration has grown, because it is very compatible with the large energy production and delivery infrastructure now in place.	Carbon sequestration R&D is largely led by universities (e.g., Virginia Tech's Virginia Center for Coal and Energy Research and the Center for Advanced Separation Technologies). VCCER is leading a coalition of universities, industry, and state agencies to identify potential carbon sequestration sinks in central Appalachia, as part of the DoE's Southeast Regional Carbon Sequestration Partnership (SECARB.

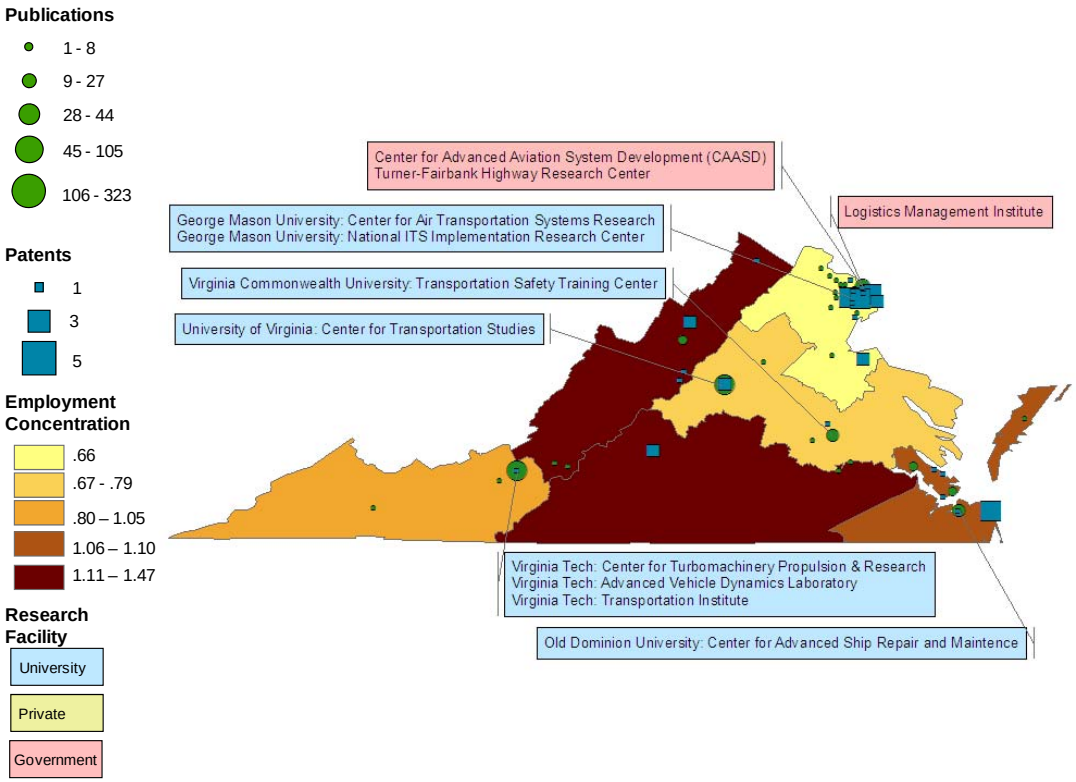
Virginia's Innovation Assets: Clean Energy and Environment



Transportation and Logistics Technology Opportunities

Technology-Based Industry Cluster	Technology	Description	Virginia's R&D Assets
Transportation and Logistics	Radio-Frequency Identification (RFID)	RFID is an automated data capture technology that uses low-power radio waves to communicate between readers and tags or contact-less cards. RFID technologies may soon become critical enabling technologies for a wide variety of sectors, including retail, health care and pharmaceuticals, manufacturing, payment systems, and security, identification and authentication.	Virginia's universities and Federal facilities offer a variety of specialized research capabilities for the transportation and logistics cluster. For example, the federally-funded Logistics Management Institute provides expertise in managing and developing the information technology for supporting today's global supply chains.
	"Smart" Roads	"Smart" roads are intended to solve or ameliorate the congestion created by the fact that, in the past 20 years, the United States has added only 2% more roadways, while the number of cars has increased by 50% and the number of miles driven by 77%. The technologies underpinning smart roads are diverse, including embedded sensors and magnetic strips as well as batteries (or other power sources) and wireless transmitters to relay information.	Virginia's Department of Transportation and Virginia Tech's Transportation Institute developed one of the nation's first test-beds for assessing vehicle movement on 12 different types of surfaces. Virginia possesses R&D assets in other critical "smart" roads technologies—scanners and sensing devices, GPS and wireless, and software. In addition, technology development for smart roads complements potential technology activities in Materials and Chemicals.

Virginia's Innovation Assets: Transportation and Logistics



Task 4: Lessons from Successful Technology Investment Programs

Virginia is not alone in addressing competitiveness challenges. SRI identified several public-private technology development programs in other states that address similar issues to those identified in the benchmarking exercise of Virginia's economic and innovation foundations. First, the SRI team identified three focal areas that address the Commonwealth's desire to improve innovation capacity, competitiveness, and future economic prospects:

- Enhancing Research Excellence at Universities
- Enhancing Collaboration Across Sectors and Disciplines
- Enhancing Entrepreneurship and Access to Capital

Then, the team conducted a thorough literature review and explored case studies that shed light on other states' experiences in dealing with these issues.[8] Best practices from these case studies were then distilled to serve as a guide to policymakers in designing future technology investment programs in the Commonwealth. These best practices are included in the inferences section that follows.

SRI identified three types of programs that address the Commonwealth's innovation weaknesses and also have a proven track record of catalyzing technology-based economic development. The following table summarizes key characteristics of these programs, including state funding levels, external funding requirements, and program governance models.

[8] There are numerous studies on this topic, which provide both in-depth analysis of specific programmatic initiatives, as well as broader analysis of key lessons learned. Two notable reports include the National Governors Association and the Pew Center on the States (2007) *Innovation America: Investing in Innovation* report, and the State Science and Technology Institute's (2006) *A Resource Guide for Technology-based Economic Development*.

Case Study Program Investment Levels and Governance Models

Program Type	Magnitude of State Investment (date founded)	Matching Requirement	Governance Models
Centers of Excellence	■ Ohio *Wright Centers of Innovation (2003)*: $5-$10 million per year per center over 3 years; 5-6 new centers awarded every other year ■ *Wright Mega-Centers of Innovation (2006)*: $10-$12 million per year per center over 5 years; currently 1 center awarded	■ Auditable 1:2 cost share match of state investment required	■ Commission is comprised of the Ohio Director of Development, the Chancellor of the Ohio Board of Regents, the S&T Advisor to the Governor, and 4 regional representatives from industry. A 16-member Advisory Board comprised of leaders from industry, academia, and government, assists.
	■ New York *Centers for Advanced Technology (CAT) (1983)*: $1 million per year per center for 10 years; 15 centers currently funded ■ *CAT Development Program (1999)*: average $1.5 million per year per center; 7 existing Centers awarded in 2005	■ 1:1 match of state investment required for first 5 years of CAT with increasing match requirement in years 6-10 ■ CAT Development awards are one-time awards to expand capabilities	■ Board is 11 members, half from the private sector and half from academia and government. The board helps make decision for each Center, which is then guided by its own Industrial Advisory Board.
Eminent Scholars Programs	■ *Georgia Research Alliance Eminent Scholars (1990)*: $750K per scholar towards endowment with 6 endowments in 2006; $2.9 million to equip labs for scholars	■ 1:1 split of $1.5 million by state government and university (university funds often come from private sector partners)	■ Georgia Research Alliance is a 501(c) 3 corporation, with the Governor an ex officio member of the Board of Trustees. The Trustees initially consisted of 12 CEOs of Georgia-based businesses and the 6 affiliated university presidents. Today, the Board of Trustees consists of 25 members—the majority from the private sector and also including representatives from academia and the government.
	■ *University of Texas System Regents' Research Scholar Program (under Science and Technology Acquisition and Retention Program (STARs) of 2005)*: $2 million per endowed chair	■ Requires a commitment by nominating institutions to match not less than 10 percent of the amount awarded by the UT System	■ The UT System Board of Regents is composed of 9 members who currently work in or are retired from the private sector.
Tech Transfer & Entrepreneurial Support Services	■ *Ohio Pre-Seed Fund Initiative (2002)*: $1 million-$2 million per fund; in 2006 invested total of $6.6 million in four Ohio-based funds	■ 2:1 cost share; the grantee will receive $2 for every $1 cost share	■ Commission is comprised of the Ohio Director of Development, the Chancellor of the Ohio Board of Regents, the S&T Advisor to the Governor, and 4 regional representatives from industry. A 16-member Advisory Board comprised of leaders from industry, academia, and government, assists.

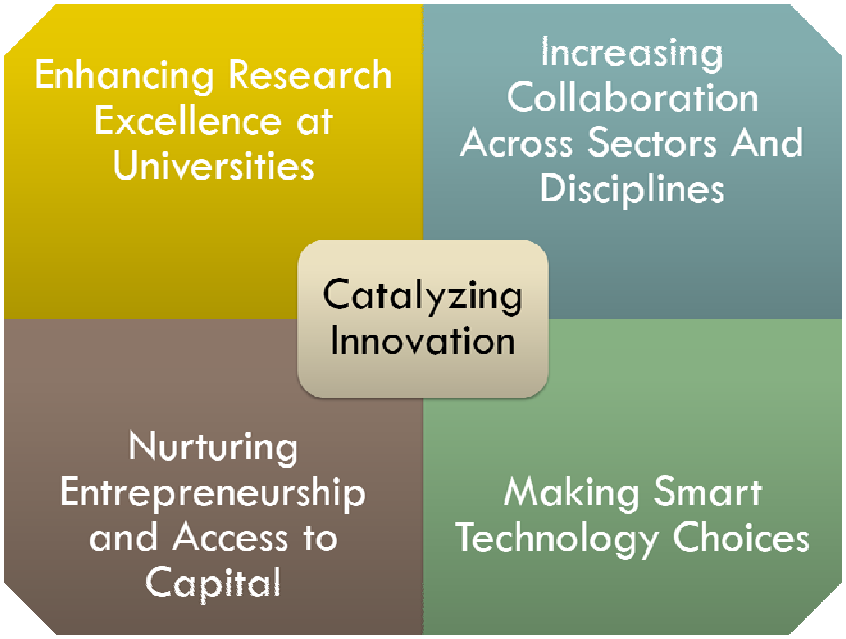
Task 5: Strategic Inferences for Virginia

Research, innovation, and technology are major drivers of the U.S. and global economies. For any given industry—materials, pharmaceuticals, electronics, energy, etc.—there are numerous technology needs and an equal number of technology possibilities for addressing these needs.

Despite these opportunities, technology development and commercialization are characterized by high levels of uncertainty and risk. In addition to the difficulties involved in technology creation, a considerable range of other factors can make technology commercialization untenable at any point in time, including the costs and time required to create a marketable product, or consumers' reluctance to adopt a new technology. To address this risk and support the growth of new or existing technology- and knowledge-driven industries, states must identify and remedy gaps and fault lines in economic and innovation foundations.

The Commonwealth of Virginia has significant economic activity and assets related to innovation. The state hosts many technology-oriented industries, including IT services, materials and chemicals, health care and biomedical sciences, research and engineering services, and aerospace and defense. Virginia also benefits from a recent record of solid economic and labor force growth and a healthy pipeline of well-educated workers to sustain and expand technology-oriented industries. The state's companies and universities attract significant Federal R&D dollars, and Virginia's technology-focused entrepreneurs have been successful in winning Federal seed capital funds (such as SBIR and STTR grants). On the other hand, the benchmarking analysis also pointed to many challenges that need to be addressed for Virginia to nurture technologies and innovations that will foster long-term, sustainable economic growth and competitiveness.

Over the course of this assignment, the SRI and VEDP team sought to glean useful policy inferences from the data and analysis. Some of these inferences were drawn from the data, some from the experience of other states in tackling similar issues, and others from the project discussions of the VEDP/SRI team. Based on these deliberations, SRI has identified four strategic areas where the Commonwealth of Virginia can play a catalytic role, as shown in the following figure:



Enhancing Research Excellence at Universities

It is no coincidence that the country's most successful high-tech regions are located near dynamic research universities. Many founders and corporate executives of technology-based firms come from and retain close ties to universities. For example, they may receive their postgraduate degrees in scientific fields, start their companies as students or faculty, and draw on department graduates for new hires.

The Commonwealth is home to many important university programs and world-class researchers. However, Virginia ranks near the bottom of nine peer and competitor states in terms of both total academic R&D expenditures and R&D expenditures per capita.[9] Commensurate with this ranking, Virginia also ranks near the bottom for university technology commercialization activities, as measured by the total annual number of patents awarded, licenses executed, and startup companies launched.[10]

Expanding university and graduate-level R&D activity is a necessary condition for catalyzing increased technology-based entrepreneurial activity in Virginia. However, increased research funding alone is not sufficient to create an environment conducive to technology commercialization. For example, universities traditionally have had cultures

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[9] In 2005, VA ranked second to last among the nine benchmark states in both total academic R&D expenditures and per capita academic R&D expenditures. Virginia spent $121 per 1,000 population, as compared to $422 in Maryland, $323 in Massachusetts, and $190 in North Carolina. Data for this indicator come from the National Science Foundation.

[10] According to the Association of University Technology Managers (AUTM) data for 2001-2005, Virginia's universities executed an average of 105 licenses per year and launched 13 startups per year, ranking the state seventh among the nine benchmark states. According to the USPTO, Virginia universities were awarded 157 patents over the 2002-2006 period, ranking the state last among the nine benchmark state for total patents awarded during this period. For comparison, Washington state universities were awarded 195 patents, Georgia universities 353 patents, and North Carolina universities 480 patents from 2002-2006.

that reward faculty for "academic" research (as measured by cited publications, research dollars attracted, etc.) over research with commercial applications (as measured by industry licenses, patents, spin-off companies, etc.).

A number of states have adopted successful strategies to improve university research excellence, including Eminent Scholars programs and competitive funding for Centers of Excellence. Both types of programs are most effective when the appropriate incentives and performance criteria are incorporated into the selection criteria. For example, a successful Eminent Scholars Program might require that the potential scholar have demonstrated entrepreneurial ability (e.g., interest in creating his/her own company or in working with entrepreneurs/companies to commercialize a new technology, etc.), can generate $1 million or more in R&D awards within a couple of years, or be able to win a major grant to establish a Center of Excellence that draws on external participants and funding.

Similarly, economic development criteria for awarding Centers of Excellence might require that the proposed center demonstrate the ability to create a pipeline of commercially viable products/processes that can be sustained beyond the award period with external funding. The award criteria could also require that the technology outputs lead to economic outcomes such as job creation, business formation, or company expansion and recruitment. With these kinds of incentives embedded from the outset, such programs can not only catalyze university research excellence, but also translate that research into realized economic gains.

Increasing Collaboration Across Sectors and Disciplines

Many technology-based economic development efforts suffer from a "stove pipe" effect, in which research, training, finance, and other programs operate independently and do not cross fertilize for maximum impact. In fact, the incentives that have evolved for the public, private, and academic sectors often encourage institutions and organizations to act independently of one another. As mentioned above, universities have not typically given faculty researchers incentives to work on the type of R&D projects that have strategic linkages with their region's economy. Similarly, profit-oriented corporate leaders may not see the benefits of partnering with university researchers. University research is commonly viewed as too removed from the marketplace, and the individual incentives for establishing such partnerships may be limited.

Even within the public, private, and academic sectors, individual institutions often do not engage with one another. For example, unlike the integrated university systems of states such as California, New York, Texas, and Maryland, Virginia's public universities operate as independent entities. This approach may serve as a strength, in that it encourages research independence and reduces state-level bureaucracy, but it may also work to discourage cross-campus collaboration or foster duplication and consequent dissipation of resources. Even within individual universities, separate academic departments may lack the institutional or individual incentives that could drive interdisciplinary collaboration.

The gulfs that exist both within and across institutions and sectors may impede scientific discovery. Many of today's leading technology areas require an interdisciplinary R&D approach, experience from many sectors, and greater investment dollars than a single entity can muster. Take, for example, biosensors (i.e., devices that measure the presence or concentration of specific substances or measure a biologically relevant parameter). Biosensors promise to offer rapid-response or real-time results with high levels of accuracy in the medical, environmental, and process industries. However, establishing research leadership in this field is difficult. First, biosensors require knowledge from disciplines such as semiconductors, electrochemistry, enzymology, microbiology, biochemistry, and polymer chemistry. Second, biosensor development is extremely expensive, requiring investment dollars that may far exceed the resources of an individual university department or company. Many technology areas in the biotechnology/biomedical sciences and micro/nanotechnology fields are characterized by similar challenges.

Like most states, Virginia could benefit from greater collaboration among the state's technology stakeholders, including universities, Federal labs, corporations, nonprofits, and state and regional government agencies. Mindful of this situation, many state-level technology programs, leading Federal R&D funding agencies (e.g., NIH, NSF, etc.), and foundations now explicitly require cross-sector and interdisciplinary partnerships in applicant proposals.[11] Virginia's policymakers can draw upon these models to structure new technology development programs with embedded incentives for collaboration across sectors and disciplines.

Nurturing Entrepreneurship and Access to Capital

Technology-based industries rely first and foremost on human capital, and here Virginia is in an enviable position. While many states—including Massachusetts and New York—have seen population growth level off in recent years, Virginia has experienced both positive population growth and strong labor force growth. The Commonwealth's K-12 students have shown solid achievements on national math and science tests and an appetite for rigorous coursework in the form of Advanced Placement courses and exams. This bodes well for Virginia's future high-tech and knowledge-based workforce.

Another critical dimension of human capital development is nurturing the next generation of entrepreneurs. Virginians are born of the same risk-taking culture for which the United States, as a country, is known. However, Virginia does not rate highly against its peer and competitor states, or against the national average, on indicators of entrepreneurial

[11] Federal-level examples include NIH's Exploratory Centers for Interdisciplinary Research and NSF's Science and Technology Centers Program. At the state-level, Ohio's new Wright Mega-Center of Innovation Award, the winning proposal in 2007 was a consortium that included the Cleveland Clinic (a non-profit, academic medical center), its technology commercialization arm, four Ohio universities, and 16 private companies.

activity. In 2005, Virginia ranked second to last among nine benchmark states for both its number of entrepreneurs per capita[12] and new firm births per capita.

An entrepreneurial environment is the sum result of numerous initiatives, such as formal training in schools and universities, mentoring and technical assistance programs, policies that reward rather than punish risk taking, effective university intellectual property commercialization and licensing systems, access to capital, etc. As mentioned above, one strategy for enhancing the environment for technology-based entrepreneurship in a state is to ensure there is a critical mass of talented university faculty with commercialization experience and interest. These faculty spark entrepreneurial aspirations in their students and research assistants, are more likely to seek out collaborative research opportunities with industry, and are important consultants to or collaborators with university spin-offs.

A second area to monitor is access to capital. SRI's benchmarking analysis found that Virginia ranked near the bottom of its peers for total venture capital (VC) dollars invested per capita in 2006. A closer look at VC data indicates two areas of potential weakness. First, in Virginia, early-stage seed capital accounts for a very small share of total VC (less than 7% in Virginia from 2000-2006)[13]—mirroring a trend evident throughout the country over the past decade. Second, Virginia's VC investments are highly skewed towards three sectors: software, telecommunications, and IT services (these sectors account for 73.5% of all VC in Virginia versus 33.3% of all VC in the United States). This means that other important technology areas, such as biotech, energy, medical devices, business products and services, etc., are not receiving a reasonable or desirable level of venture capital.

Many states have identified a dearth of private sector seed capital as a constraint to technology-based startup activity. Seed capital funding is especially critical in industries where there is a significant gap between the personal assets of the entrepreneur and the stage at which they would be able to receive funding from a private equity or VC firm. Consequently, state governments have played a role in establishing seed capital funds. Most set caps on investments at $500,000. Some require a one-to-one match by private investors. Nearly all require that the technology-based firm reside in that state for a set period of time (e.g., three to five years) and that the money be paid back. Virginia could benefit from initiatives like these, to make VC funding available to early-stage ventures in strategic technology sectors that are currently underrepresented (e.g., biotech, energy, medical devices, etc.).

The other side of attracting VC to currently underrepresented sectors is to improve the demand side—the number of deals being generated in these strategic sectors. As mentioned earlier, improving the graduate research environment with an eye on enhancing the pipeline of commercializable technologies in strategic areas should help address this challenge.

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[12] *Kauffman Index of Entrepreneurial Activity State Report 2005*, www.kauffman.org/pdf/KIEA_state_052206.pdf.
[13] VC data comes from PwC/National Venture Capital Association/Thomson Financial *MoneyTree™ Survey*.

Making Smart Technology Choices

Given the constraint of finite public sector resources, all technology-based programs and initiatives require some form of strategic selection process. Many states are choosing to focus their efforts on a range of 3-6 broadly defined high-technology sectors, and the most successful programs typically select these technology areas based on their promise for real market potential and commercial applications in the state.

Virginia has existing strengths across many technology-based sectors. In particular, the Commonwealth is a national and world leader in the development of IT and Internet-based services, as well as defense-related technologies. Looking forward, it makes sense for the state to build on these and other assets to move into new application areas (e.g., healthcare IT applications) that can compete in the global market.

There are several technology areas in which Virginia has competitive advantages (e.g., existing private sector activity, "anchor" research institutions, and other critical R&D assets) and where there is potential for significant future commercial application and economic impact. Public and private monies can be leveraged to make these technology areas "best-in-class." Significant opportunities can be found in Virginia in the following technology-oriented industry clusters: (1) health care and the biomedical sciences, (2) information technology services, (3) chemicals and materials, (4) clean energy and the environment, and (5) transportation and logistics.

Virginia can achieve maximum return on its investments by targeting competitive technology sectors and by ensuring appropriate linkages among these sectors. Specific areas of focus may include the high-potential technologies identified in Task 3 of this analysis, or may include other strategic areas identified by private sector technology experts. A common thread among the target sectors identified in this report is that they all seek to address key problems and challenges faced by Virginia (and the world) in such broad issue areas as health, aging, the environment, security, traffic congestion, and industrial competitiveness. Smart state initiatives should address the development of core technologies with the ultimate aim of tackling economic objectives and key human needs.

Guiding Principles for Successful Technology Development Programs

A number of cross-cutting principles for successful technology development programs have been distilled from the research and analysis conducted under this assignment. These operational guidelines could be applied across any specific policies and programs developed in Virginia to address the four areas highlighted above. They are intended to enhance the clarity and pragmatism of program objectives, the commitment of stakeholders, the sustainability of funding, and appropriate checks and balances built into program management.

1) Highlight collaboration as a central component in all programs. Today's leading technology areas require an interdisciplinary R&D approach and experience gained from many sectors (industry, academia, nonprofit, Federal labs). State-level technology

programs, leading Federal R&D funding agencies (e.g., NIH, NSF, etc.), and foundations now explicitly require cross-sector and interdisciplinary partnerships in applicant proposals for R&D funding. This principle was presented as one of the four strategic areas discussed, but is repeated here as an important guideline for all related state initiatives.

2) Seek to leverage multiple sources of funding. Research and innovation, as well as translating research outputs into commercial activities, takes money, a scarce commodity. The most successful programs actively seek to identify and attract multiple funding sources—ranging from Federal and state agencies, industry, foundations, universities, etc.—and to make the award of state funding contingent upon matching funds from external sources. The ability to attract external funds from the outset is a means of vetting the merit of the research or the business idea being proposed. It encourages funders to become stakeholders and demonstrate "skin in the game," and it promotes cross-sector collaboration.

3) Utilize industry and technology experts as key players in decision-making. Successful regions and states engage the "experts" in shaping and operating innovation programs. Such efforts may include using a peer review process for selected proposals to be funded or creating a board of industry experts to provide program oversight. Industry partners can breathe economic reality into initiatives; they help ensure that research activities have real market potential that can lead to economic impacts.

4) Incorporate key economic development objectives and milestones. Ultimately, public resources allocated to any development effort should yield benefits to the public, mostly in this case in the form of productive employment opportunities. Innovation and technology-based programs should be driven by economic outcomes and should be monitored against economic milestones.

5) Introduce and maintain strong systems of accountability. All programs, public or private, need systems to assure accountability and transparency, both financial and operational. For example, those conducting research should accurately report their progress, successes, and failures. Entrepreneurs need to account for the resources they receive. Programs in general should have structures in place to monitor and report performance objectively. Overall, accountability creates and sustains credibility and confidence. Funding should be tied to well-articulated requirements for technology commercialization, sustainability, and/or economic benefits (such as jobs, company creation, etc.).

6) Include flexibility to allow for corrections and to support longevity. Nearly all state and regional innovation programs have evolved over time, both to address problems and to accommodate altered circumstances or needs. Some of the most successful state programs have spanned multiple gubernatorial administrations. Those responsible for authorizing programs need to recognize that, for programs to be ultimately effective,

they need sufficient time and resources to allow them to incubate, adapt, mature, and perform.

7) Measure innovation progress. Any state effort for improved innovation and economic competitiveness should include a set of metrics for measuring broad outcomes and performance. Several states (including Massachusetts, Washington, Oregon, and Pennsylvania among others) have developed a set of innovation indicators to monitor economic and R&D-related performance over time. Such metrics can not only throw light on the objectives being sought, but can also serve as a vehicle for marketing the state as a center of research, innovation, and technology industries.

Recommended Course of Action

The overall picture that emerges from the analyses is that Virginia possesses a relatively robust economy that has not suffered from the industry collapses faced by a number of other states. However, the Commonwealth is heavily dependent on its proximity to the Federal government market—the state's highest industry concentrations are in IT services; research and engineering services; and aerospace, defense, and national security, all of which cater to the Federal market.

Virginia's economic and innovation foundations, like its overall economy, are relatively sound. However, the Commonwealth does not generate the research output and economic outcomes that characterize world-class innovation economies. The state has considerable innovation assets in a number of key technology arenas, but they do not appear to be sufficiently linked to provide the synergies that transform R&D activity into technology-driven economic growth.

The "bottom line" of this assessment is that Virginia possesses very important assets and praiseworthy initiatives related to innovation economy development; however, the Commonwealth's innovation economy has not, to date, approached the ceiling of its demonstrable potential.

Virginia should aspire to exceeding strategic expectations by ushering in an economy which creates, nurtures and connects world class research centers, which develops entrepreneurs and high performing firms, and which establishes an annuity stream of 21st Century jobs and industries. Through sustained and disciplined collaboration of the private, public, and academic sectors, a model innovation economy integrates the value chain linking research to entrepreneurship and ultimately to positive economic outcomes, maximizing the returns derived from public and private human and financial capital investments.

A carefully crafted set of initiatives that focuses on enhancing R&D assets and actors, creating a culture of entrepreneurship, inducing universities and industries to collaborate, and essentially "connecting all the dots" has the potential to generate a quantum leap for Virginia's economic future.

Based on the findings and inferences presented in this and previous reports, the SRI team was asked to present a tailored approach for Virginia to seize its potential opportunities and address its identified challenges. Numerous options are available. The approach summarized below is designed to be consistent with the specific situation facing the Commonwealth and to incorporate best practices and lessons learned from other states' initiatives. Operating on the principle that the most innovative efforts build upon, tailor, and improve upon previous initiatives and approaches, the SRI team proposes the following initiatives:

- ✓ Virginia's business, government, and university leaders should discuss and craft a vision for the Commonwealth to become a *model innovation economy*, which would build on the state's assets and propel it into a set of productive activities that offer competitiveness, growth, and rising standards of living.

- ✓ The Commonwealth should establish a **Virginia Innovation Alliance (VIA)**, a public-private partnership and powerful collaborative structure to guide state efforts and implement a program to stimulate R&D, technology commercialization, and entrepreneurship activities. A key objective of VIA would be to integrate a range of innovation initiatives under a common framework in order to (a) catalyze the Commonwealth's assets more effectively and (b) put into place a state-level innovation value chain that is as seamless as possible. A key feature of VIA would be bringing economic actors (the business community) together with the R&D community through both the structure and programs of VIA.

Governance

- ✓ A majority of the governing board of VIA (consisting of perhaps 15-20 individuals) should be private sector leaders. Representation should also include relevant government leaders (i.e., Secretaries of Commerce and Trade, Technology, and Education), university leaders, key R&D institute leaders, etc. Strong private sector leadership will not only keep the alliance and its activities focused on practical, economic outcomes, but also help build a structure that can accommodate and withstand political changes in the administration and/or General Assembly.

- ✓ VIA should organize advisory committees based on technology platforms. These groups would include technical experts and business representatives to guide selection processes and other efforts to stimulate new investments.

- ✓ VIA should constitute a small management unit to execute its programs. The staff size can be limited, since implementation will be the responsibility of existing entities.

Funding

- ✓ Funding for VIA would initially be provided by the Commonwealth, but future activities could leverage support from the university and business communities.

- ✓ In order to facilitate collaboration and a market-based approach, specific programs and initiatives developed by VIA to fund R&D activities should require awardees to provide external matching funds.

Activities

- ✓ VIA should serve as a catalyst that operates similarly to a foundation, supporting the initiatives described below. Some of these initiatives may represent expanded versions of current programs, while others may represent new activities. In either case, all initiatives should encompass a coordinated and integrated approach, with enhanced private sector leadership, and should be designed and administered to encourage adherence to best practices.

  1. **Virginia Research Excellence Program.** This program would expand funding for research in strategic technology areas at Virginia universities. The program would essentially represent an enhanced and larger version of the Commonwealth Technology Research Fund (CTRF), and in fact could be implemented under the CTRF banner, assuming it incorporates appropriate industry involvement. For example, it could take on major initiatives, such as large-scale research center development, which are currently beyond the scope and resources of CTRF. Under this approach, the program would be integrated with other initiatives (described below). The program should be competitive, and selection criteria should include active collaboration with industry and/or other research institutions, potential for commercialization, as well as economic impact. Continued funding should be contingent on achievement of milestones.

  2. **Virginia Scholar Program.** This activity would enhance the profile of Virginia's universities by assisting in the recruitment and retention of world-class researchers. The program would support salaries, laboratory equipment, and research assistance. Eligibility criteria should include technical area focuses, cost sharing, milestones, commercialization potential, and other requirements. The selection process should be competitive, and the selection committee should include technical experts and industry representatives in relevant fields.

  3. **Virginia Entrepreneurial Support Program.** This program will provide grants to (a) enhance technology commercialization programs at universities and (b) establish, or expand, technology-based entrepreneurial training and start-up support programs, e.g., through partnerships with VC firms, incubators, and related organizations. This initiative could leverage and expand upon CIT's existing entrepreneurial-focused programs, including an enhanced version of the GAP Funds program.

Measuring Progress

- ✓ VIA should develop a series of innovation indicators to monitor the impact of the initiative. Two types of indexes (or sets of indicators) should be considered.

- ✓ The first set of indicators would be more general, seeking to inform stakeholders on how Virginia is making progress in its overall innovation enterprise. These indicators should include research outputs (e.g., citations, patents, outside program awards, etc.) and economic results (e.g., startups, VC funding, spinoffs, economic concentration ratios, etc.). Progress should be measured annually and presented to VIA stakeholders and Virginia citizens. Successful countries and states use these kinds of performance metrics as scorecards—not only to challenge leaders, but also to constructively engage stakeholders and the broader community. The General Assembly is currently considering a resolution to request CIT to establish such a community-driven "innovation index," which could serve this purpose.

- ✓ The second set of indicators would relate directly to the performance of various VIA programs. Beneficiaries of program resources would be required to report on specific R&D and economic outcomes of their projects, so that the performance, impacts, and benefits of the programs can be monitored.

Conclusion

This report is intended to provide solid and objective analysis of Virginia's current technology industry performance and future potential. Virginia boasts significant competitive advantages, such as a strong and growing knowledge-based workforce. However, to seize emerging opportunities, Virginia needs to invest its public and private resources strategically to eliminate existing barriers and address future challenges. The goal of the overall study has been to establish the basis for a catalytic innovation/technology framework, upon which effective, sustainable programs can be built. The experience of other states and regions has shown that thoughtfully crafted and implemented programs can propel the Commonwealth to the front ranks of the nation's and world's innovation economies.

To achieve success, the framework must garner sustained support across all key stakeholder groups—companies, universities, entrepreneurs, Federal laboratories, and state agencies and programs. A lasting commitment to foster innovation demands a framework flexible enough to adapt to shifting technological, socioeconomic, and political tides. It must not be linked to specific political interests, parties, or gubernatorial administrations. Throughout 400 years of history, Virginia has been a wellspring of innovative ideas. Drawing on this tradition, Virginia is poised to build a vibrant innovation-based economy for the 21st century.

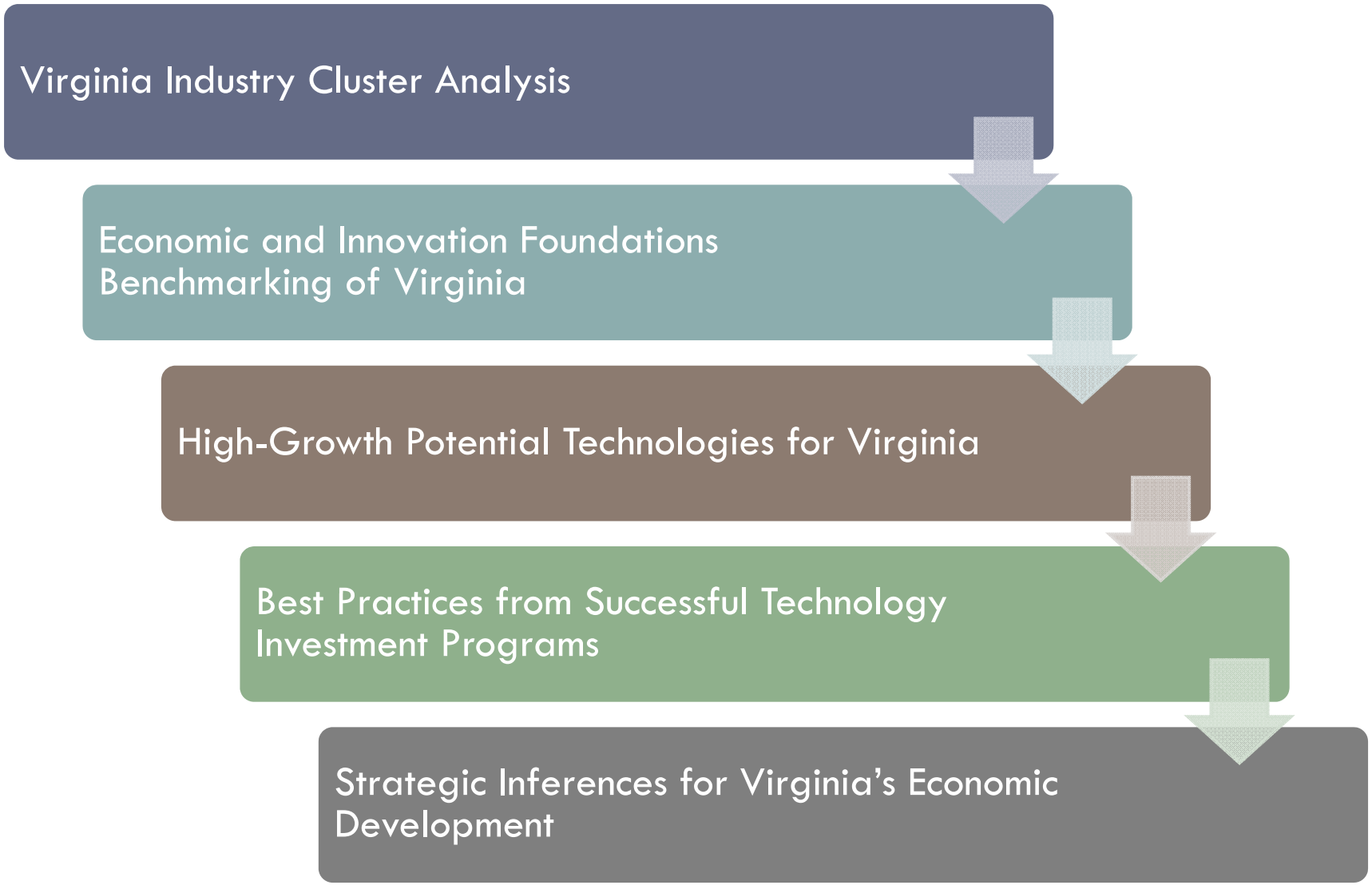
Catalyzing Innovation in the Commonwealth of Virginia

Prepared for the Virginia Economic Development Partnership

SRI International

August 2008

Project Process: Logical Analytical Tasks



Virginia Industry Cluster Analysis

- **Like most states, Virginia's economy is dominated by service industries:**
  - ✓ ***Education & Government***
  - ✓ ***Retail Trade***
  - ✓ ***Construction & Real Estate***
  - ✓ ***Tourism***
  - ✓ ***General & Business Services*.**
- **Several technology and knowledge-based sectors stand out for their high levels of employment:**
  - ✓ ***Life Sciences & Medicine* (336,535 workers)**
  - ✓ ***Research & Engineering Services* (161,633 workers)**
  - ✓ ***IT Services* (140,016 workers)**

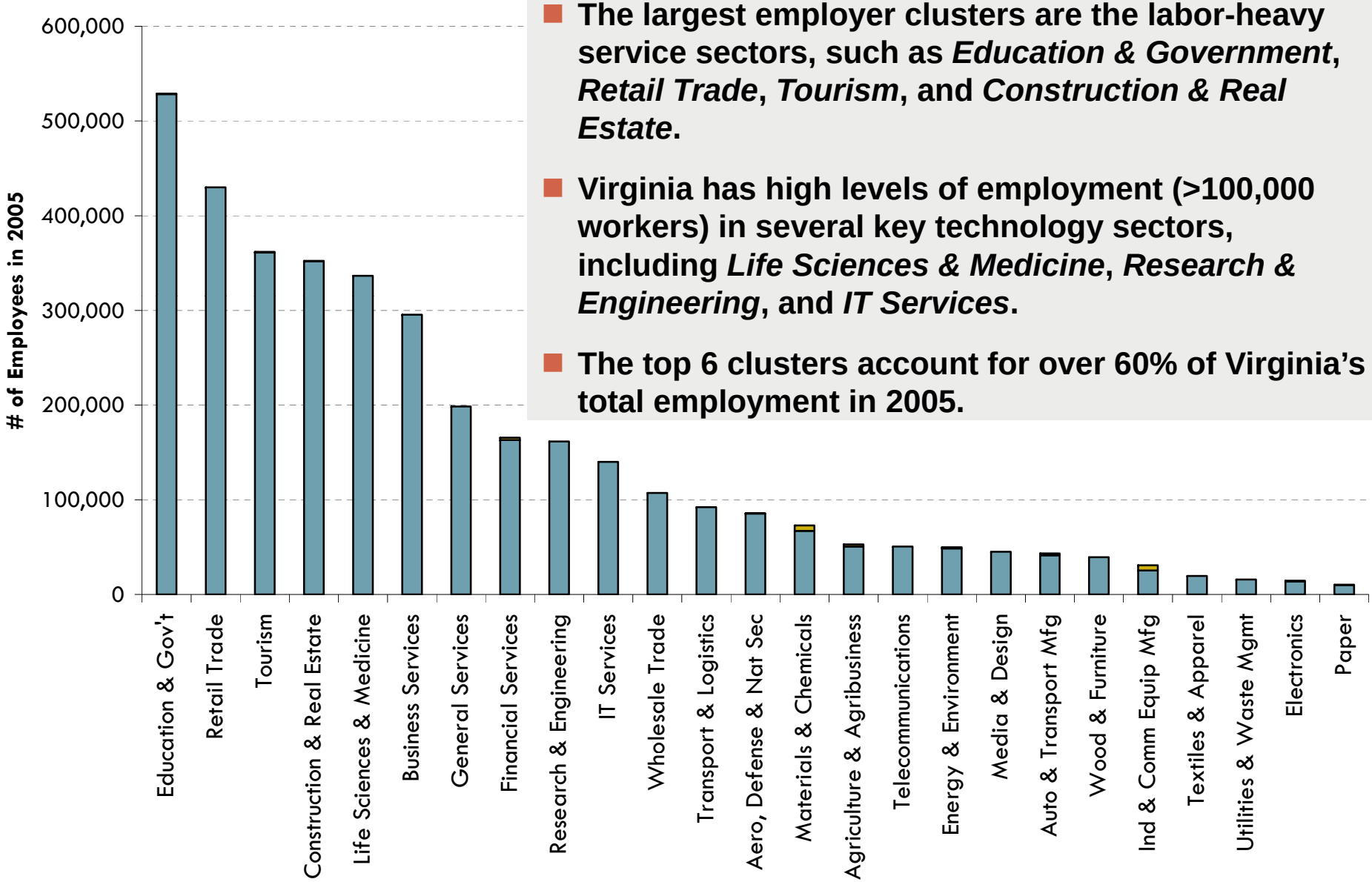
Virginia Industry Cluster Analysis

- **Several technology and knowledge-based sectors also have high levels of employment concentration in Virginia (compared to the national average):**
  - ✓ ***IT Services* (2.69)**
  - ✓ ***Research & Engineering Services* (1.96)**
  - ✓ ***Aerospace, Defense, & National Security* (1.76)**
  - ✓ ***Telecommunications* (1.32)**
- **Clusters that have experienced high employment growth rates in recent years (2003-2005) include:**
  - ✓ ***Research & Engineering Services* (26.6%)**
  - ✓ ***Construction & Real Estate* (12.4%)**
  - ✓ ***Transportation & Logistics* (8.1%)**
  - ✓ ***Tourism* (6.7%)**
  - ✓ ***Business Services* (6.5%)**

Employment By Cluster

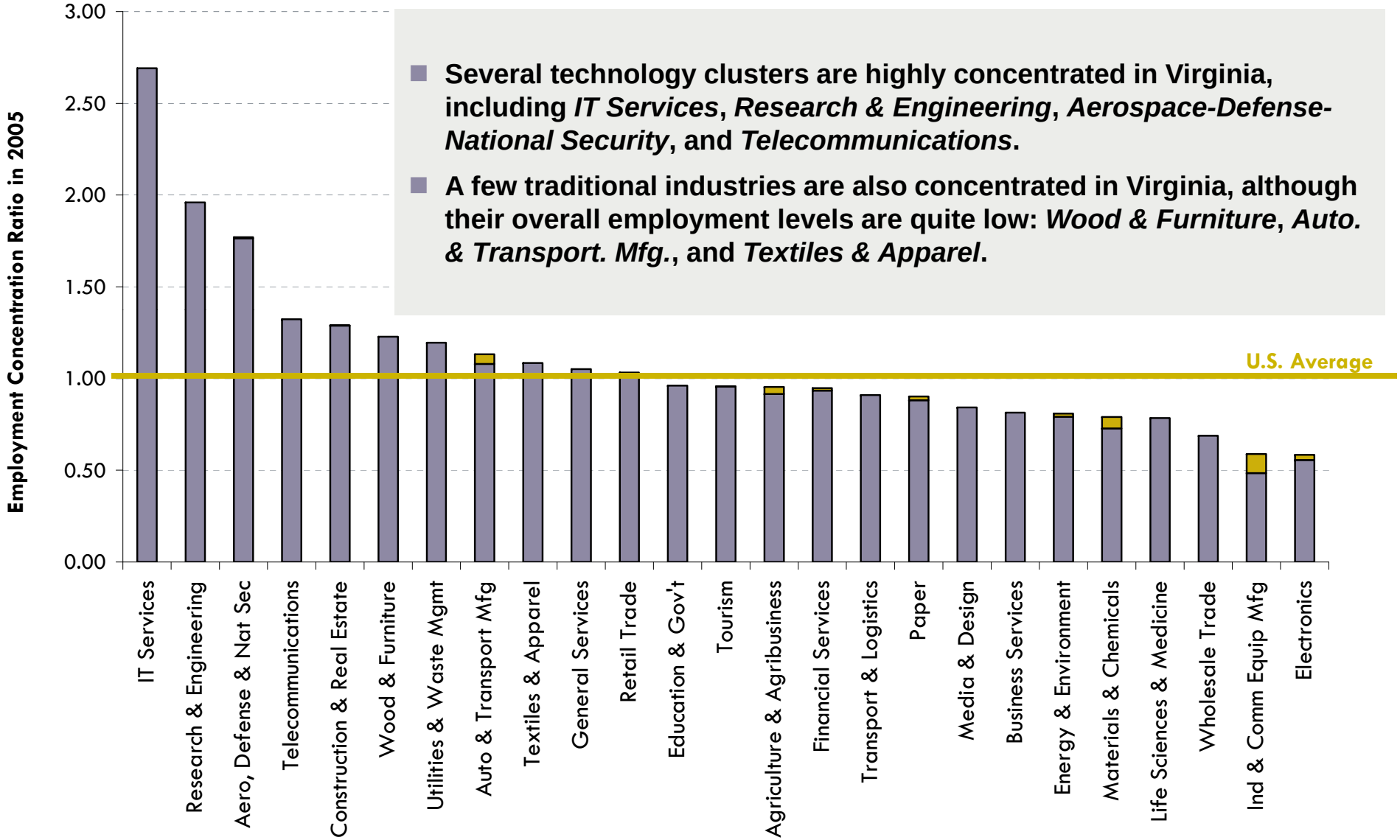
State-Level Analysis

- **The largest employer clusters are the labor-heavy service sectors, such as *Education & Government*, *Retail Trade*, *Tourism*, and *Construction & Real Estate*.**
- **Virginia has high levels of employment (>100,000 workers) in several key technology sectors, including *Life Sciences & Medicine*, *Research & Engineering*, and *IT Services*.**
- **The top 6 clusters account for over 60% of Virginia's total employment in 2005.**



Employment Concentration Ratio By Cluster

State-Level Analysis



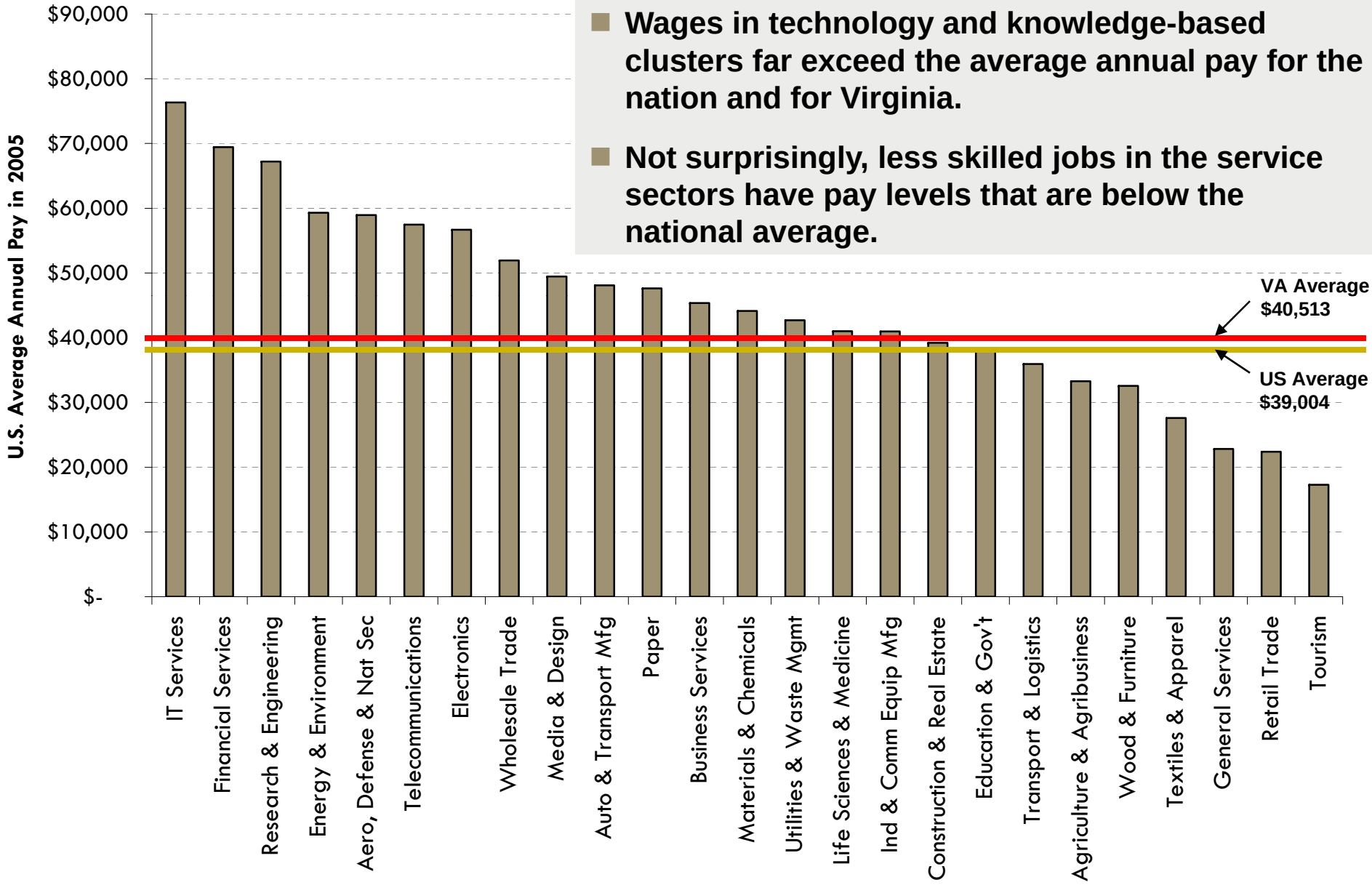
- **Several technology clusters are highly concentrated in Virginia, including *IT Services*, *Research & Engineering*, *Aerospace-Defense-National Security*, and *Telecommunications*.**
- **A few traditional industries are also concentrated in Virginia, although their overall employment levels are quite low: *Wood & Furniture*, *Auto. & Transport. Mfg.*, and *Textiles & Apparel*.**

The Employment Concentration Ratio is the industry cluster's share of total employment in the state versus its share in the country. Clusters with a ratio greater than 1.0 are more concentrated in Virginia than in the United States.

U.S. Average Annual Pay By Cluster

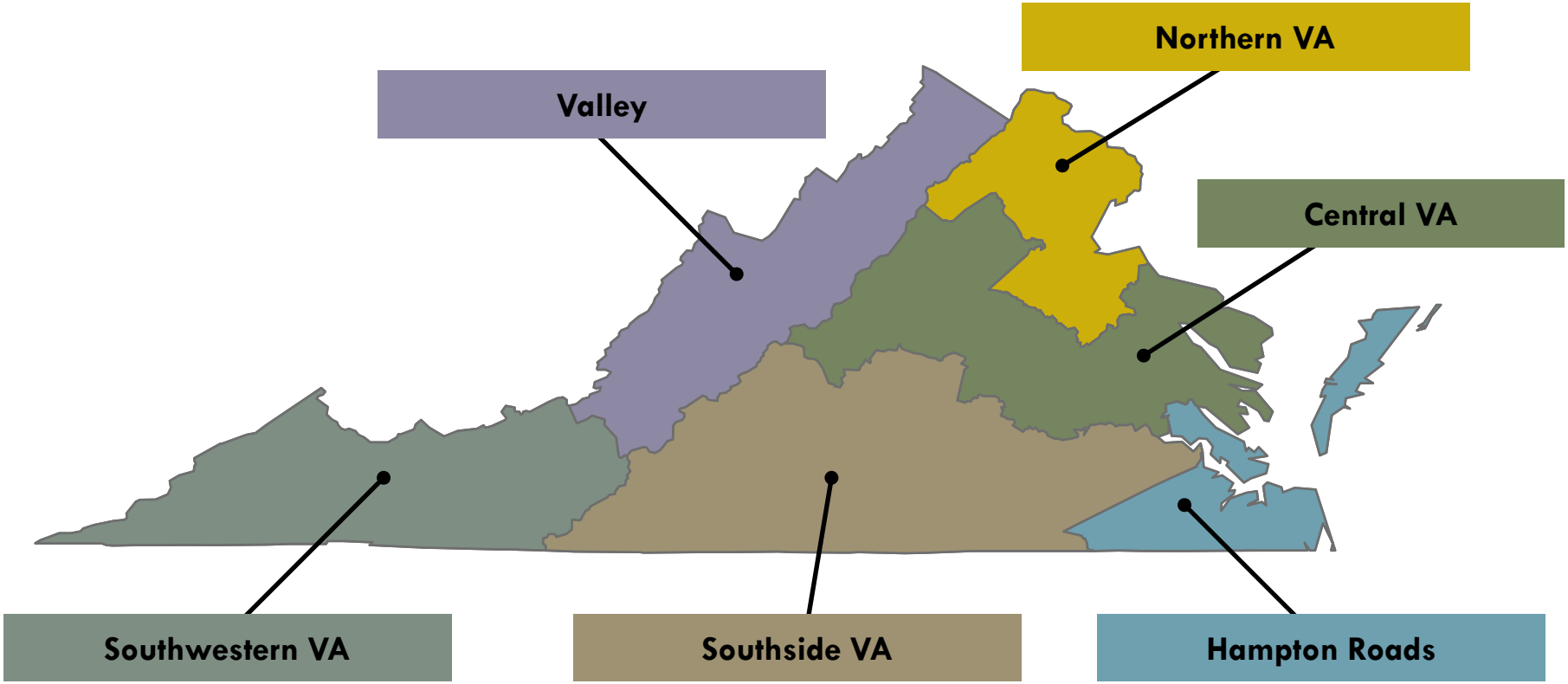
State-Level Analysis

- **Wages in technology and knowledge-based clusters far exceed the average annual pay for the nation and for Virginia.**
- **Not surprisingly, less skilled jobs in the service sectors have pay levels that are below the national average.**



Virginia Industry Cluster Analysis

Industry cluster data and trends were analyzed across six regions in Virginia.



Regional Cluster Analysis

Common employment trends across all regions:

- ***Retail Trade*, *Tourism*, and *Construction & Real Estate* are major employment-generating sectors across every region. (typical throughout the U.S.).**

- ***Life Sciences & Medicine* also dominates in employment, ranking in the top 3 clusters for every region except Northern Virginia. This is driven by its service component (the *Health & Medical Services* sub-cluster).**

- ***Business Services* and *General Services* rank in the top tier of clusters for employment across every region, but do not have especially high employment concentrations.**

Regional Cluster Analysis

Significant variations across state's regions:

- **Northern Virginia and Hampton Roads: Technology and knowledge-based clusters – *Research & Engineering*, *IT Services*, *Aerospace/Defense/National Security*.**
- **Southwestern/Southside: Natural resource-based clusters such as *Materials & Chemicals* and *Energy & Environment*.**
- **Rural Regions: Traditional industries such as *Wood & Furniture* (Southwestern, Southside, Valley), *Paper* (Southside, Valley), and *Textiles & Apparel* (Southwestern, Southside, Valley). But overall employment is relatively low.**
- **Central region: *Financial Services* (strong in both employment and employment concentration).**

Benchmarking Virginia's Innovation Foundations

Methodology

- The SRI team selected 4 competitiveness areas for benchmarking:

Financial Resources	Innovation Resources
Human Resources	Innovation Economy Outcomes

- These 4 competitiveness areas provide a robust, objective, and trackable assessment of Virginia's technology industry potential, based on the state's current strengths and assets and its position for growth relative to other states.

- Virginia was benchmarked against 9 other states selected on the following criteria:
  - National technology leaders;
  - Similar-sized economies (as measured by GSP);
  - Similar high-tech industry focuses or profiles; and/or
  - Traditional regional competitors.

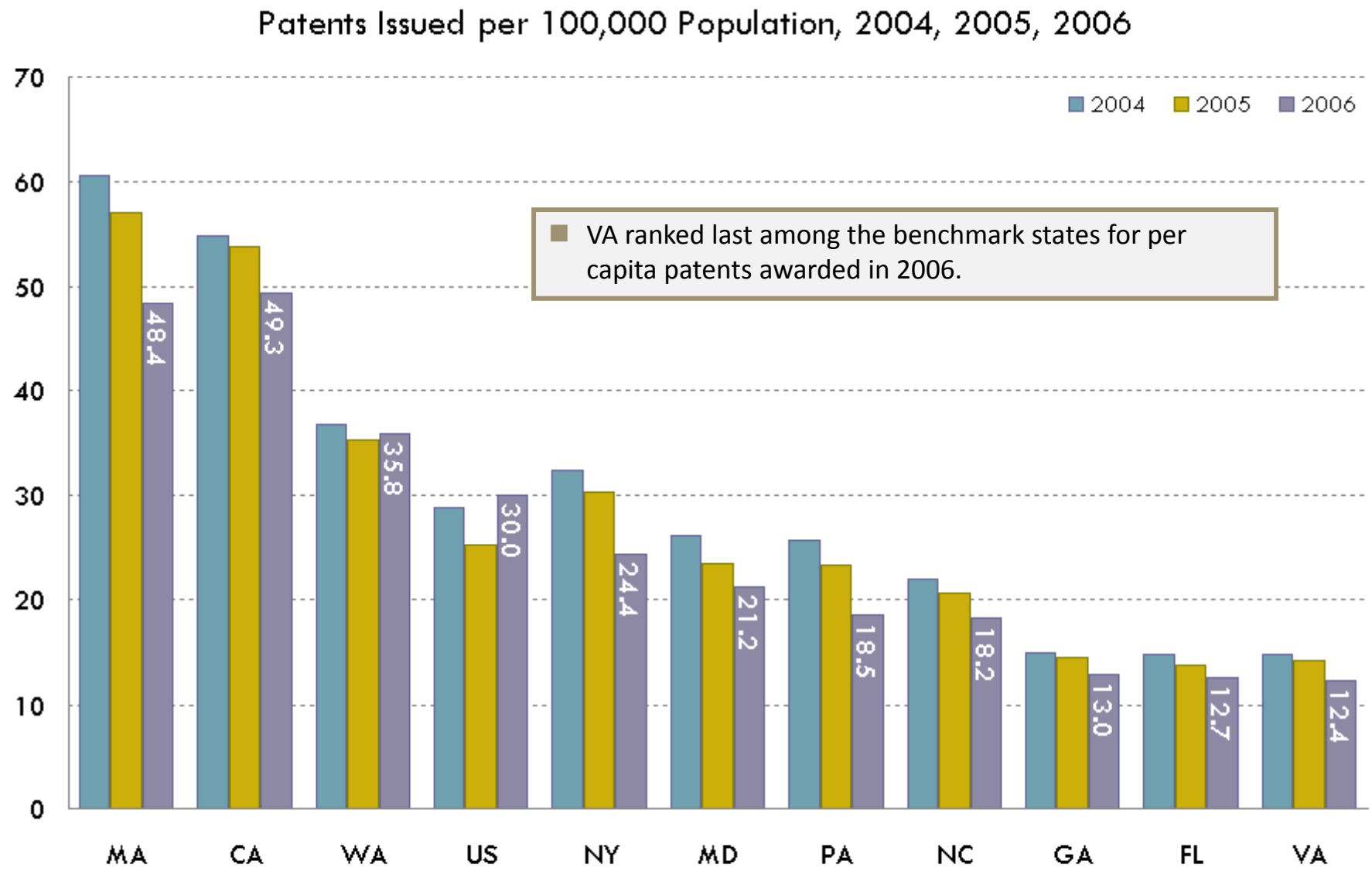
Benchmarking Virginia's Innovation Foundations

Summary Results

	Weakness	Average	Strength
Financial Resources	Small business loans ($) VC investment ($)		STTR awards ($) SBIR awards ($)
Human Resources		Advanced S&E degrees	NAEP Science & Math Scores S&E degrees Labor force growth
Innovation Resources	Patents Academic R&D expenditures ($) Industrial R&D expenditures ($)	Academic R&D productivity	Federal R&D performance ($)
Innovation Economy Outcomes	Business Start-Ups Entrepreneurs Exports ($)	R&D to GSP ($ ratio)	Tech Fast 500 companies Real GSP growth

Innovation Resources

Patents per Capita

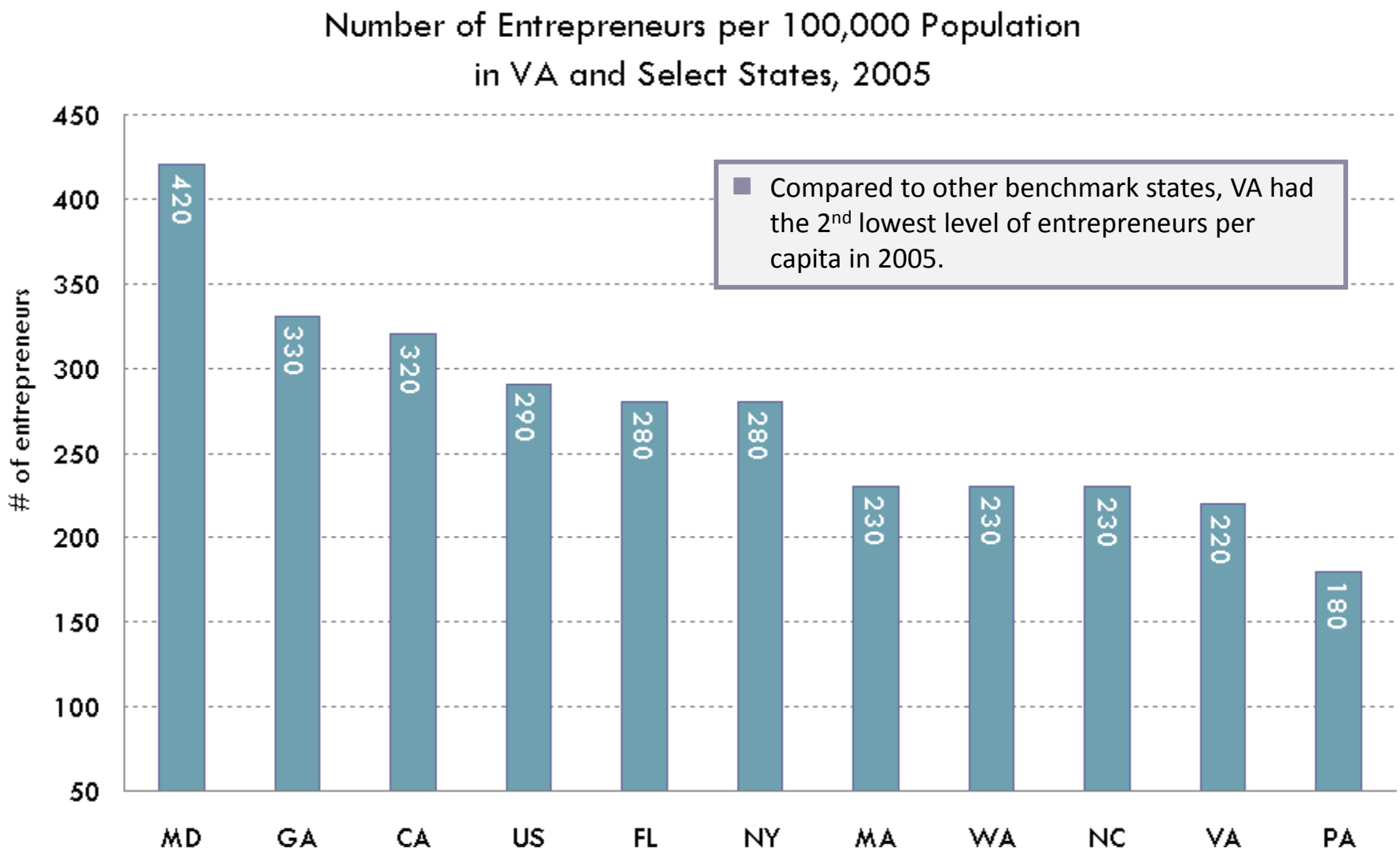


- VA ranked last among the benchmark states for per capita patents awarded in 2006.

Source: US Patent & Trademark Office and US Census Bureau

Innovation Economy Outcomes

Entrepreneurs Per Capita



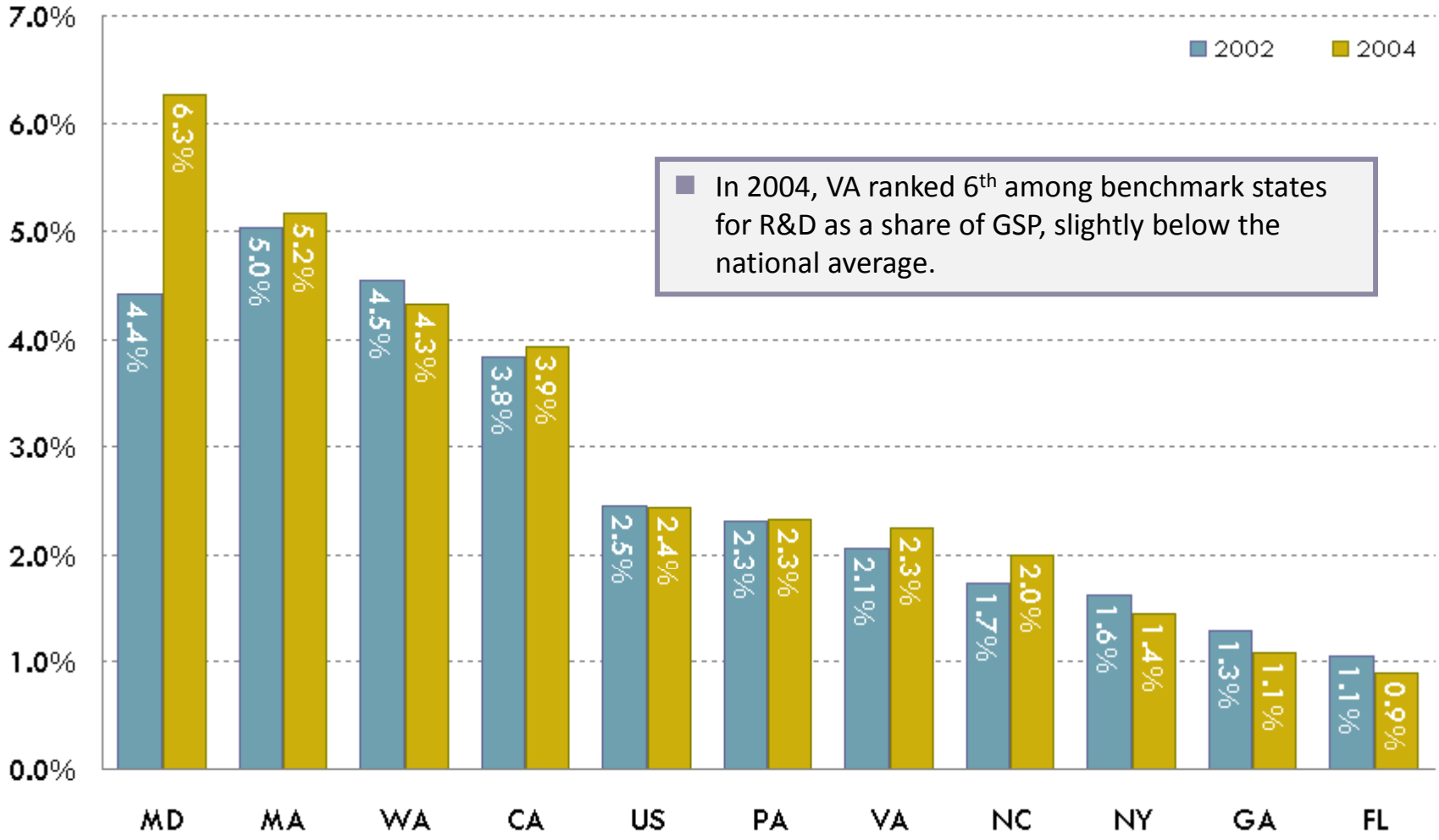
- Compared to other benchmark states, VA had the 2nd lowest level of entrepreneurs per capita in 2005.

Source: Kauffman Foundation

Innovation Economy Outcomes

R&D Share of GSP

Total R&D Expenditures as a Share of GSP in VA and Select States, 2002 and 2004



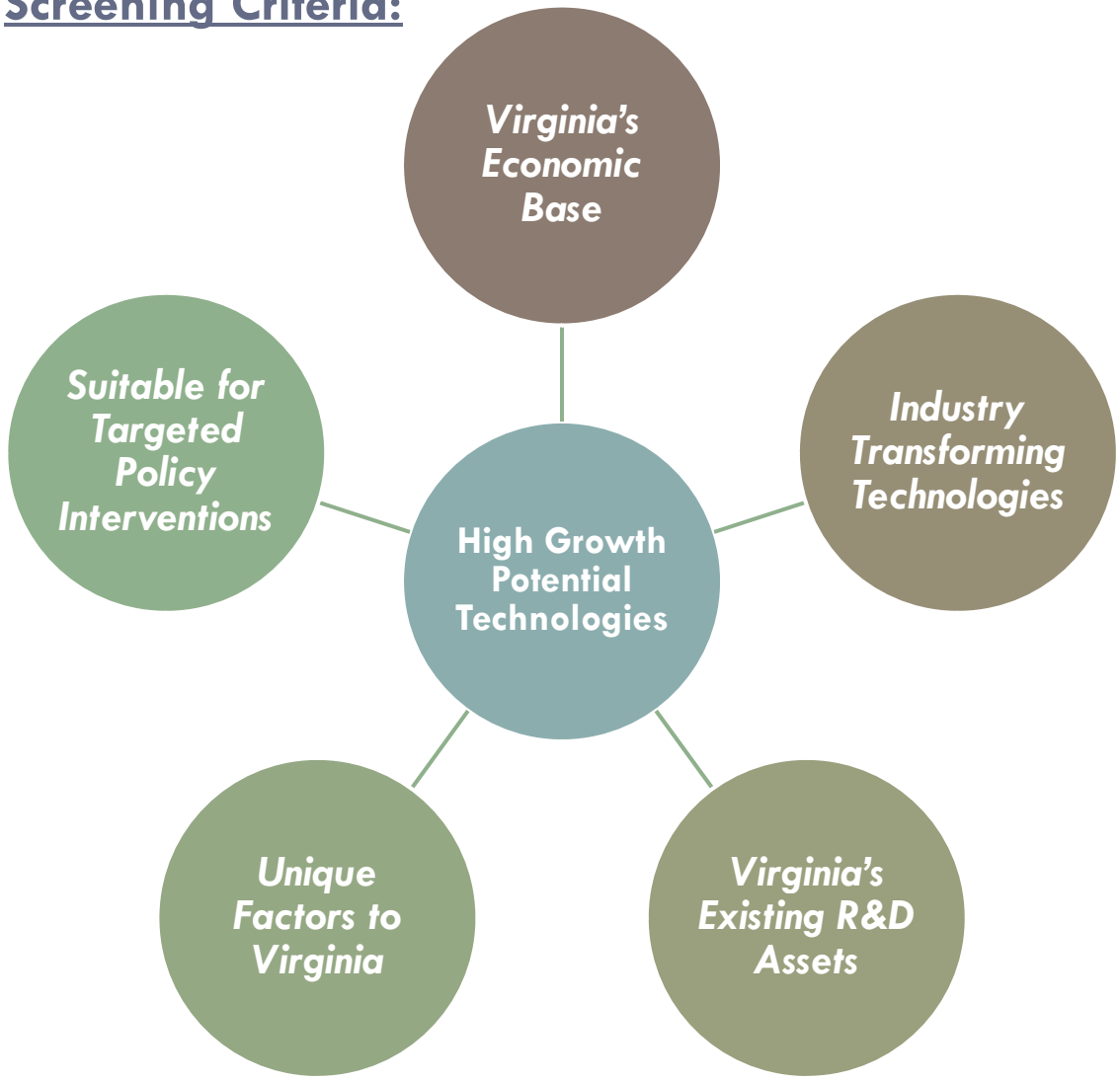
- In 2004, VA ranked 6th among benchmark states for R&D as a share of GSP, slightly below the national average.

Source: National Science Foundation and US Bureau of Economic Analysis

High Growth Potential Technologies for VA

Resources for R&D and technology development are limited. Determining where scarce resources should be deployed is a critically important task.

Screening Criteria:



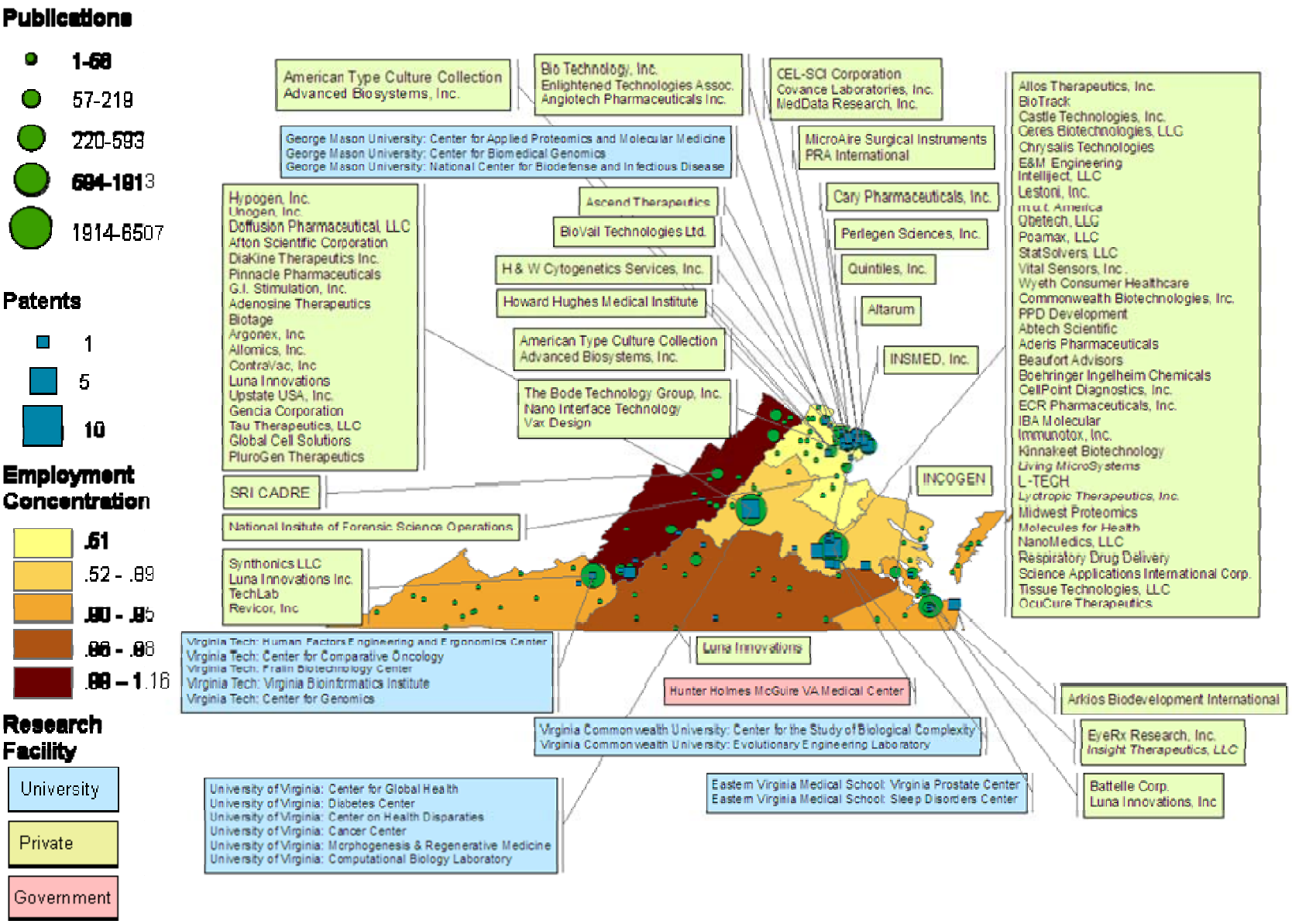
Technology Industry Selection

Industry Cluster	Industry Sub-Clusters	Current Industry Base	Growth Potential	Existing R&D Assets	Other Factors
National Security and Aerospace	Aerospace	✓	✓	✓	✓✓
	National Security	✓✓	✓✓	✓✓✓	✓✓✓
Agriculture and Food	Agriculture and Processed Food	✓✓	✓✓	✓	✓
Biomedical and Health Care	Health Care	✓✓✓	✓✓✓	✓✓	✓✓
	Biomedical Sciences	✓	✓✓✓	✓✓	✓
Chemicals and Materials	Chemicals	✓	✓✓	✓	✓✓
	Materials	✓✓	✓✓✓	✓	✓✓
Energy and Environment	Energy	✓✓	✓✓✓	✓✓✓	✓✓✓
	Environment	✓	✓✓	✓✓	✓✓
Information and Communications	IT Services	✓✓✓	✓✓✓	✓✓	✓✓✓
	Telecom	✓✓	✓✓	✓	✓✓
	Electronics	✓	✓✓	✓	✓
Transportation and Logistics	Transportation and Logistics	✓✓	✓✓✓	✓	✓✓✓

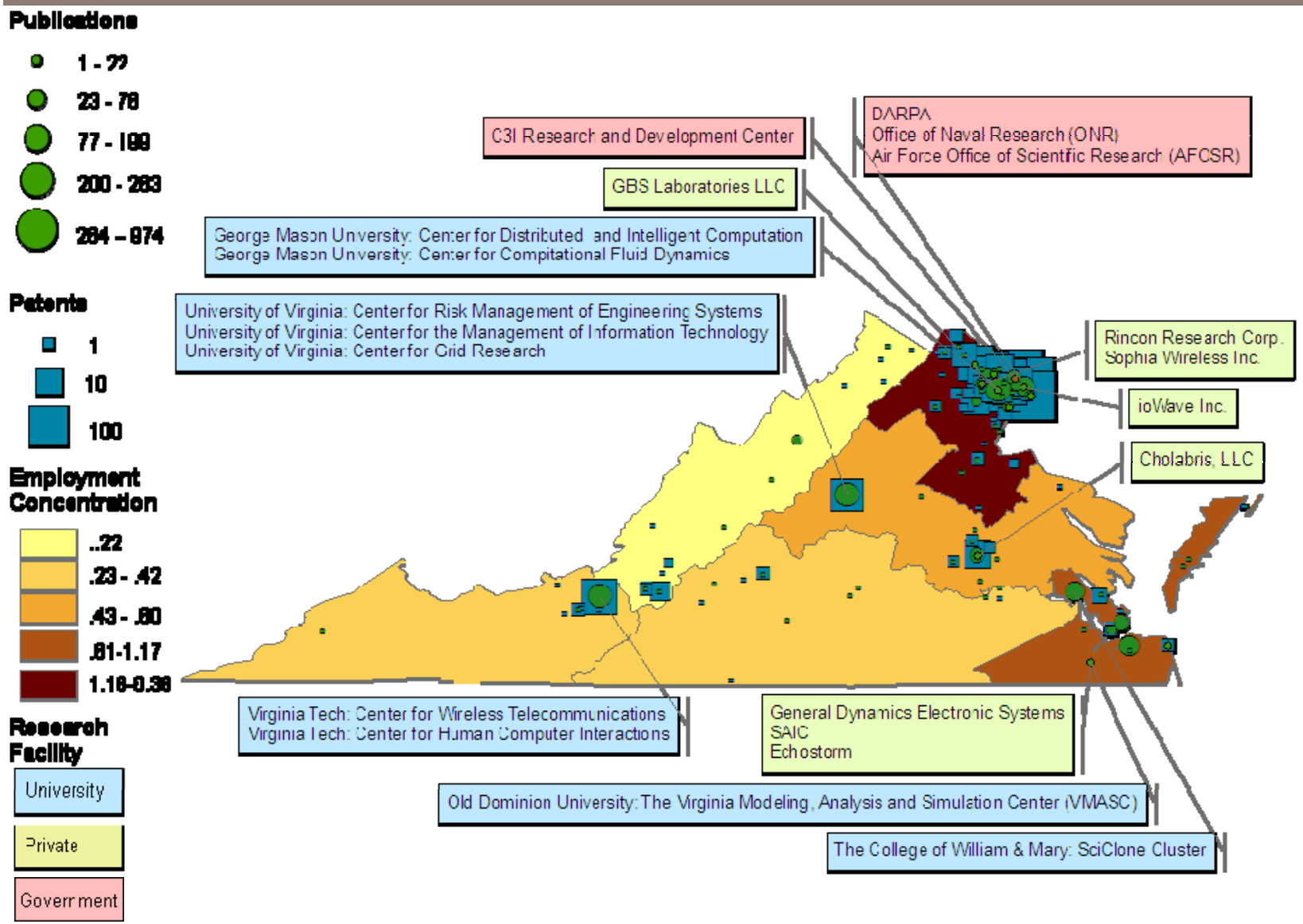
High Growth Potential Technologies

Technology-Based Industry Cluster	High Growth Potential Technologies
Biomedical Sciences and Health Care	Point of Care Diagnostics
	Computational Technologies
Information Technology Services	Health IT
	Cybersecurity
Chemicals and Materials	Nanomaterials
	Biopolymers
Clean Energy and Environment	Fuel Cells and Distributed Hydrogen
	Carbon Capture and Storage
Transportation and Logistics	Radio Frequency Identification
	"Smart" Roads

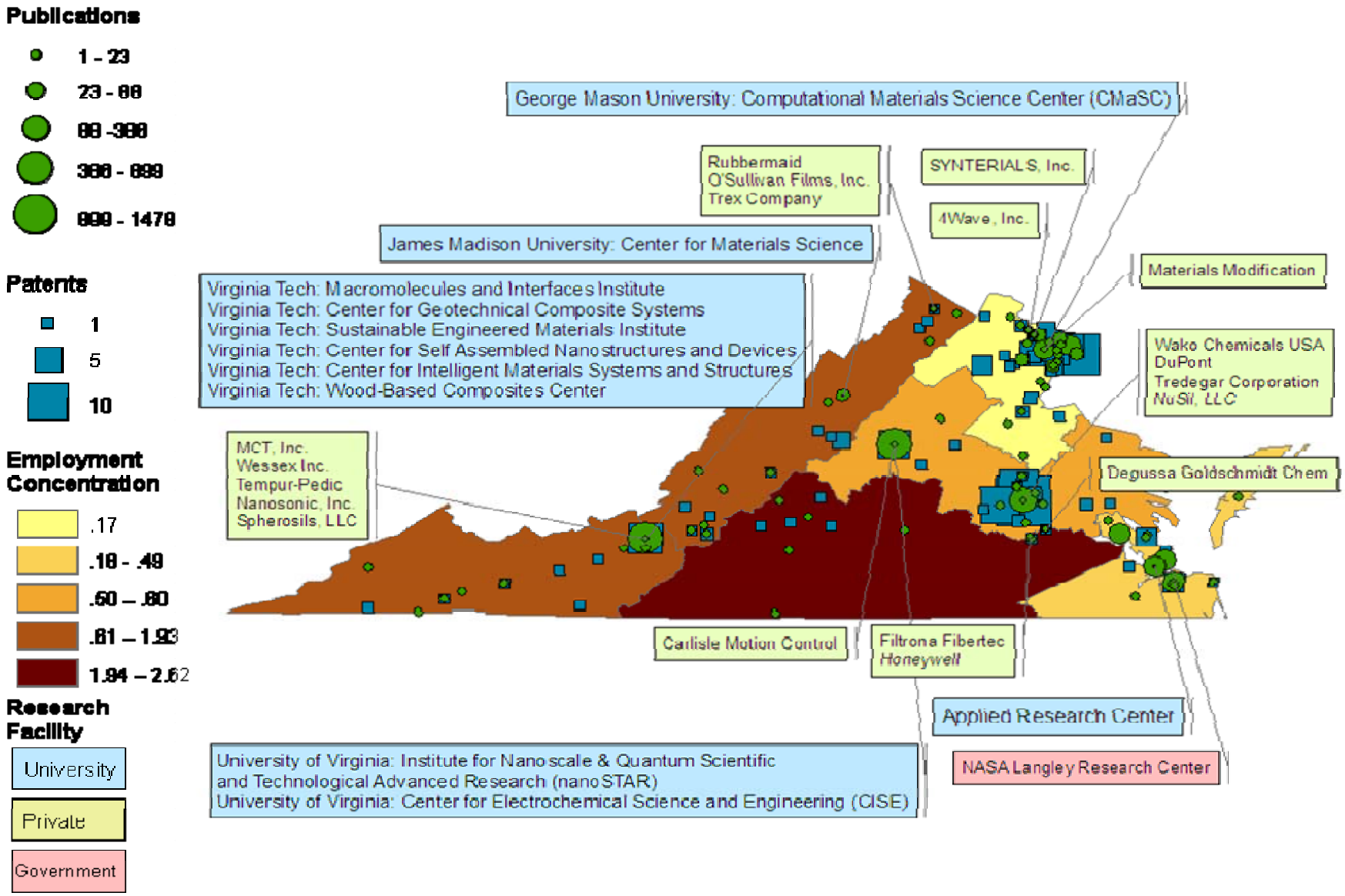
Biomedical Sciences and Health Care



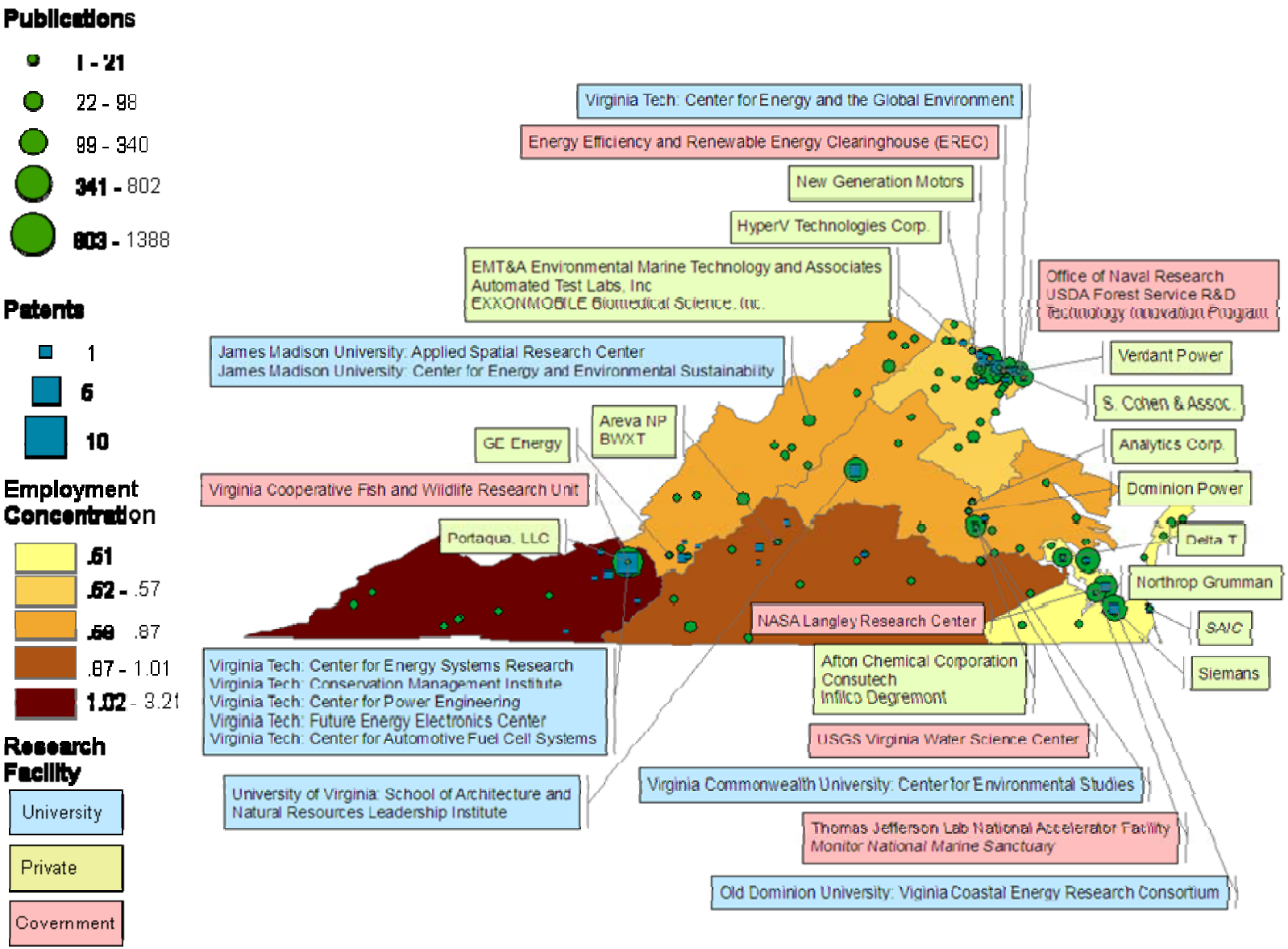
Information Technology Asset Map



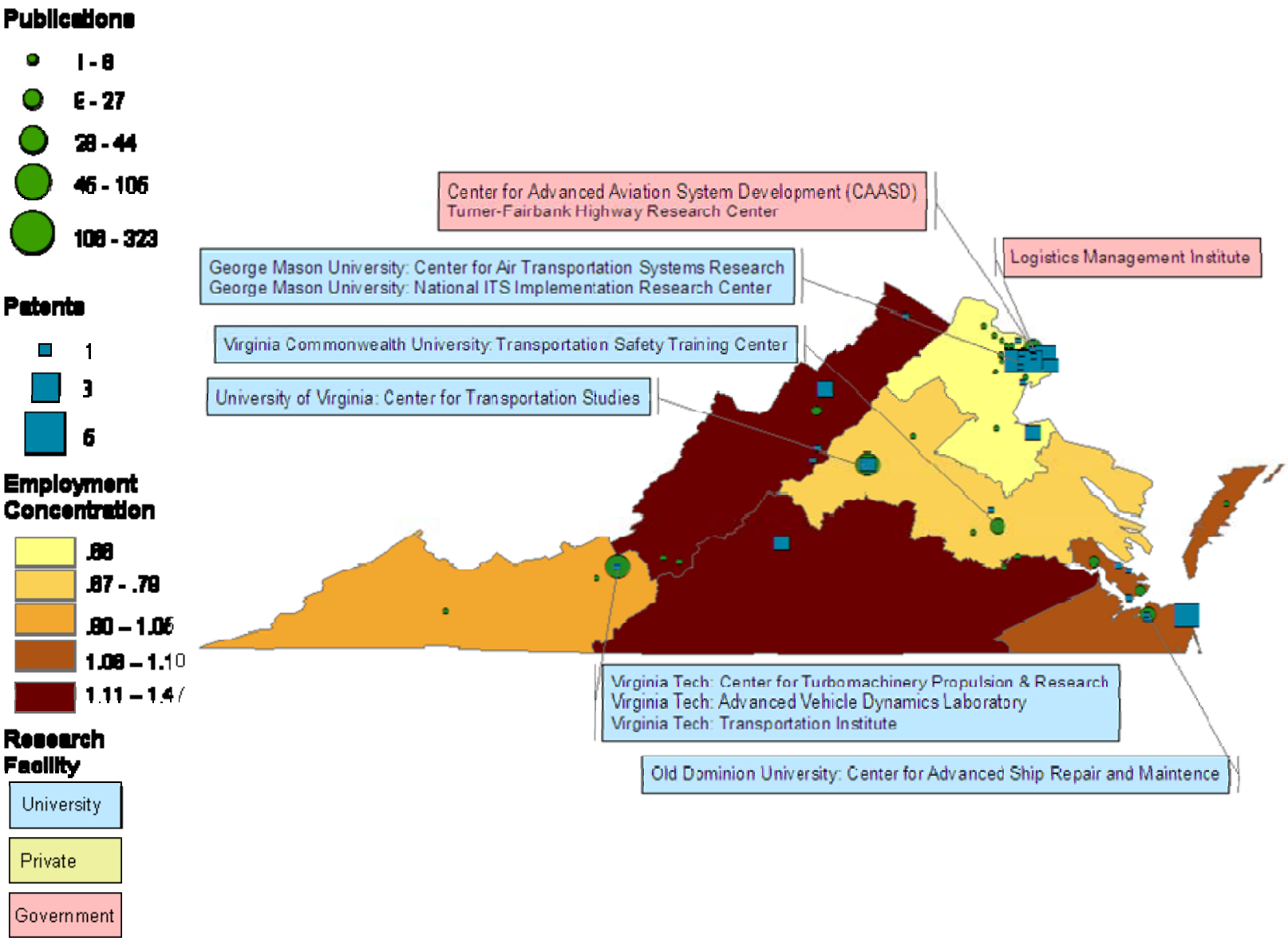
Materials and Chemicals Asset Map



Energy and Environment Asset Map



Transportation and Logistics Asset Map



Case Studies

- **Enhancing Research Excellence at Universities**
  - ✓ Georgia Research Alliance
  - ✓ University of Texas Eminent Scholars Program
  - ✓ Ohio Third Frontier (Wright Mega-Centers)
- **Enhancing Collaboration Across Sectors/Disciplines**
  - ✓ NY Centers for Advanced Technology
  - ✓ MD Industrial Partnerships Program
  - ✓ CA Industry-University Coop. Research Program
  - ✓ NC Research Triangle
- **Enhancing Entrepreneurship and Access to Capital**
  - ✓ MD Venture Fund
  - ✓ GA Advanced Technology Development Fund
  - ✓ PA Ben Franklin Technology Partners

Lessons Learned

- **Highlight collaboration as a central component of all programs.**
- **Utilize industry and technology experts as key players in decision-making.**
- **Seek to leverage multiple sources of funding.**
- **Incorporate key economic development objectives and milestones.**
- **Introduce and maintain strong systems of accountability.**
- **Include flexibility to allow for corrections and to support longevity.**
- **Measure innovation progress.**

Recent Intelligence – Other States

- **Most U.S. innovations (2/3) come from business/government partnerships, including Federal labs and universities. (Information Technology and Innovation Foundation)**
- **MD ranked 2nd (VA 6th) in position to achieve high-quality economic growth due to technology and science assets, due to strong partnerships. (Milken Institute)**
- **SC legislative and business leaders form a new technology partnership.**
- **PA commits $650M for alternative energy package.**
- **Michigan enacts $45M Centers of Energy Excellence Program.**

Summary Assessment

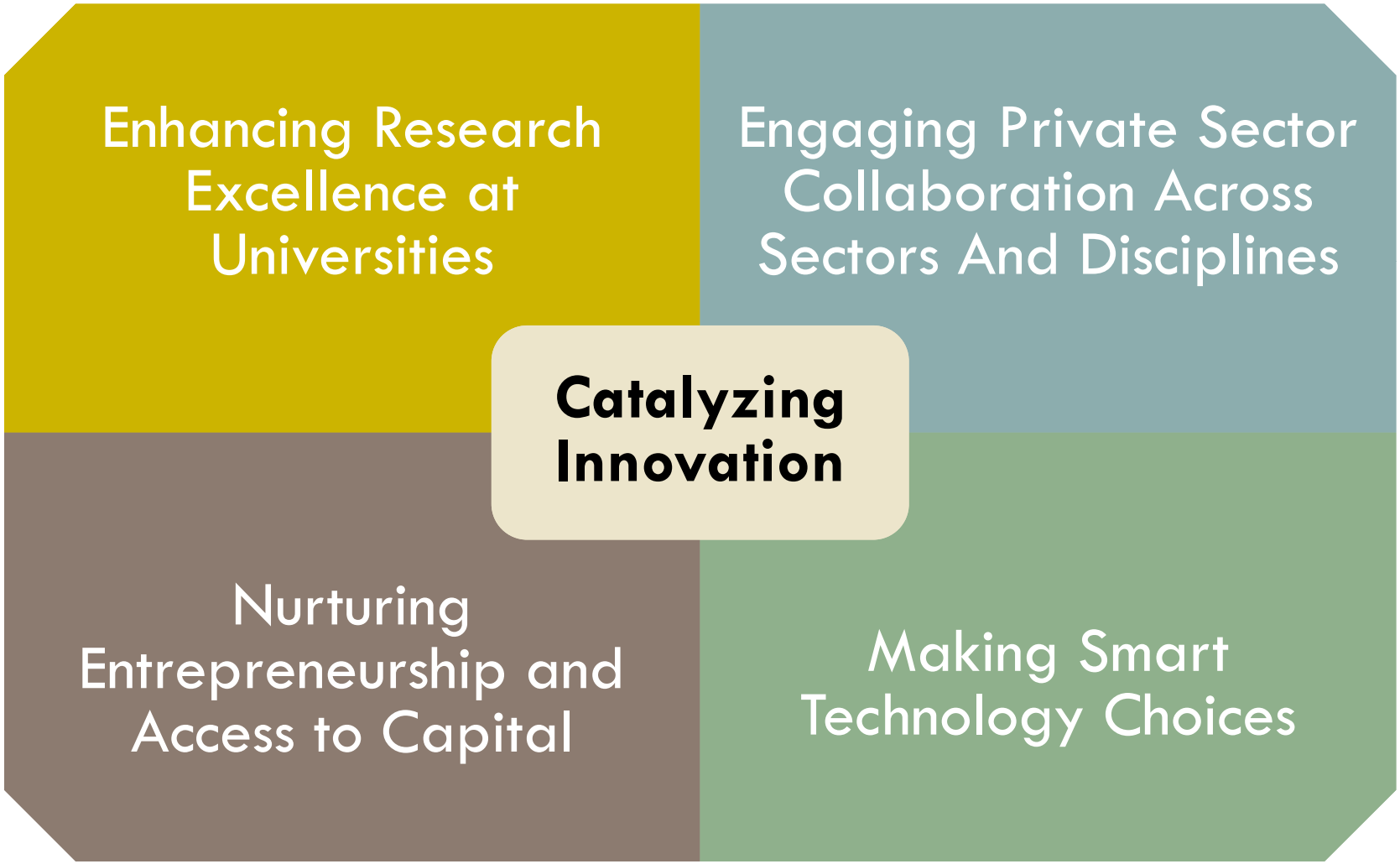
Global and national economic realities challenge forward-looking states to expand industries driven by technology and innovation.

Many of Virginia's high-tech industries serve the Federal market. While important, this narrow focus limits the state's diversity and overall ability to provide high value jobs.

Virginia possesses important assets and initiatives related to innovation, but the Commonwealth has not reached its potential.

An initiative to stimulate innovation and catalyze collaboration among industries, universities, laboratories, etc., can transform Virginia into a model innovation economy.

Strategic Focuses for Virginia



Recommended Approach for Virginia

- **Overall Strategic Goal:**

  Virginia will become a *Model Innovation Economy*

  - ***Crafted and directed by business, government and university communities***

- **Implementation Mechanism:**

  Virginia Innovation Alliance (VIA)

  - ***Public/Private Partnership***
  - ***A structure to power collaboration***
  - ***Catalyzes Virginia's assets, addresses liabilities***
  - ***Introduces a seamless innovation value chain***

VIA Governance and Funding

- **Governance:**
  - ✓ *Governing board (15-20) with a majority industry leaders.*
  - ✓ *Membership from government, universities, research labs, etc.*
  - ✓ *Advisory committees for technology platforms.*
  - ✓ *Small management unit.*
- **Budget: Source & level to be decided**
  - ✓ *Stable and sustained multi-year funding.*
  - ✓ *Initial core funding from the Commonwealth, with major support from industry.*
  - ✓ *To be successful it will require matching funds.*

VIA Principles and Intent

- Catalyze technology and innovation activities and outcomes
- Leverage additional, sustained private and public resources for R&D
- Gain political support that transcends administrations
- Stimulate increased collaboration among public and private stakeholders
- Support and strengthen existing technology centers of excellence

Monitoring Innovation Progress

- **Overall Progress in the Commonwealth:**
  - ✓ *Scorecard or index to measure performance of Virginia's innovation enterprise.*
  - ✓ *Research outputs (patents, citations, outside funding, etc.).*
  - ✓ *Economic results (startups, VC funding, spinoffs, employment concentration, sector growth, etc).*
- **Performance of specific VIA programs:**
  - ✓ *Metrics to monitor program performance.*
  - ✓ *R&D and economic outcomes.*
  - ✓ *Participants will be required to report on progress.*

Next Steps

Reviewed with:
→Secretary of Commerce
→Secretary of Finance
→Secretary of Technology
→Secretary of Education
→Governor

↓

Completed

11 CEOs
→Presented Overview
→CEOs were supportive

↓

Completed

Review with Stakeholders:
→Economic Developers
→Universities
→Legislators

Target: September 2008

↓

In Progress

Action Plan:
→Develop program structure, governance, and participants
→Identify prototype market for public/private collaboration

Target: TBD

↓

In Progress