Vision 2025:

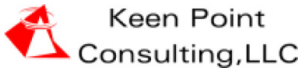
West Virginia Science & Technology Plan

April 2021

WEST VIRGINIA Higher Education Policy Commission

RTI INTERNATIONAL

Keen Point Consulting, LLC



The Vision 2025: West Virginia S&T Plan was developed by Jennifer Ozawa at RTI International and Anthony Gillespie at Keen Point Consulting in collaboration with the Science and Research Council working group. Michael Hogan and Rizwaan Lakhani of RTI provided research and data analysis, and Lisa Gardner created the report design. The plan was adopted by the West Virginia Higher Education Policy Commission Science and Research Council on April 29, 2021.

WEST VIRGINIA
Higher Education
Policy Commission

Michael J. Farrell, Esq., *Chair*
Sarah Armstrong Tucker, Ph.D., *Chancellor*

April 30, 2021

The West Virginia Science and Research Council, established by the State Legislature in 2009, works to increase the capacity of the state and its colleges and universities to attract, implement, and use cutting-edge, competitive research funds and infrastructure. Members of the Council provide expertise and policy guidance to the state regarding federal and state programs, including EPSCoR, the Research Challenge Fund, and the former Research Trust Fund. The Council serves as the EPSCoR jurisdictional steering committee for West Virginia. Representatives of government, industry, business, and academia comprise its membership.

As a critical part of its mission, the Council is responsible for developing and updating West Virginia's Science and Technology Strategic Plan. The plan, originally called *Vision 2015*, is updated every five years. The current version, called *Vision 2025*, has undergone a significant update with the assistance of RTI International and the input of key stakeholders across the state.

The 2021 update of *Vision 2025* is presented in this document and provides a strategic plan to improve the quality of life in West Virginia by leveraging and growing scientific research and innovation at higher education institutions and in the public and private sectors. The plan was approved and adopted by the Science and Research Council on April 29, 2021.

As stated in the Executive Summary, "The *Vision 2025* goals … aim to develop West Virginia's STEM talent pipeline, expand the research enterprise, catalyze more innovation and entrepreneurship activity, and support the growth of high-tech companies. The set of proposed actions to advance these goals build on existing initiatives and collaborative efforts between higher education, industry, and government."

Through *Vision 2025*, West Virginia can reach even greater heights in research and innovation through our higher education community, benefitting our state's students, institutions, residents, and economy for years to come.

Sincerely,

Sarah Armstrong Tucker, Ph.D.
Chancellor

WEST VIRGINIA
DEVELOPMENT OFFICE

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May 10, 2021

Dr. Sarah Armstrong Tucker
Chancellor
West Virginia Higher Education Policy Commission
1018 Kanawha Boulevard, East - Suite 700
Charleston, WV 25301

Dear Chancellor Tucker:

It is with great pleasure that on behalf of the West Virginia Development Office, as part of the Department of Commerce, I hereby offer full support and total commitment to the West Virginia Higher Education Policy Commission's Vision 2025: West Virginia's Science and Technology Plan.

As an organization whose mission is to grow our state's vibrant economy and outstanding quality of life, we understand the importance science and technology play to drive West Virginia's future economic growth.

This plan brought together a cross-section of science and technology representatives from higher education, industry, and government. The final product represents a diverse set of voices and is grounded in an understanding of how West Virginia can harness existing resources, opportunities, and partnerships to grow our economy.

The aspirations of West Virginia stakeholders present a vision for the role that science and technology will play in West Virginia's economic growth and competitiveness in the next five years and beyond.

We are pleased to support the S&T plan and look forward to collaborating with stakeholders to bring the vision into reality.

Sincerely,

Michael R. Graney

Michael R. Graney
Deputy Secretary

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Executive Summary

"Science and technology, paired with design thinking and an entrepreneurial spirit, will be critical to West Virginia's ability to effectively participate and compete in the 21st century. Who will be accountable for transforming this vision into reality?"

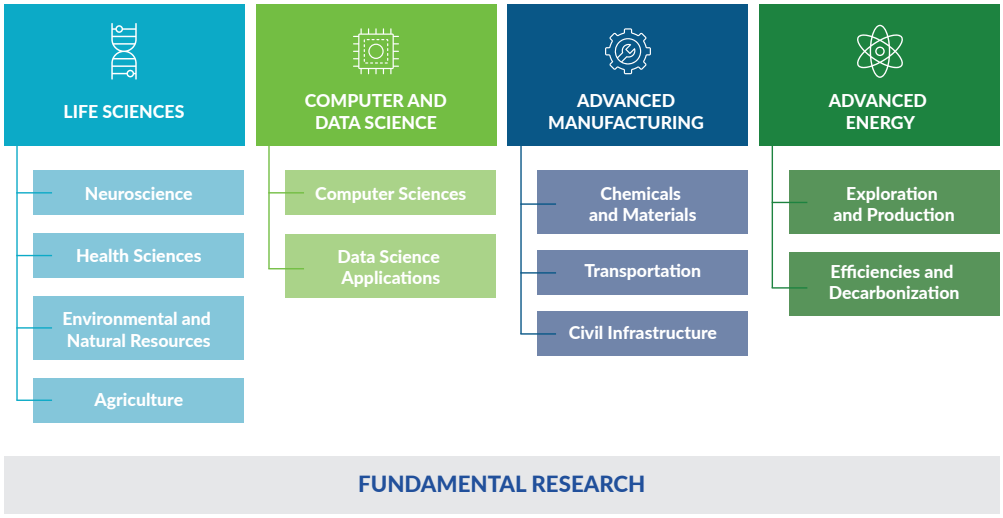
- Brad Smith, Executive Chairman of the Board, Intuit

The aspirations of West Virginia stakeholders present a vision for the role that science and technology (S&T) will play in West Virginia's economic growth and competitiveness in the next five years and beyond. Science, technology, and innovation have driven similar industry growth in West Virginia in the past, most notably in the first-to-world chemical engineering and process technologies invented by Union Carbide.

Today, a new generation of innovation-based companies are growing in West Virginia. They are delivering information technology solutions and data analytics (Leidos, NextGen Federal), high-performance manufactured products (Boeing, Procter & Gamble, Toyota, Dow), and engineering and scientific research, development, and testing (Virgin Hyperloop, MATRIC).

In positioning the state to launch and attract more of these companies, Vision 2025, West Virginia's S&T plan, identified four high-priority S&T platforms, shown in the figure below. These four platforms leverage corporate and federal demand for technologies driven by the megatrends of digitalization, robotics and automation, and sustainability. They represent large and growing university-based research and educational activities and align strongly with target industries and workforce needs.

FIGURE ES-1. S&T PLATFORMS FOR VISION 2025: WEST VIRGINIA S&T PLAN



The Vision 2025 goals, presented in the table below, aim to develop West Virginia's science, technology, engineering, and mathematics (STEM) talent pipeline, expand the research enterprise, catalyze more innovation and entrepreneurship activity, and support the growth of high-tech companies. The set of proposed actions to advance these goals build on existing initiatives and collaborative efforts among higher education, industry, and government. A few are new and others re-establish state programs recognized for contributing to research capacity-building in the past. Each action is supported by a strong business case with metrics to track progress.

FIGURE ES-2. VISION 2025: WEST VIRGINIA S&T PLAN GOALS AND ACTIONS

	GOALS	ACTIONS
STEM TALENT PIPELINE	• Increase two-year and four-year STEM degree enrollment • Increase research experiences and internships supported by federally funded grants and the Research Challenge Fund • Increase STEM degrees conferred	• Expand K-12 STEM opportunities for teachers and students • Partner with HSTA, First2Network, etc., to prepare and retain STEM college students • Partner with companies and federal labs to increase internships
RESEARCH ENTERPRISE	• Increase number of PhDs to support research activity • Increase research expenditures in target platforms	• Re-establish $4.5M funding model for Research Challenge Fund • Win large federal capacity-building grants (e.g., NSF EPSCoR) • Increase federal R&D grants and contracts in target platforms • Identify critical lab and facility needs and assess funding mechanisms in other states
INNOVATION & ENTREPRENEURSHIP	• Increase number of industry-university R&D collaborations • Increase innovation activity, invention disclosures, and patents • Increase number of SBIR/STTR awardees and awards	• Pilot WV $350K R&D Voucher Program • Support FAST Program led by TechConnectWV and WV SBDC • Fund $1.1M for WV Entrepreneurship & Innovation Investment Fund
HIGH-TECH COMPANIES	• Attract R&D-oriented federal operations with contracting activity • Ensure WV has the infrastructure, facilities, and access to specialized equipment appropriate for high-tech companies • Work with the WV DED[1] to proactively recruit high-tech and R&D-based companies	• Support Opportunity Move, the federal anchors strategy • Invest in sites identified by Opportunity Move Steering Committee Leverage new WV R&D Vouchers Program • Continue collaboration on high-tech recruitments and WV business case development

West Virginia's five-year plan is fully supported by the three EPSCOR Research Infrastructure Improvement (RII) Program Track-1 research universities and was developed in consultation with over 60 stakeholders representing the perspectives of West Virginia companies, higher education, and state government. Vision 2025 articulates their shared vision of what West Virginia can accomplish by continuing to work together, as well as with new partners.

1 *The West Virginia Development Office changed its name to the West Virginia Department of Economic Development (WV DED) in the spring of 2021.*

1. About This Plan

In December 2020, STaR Division: Science, Technology and Research (STaR) at the West Virginia Higher Education Policy Commission (WV HEPC) launched a study to analyze the recent performance of West Virginia's science and technology enterprise and to develop a five-year strategic plan to guide its future development. The STaR and the Science and Research Council sought independent and objective analysis to:

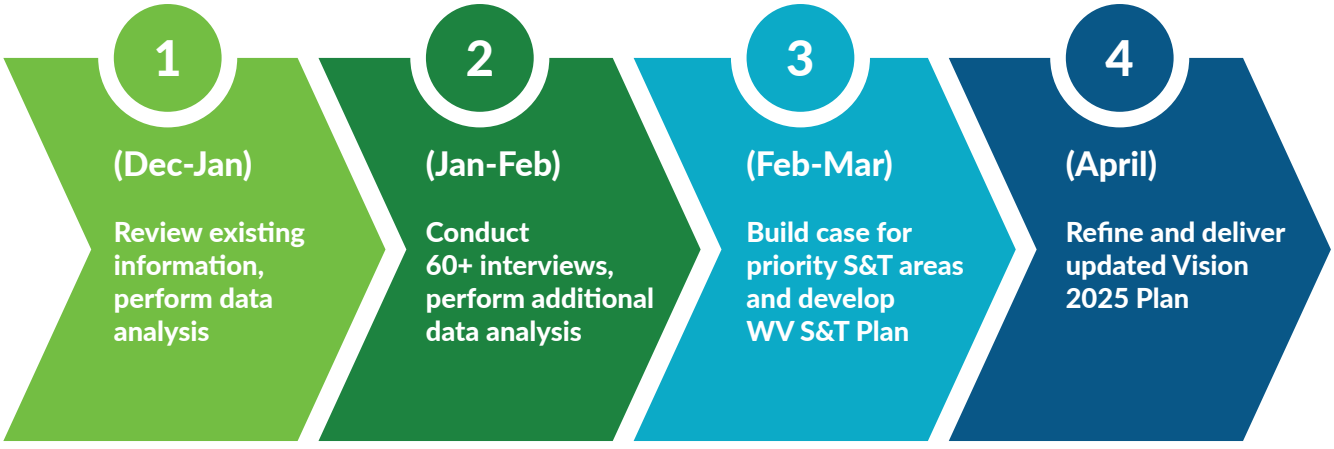
1. Identify high-priority S&T research areas aligned to target industries, and
2. Develop a plan for strengthening these STEM research areas to increase West Virginia competitiveness and generate economic growth.

A further purpose of the plan is to meet a key requirement of the NSF Established Program to Stimulate Competitive Research (EPSCoR) program and the associated new proposal that West Virginia will submit in Q3 of 2021.

RTI International, a non-profit research and consulting firm headquartered in Research Triangle Park, NC, and its partner, Keen Point Consulting (KPC), a technology-based economic development consulting firm located near Cleveland, OH, were selected to lead the development of this plan in collaboration with the working group of the Science and Research Council.

The RTI and KPC team (hereafter, the RTI team) collected and analyzed data for the most recent five-year period to understand West Virginia's industry structure and recent economic performance, especially in high-tech industry sectors. The team also analyzed West Virginia's research activity relative to the size of its economy and rankings compared to other institutions. Patent data, SBIR/STTR awards, and VC activity were used to identify top companies and sectors involved in innovation activity and also to benchmark overall levels of innovation activity relative to the size of the economy and nationally.

FIGURE 1. VISION 2025 PROJECT TIMELINE



The RTI team performed over 60 interviews and focus groups. These interviews spanned SBIR/STTR awardee companies and large chemicals and aerospace manufacturers, industry trade associations, high-tech parks, and federal laboratories. RTI spoke with administrators, faculty, and staff at West Virginia higher education institutions, including the West Virginia University (WVU) and Marshall University medical schools and the Rockefeller Neuroscience Institute. The RTI team interviewed the program directors of TechConnectWV, Innova, the Benedum Foundation, and multiple non-profits engaged in STEM education, technology commercialization, and helping companies access early-stage financing. Finally, RTI spoke with representatives from state government agencies to understand how they partner and work with West Virginia universities to support West Virginia's strategic economic and workforce development objectives.

The findings from the data analysis, stakeholder interviews, and other research were used to identify high-priority S&T platforms using a strengths, weaknesses, opportunities, and threats (SWOT) analysis. Goals, actions, and metrics were developed and prioritized to align with stakeholders' vision of where West Virginia should be aiming.

Throughout this four-month project, the RTI team worked closely with the WV Science and Research Council working group. The draft West Virginia Vision 2025 S&T Plan was presented to the full Science and Research Council at the end of March and their feedback was incorporated. The final plan was adopted by the Council in April 2021.

Photo: Mark Webb; Marshall University

2. The Vision

The world is embracing science and technology to solve big problems and to drive future economic growth and production efficiencies.

What type of research and innovation activities should West Virginia be nurturing and pursuing? What key actions can West Virginia take today that will put the state on a stronger economic growth trajectory?

The five-year plan presented in this report is fully supported by the three EPSCOR RII Track-1 universities.[1] It articulates the shared vision of what West Virginia can accomplish by continuing to work together, as well as in partnership with other public and private S&T stakeholders. The plan actions build on existing collaborative efforts and reflect a long-standing commitment to developing West Virginia's STEM talent pipeline development, research enterprise, innovation and entrepreneurship, and high-tech industry base.

Figure 2 presents stakeholder-inspired aspirations for West Virginia's S&T enterprise and economy. This vision was generated by stakeholder response to two questions:

- What is your vision of the role that S&T plays in West Virginia's future?
- How does this vision translate into the type of activities and characteristics that you would like to see occurring in West Virginia?

FIGURE 2. STAKEHOLDER VISION FOR ROLE OF S&T IN WEST VIRGINIA'S ECONOMY

	VISION
STEM Talent Pipeline	• Companies come to WV because of availability of STEM talent • Applied research experiences pique student interest in high-tech career pathways • WV students, including rural and first-generation, actively pursue STEM degrees
Research Enterprise	• WV is recognized for its academic research in target platforms • Companies seek WV technical expertise and R&D collaboration
Innovation & Entrepreneurship	• Startup successes are visible and celebrated • WV startups attract more SBIR/STTR funding and VC to scale operations
High-Tech Companies	• WV is home to dynamic high-tech companies and industries • Business R&D and innovation activity grows
Stakeholder Alignment	• Industry-university-government stakeholders agree on role of S&T in WV's economy • Stakeholder collaboration on S&T goals and actions builds trust

1 *These three universities are West Virginia University, Marshall University, and West Virginia State University.*

3. Vision 2025: West Virginia's S&T Plan

Vision 2025, West Virginia's five-year S&T plan, harnesses the aspirations of West Virginia stakeholders, alongside data-driven analysis and interview-generated perspectives, to present a clear picture of what West Virginia is doing well in STEM-based education, research, innovation, and industrial activity and what challenges remain. The Plan identifies specific goals and recommends a set of actions aligned to each goal to move West Virginia forward.

"To achieve great things, two things are needed: a plan and not quite enough time."

– Leonard Bernstein, composer and conductor

Photo: Alex Wilson; West Virginia University

3.1 Plan Goals

A good plan channels and directs the energy of individual stakeholders towards the larger end game. Good plans are liberating because good plans have a bias towards action.

STaR at WV HEPC and the WV Science and Research Council sought to achieve two main objectives through the work undertaken:

1. Identify high-priority S&T research areas aligned to target industries, and
2. Develop a plan for strengthening these STEM research areas to increase West Virginia competitiveness and generate economic growth.

The Vision 2025 goals are important to the state from a STEM education and research stature perspective. They contribute to the state's economic growth and dynamism. The goals are measurable on an annual basis. Figure 3 presents the S&T plan goals aligned to stakeholders' vision for West Virginia.

FIGURE 3. VISION 2025: STAKEHOLDER ASPIRATIONS AND GOALS

	VISION	GOALS
STEM TALENT PIPELINE	• Companies come to WV because of availability of STEM talent • Applied research experiences pique student interest in high-tech career pathways • WV students, including rural and first-generation, actively pursue STEM degrees	• Increase two- and four-year STEM degree enrollment (in line with U.S. growth) • Increase applied research experiences and internships supported by federally funded grants and the Research Challenge Fund • Increase STEM degrees conferred (in line with U.S. growth)
RESEARCH ENTERPRISE	• WV is recognized for its academic research in target platforms • Companies seek WV technical expertise and R&D collaboration	• Increase number of PhDs • Increase research expenditures in target platforms (in line with U.S. growth)
INNOVATION & ENTREPRENEURSHIP	• Startup successes are visible and celebrated • WV startups attract more SBIR/STTR funding and VC to scale operations	• Increase industry-university R&D activity • Increase innovation activity, invention disclosures, and patenting • Increase SBIR/STTR awards
HIGH-TECH COMPANIES	• WV is home to dynamic high-tech companies and industries • Business R&D and innovation activity grows	• Attract more R&D-oriented federal operations with contracting activity • Ensure WV has the infrastructure, facilities, and access to specialized equipment appropriate for high-tech companies • Work with WV DED on proactive recruitment of high-tech companies
STAKEHOLDER ALIGNMENT	• Industry-university-government stakeholders agree on role of S&T in WV economy • Stakeholder collaboration on S&T goals and actions builds trust	• Re-establish good communication among stakeholders • Collaborate on big opportunities and work together on tough challenges

3.2 Target S&T Platforms

Four high-priority S&T platforms were identified as Vision 2025 plan focus areas for development:

- Life Sciences
- Computer and Data Science
- Advanced Manufacturing
- Advanced Energy

Within each S&T platform, second-level research areas were also identified. Examples include Neuroscience and Environmental Science and Natural Resources within the Life Sciences platform, Chemicals and Materials within Advanced Manufacturing, and Efficiencies and Decarbonization within Advanced Energy, among the others shown in Figure 4.

Both the Vision 2025 S&T platforms and research areas build upon fundamental research strengths in disciplines such as physics, astrophysics, biology, genomics, chemistry, materials, and geology. The four platforms also build on the research talent and infrastructure developed through West Virginia's previous NSF ESPSoR Research Infrastructure Improvement Program Track-1 grants.[2]

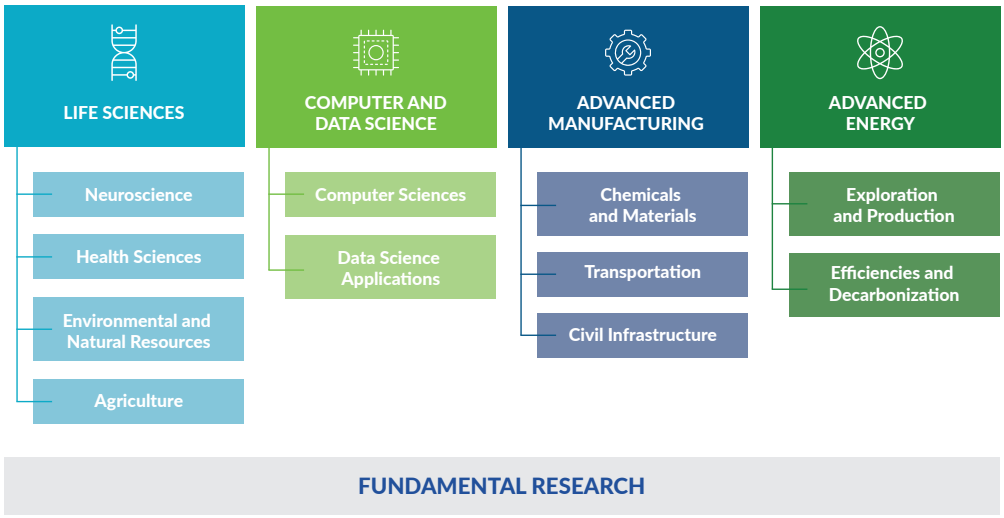
The S&T platforms and second-level research areas meet two or more of the following criteria:


Photo: Mark Webb; Marshall University

- Large and growing university-based research and educational activities,
- Strong alignment with state target industries and workforce needs,
- Active patenting and innovation activity, and
- Leverage megatrends affecting a wide swath of industries

RTI used a strengths, weaknesses, opportunities, and threats (SWOT) analyses to validate these S&T platforms for Vision 2025. The SWOTs are presented in Section 4.

FIGURE 4. S&T PLATFORMS FOR VISION 2025: WEST VIRGINIA S&T PLAN



2 *The two themes of the current West Virginia NSF RII Track 1 award are Gravitational Waves Astrophysics and the Appalachian Freshwater Initiative.*

3.3 Recommended Actions

The RTI team, working with the WV Science and Research Council working group, developed a set of recommended actions to advance the Vision 2025 goals over the next five years (2021-2025). Many of the recommended actions build on existing initiatives and collaborative efforts between higher education, industry, and government partners. Other actions re-establish state programs recognized for contributing to research capacity-building in the past. Each action is supported by a strong business case.

The opportunities and case for change that underpin the Vision 2025 goals and set of actions are summarized in Figure 5.

FIGURE 5. OPPORTUNITIES AND CASE FOR CHANGE ALIGNED TO VISION 2025

STEM TALENT PIPELINE

- 60% of adults will need a two-year or four-year degree by 2030 (31% hold these degrees currently)
- From 2016-2020, enrollment in two-year and four-year colleges and universities declined by -8.0%

R&D ENTERPRISE

- WV has one R1 research university and one R2 university[2], but needs more robust R&D activity in target platforms at its public universities
- R&D expenditure growth lower than the U.S. average, need higher than average growth to improve over time

INNOVATION & ENTREPRENEURSHIP

- WV ranks near the bottom (bottom 10% of states) for patenting, new business creation, VC investment; need much more technology-based innovation activity
- Small number of SBIR/STTR awardees, but some growth (bottom 20% of states)

HIGH-TECH COMPANIES

- Low level of business R&D expenditures (0.36% of private sector output)
- Most common way to recruit high-tech companies is through M&A of startups, so need to focus on both new and existing companies

STAKEHOLDER ALIGNMENT

- Individual institutional efforts to support WV's S&T enterprise, but need above average growth in R&D expenditures, new innovations, new companies to catch up
- Examples of productive collaboration on Virgin Hyperloop, Opportunity Move, aerospace workforce development; need more of this

3 *Carnegie R1 and R2 classifications refer to doctoral universities with very high research activity (R1) and high research activity (R2) based on research expenditures and number of research doctorates conferred. See the Carnegie Classification of Institutions of Higher Education. About Carnegie Classification. http://carnegieclassifications.iu.edu Retrieved April 14, 2021.*

Vision 2025 will require the time, energy, and resources of West Virginia higher education, government, and private sector stakeholders to truly generate movement on macro-level goals, such as two-year and four-year STEM degree enrollment or increasing West Virginia's research stature and innovation activity in the target S&T platforms. However, the Plan seeks to strike a balance between actions that require state investment and actions that can be supported through federal government, private sector, and philanthropic support. Plan goals and actions are presented below.

3.3.1 STEM Talent Pipeline

Nationally, STEM occupations are projected to grow twice as fast as occupations overall during the next 10 years: 0.8% compound annual growth rate (CAGR) for STEM occupations versus 0.4% CAGR for all occupations.[4] RTI analysis of West Virginia employment growth by industry sector over the past 5 years (2014-2019) shows high demand for STEM workers in the healthcare, manufacturing, and professional and technical services sectors (e.g., computer systems design, software, data processing, engineering, and technical consulting) (See Appendix 3.)

STEM occupations require a two-year or four-year STEM degree, and Vision 2025 goals include increasing STEM enrollment and STEM degrees conferred, as well as increasing research experiences and internships which help to retain students in STEM and to improve career pathways.

RTI analysis of STEM degrees awarded by West Virginia public universities from 2016-2020 indicates higher growth rates for STEM bachelor's and STEM doctoral degrees compared to all bachelor's and doctoral degrees conferred over the past five years.[5] However, West Virginia is starting from a low base with ample room and need to grow. For example, West Virginia State University conferred 33 STEM bachelor's degrees in 2020, West Virginia University Institute of Technology conferred 101, Marshall University conferred 308, and WVU conferred 1,423.

Consequently, the first recommended action calls for a continued focus on expanding K-12 STEM mentoring and research opportunities for teachers and students. This action builds on highly regarded programs, such as the NIH-supported Health Sciences & Technology Academy (HSTA) mentoring program for West Virginia high school students, which reports the following 20-year impact data:

- 2,879 high school students graduated from HSTA from 1998-2019.
- 99% of HSTA graduates attend college.
- 89% graduate from college; 86% of these students graduate with a 4-year degree or higher.
- 84% stay in West Virginia to work.

FIGURE 6. STEM TALENT PIPELINE GOALS AND ACTIONS

GOALS	ACTIONS
◯ Increase two-year and four-year STEM degree enrollment (in line with U.S. growth rate)	◯ Expand K-12 STEM opportunities for teachers and students
◯ Increase research experiences and internships supported by federally funded grants and the Research Challenge Fund	◯ Partner with HSTA, First2Network, etc., to prepare and retain STEM college students
◯ Increase STEM degrees conferred (in line with U.S. growth rate)	◯ Partner with companies and federal labs to increase internships

4 *Alan Zilberman and Lindsey Ice (2021). "Why computer occupations are behind strong STEM employment growth in the 2019–29 decade," Employment & Unemployment. U.S. Bureau of Labor Statistics. January 2021. https://www.bls.gov/opub/btn/volume-10/why-computer-occupations-are-behind-strong-stem-employment-growth.htm*

5 *RTI uses the U.S. Department of Homeland Security STEM-designated degree program list which identifies STEM degrees by 2-digit and 6-digit Classification of Instructional Program (CIP) codes. https://www.ice.gov/sites/default/files/documents/stem-list.pdf*

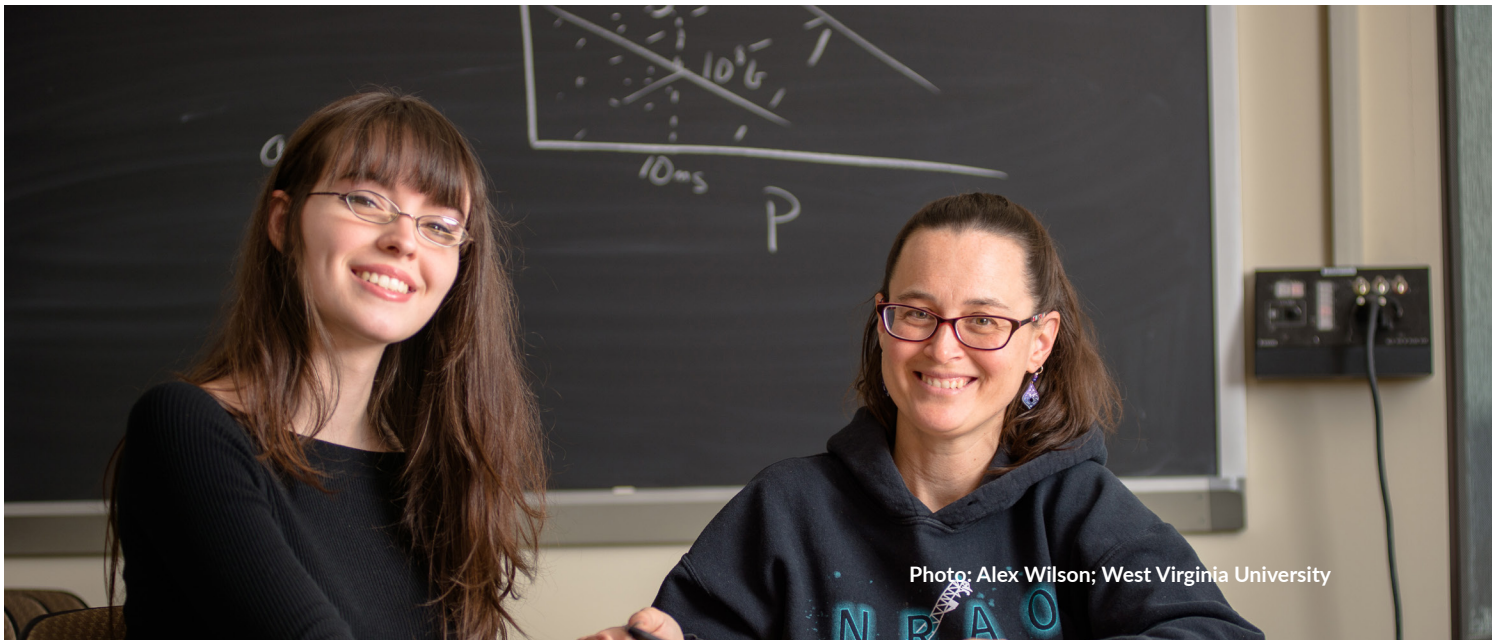


Photo: Alex Wilson; West Virginia University

- On average, HSTA students earn $30,000 per year more than their parents.
- State schools provide substantial tuition support through medical school and other advanced STEM-based degrees.[6]

Action two focuses on partnering with HSTA, the NSF-supported First2Network, and similar programs to prepare and retain STEM college students.

A final recommended action that relates to graduates is the importance of increasing funding for WV Promise to ensure that two-year and four-year degree programs are affordable for West Virginia students. The share of tuition that the WV Promise Scholarship covers has fallen from 94% of the average tuition and fees at a four-year public college or university in 2010 to 63% in 2020.[7]

3.3.2 Research Enterprise

Both basic and applied R&D drive the incremental and breakthrough innovation that enhance functionality, increase throughput and productivity, and lead to entirely new products and services that did not exist before. In West Virginia, total R&D performance (R&D performed by industry, academia, and government) decreased 29.6 % in real terms since 2000.[8]

This decline is due largely to the steep decrease in West Virginia's business R&D expenditures. Business R&D expenditures declined from 1.0% of private sector output in 1998 to 0.36% of private sector output in 2018.[9],[10] While West Virginia's academic research expenditures have grown over the past decade, led by WVU, the 2.3% CAGR in total West Virginia academic R&D expenditures is less than the national average of 3.5% CAGR over the past decade.[11]

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6 *Health Sciences & Technology Academy (2021). "What is HSTA?" Accessed April 2, 2021. http://www.wv-hsta.org/about-hsta/faqs/what-is-hsta/*

7 *O'Leary, Sean. "Disinvestment in Higher Education Continues to Hurt West Virginia's Future." Blog Post. West Virginia Center on Budget & Policy. https://wvpolicy.org/disinvestment-in-higher-education-continues-to-hurt-west-virginias-future/*

8 *National Science Board (2020). Science & Engineering Indicators 2020: State of West Virginia One Pager. https://nsf.gov/nsb/sei/one-pagers/state/2020/West-Virginia.pdf*

9 *National Science Board. "Business-Performed R&D as a Percentage of Private-Industry Output." Science and Engineering Indicators: State Indicators. Alexandria, VA: National Science Foundation.*

10 *In the 1970s and 1980s, the Union Carbide South Charleston Technical Center was one of the most highly regarded R&D facilities of its kind in the chemicals and plastics industry. The R&D facility employed nearly 3,000 people, including nearly 300 PhD However, financial difficulties in the late 1980s and 1990s resulted in Union Carbide's acquisition by Dow in 2001. Dow decided to consolidate many Union Carbide R&D and engineering groups from Charleston to its existing facilities in Michigan and Texas beginning in 2004. See Gary Brown (2018). "Carbide's Tech Center was a special place," Charleston Gazette Mail. 9 August 2018. Accessed April 3, 2021. https://www.wvgazettemail.com/dailymailwv/daily_mail_features/gary-brown-carbides-tech-center-was-a-special-place-daily-mail-wv/article_88ca5f16-ecd4-5477-ab84-c15724b67747.html*

11 *RTI analysis of 2009-2019 National Science Foundation Higher Education Research & Development Survey data.*

FIGURE 7. RESEARCH ENTERPRISE GOALS AND ACTIONS

GOALS

- Increase number of PhDs to support research activity
- Increase research expenditures in target platforms (in line with U.S. growth rate)

ACTIONS

- Re-establish $4.5M funding model for Research Challenge Fund (to seed work on larger competitive grants, provide PhD scholarships, etc.)
- Win large federal capacity-building grants (e.g., NSF EPSCoR, NASA EPSCoR, NIH IDeA, etc.)
- Increase federal R&D grants and contracts in target platforms
- Identify critical lab and facility needs and assess funding mechanisms in other states

This Research Enterprise section of the plan presents actions for increasing West Virginia's academic research stature in the four S&T platform areas. (Actions for spurring more business R&D, innovation, and entrepreneurship are presented in the Innovation & Entrepreneurship section.)

Currently, West Virginia has one R1 research university, WVU, and one R2 university, Marshall University. West Virginia State University is also engaged in research. It is the state's second land-grant university and a historically black college and university. Marshall and WVSU are actively working to increase their research stature which, in turn, helps to improve competitiveness in attracting more federal research dollars and students to West Virginia and to increase their economic development footprints locally. Other, primarily undergraduate, higher education institutions are also working to expand their research activities.

Vision 2025 identifies two five-year goals that build towards the state's longer-term vision of having more robust research activity across all public universities in the target S&T platforms:

- Increase the number of doctoral students (i.e., PhDs students) to support academic research activity and
- Increase R&D expenditures in the four S&T platforms.

To make progress on these goals, West Virginia stakeholders will need to execute on four actions over the next five years. West Virginia will need to win large federal capacity-building grants, such as NSF EPSCoR, NASA EPSCoR, NIH IDeA, etc. These multi-million-dollar five-year federal grants provide funding to hire new faculty and invest in equipment and other research infrastructure.

Second, West Virginia should re-establish the original funding model for the Research Challenge Fund with the goal of returning the Fund to its original $4.5 million a year. It is currently funded at $1.5 million a year. The Research Challenge Fund provides funding for research projects that later form the basis of larger competitive research center grant proposals, provides scholarships for 20 PhD students (STEM Fellows), supports external peer review services for faculty proposals, and provides cost share for the NSF EPSCOR grant.[12] A machine learning group (the Center for Cognitive Computing) that received Research Challenge Grant support is now a part of West Virginia's EPSCoR proposal to NSF.

A third recommended action is to leverage the capacity-building resources of the first two actions to help West Virginia pursue and win more competitive federal grants and contracts in the four S&T platforms identified in Vision 2025.

Finally, in the same way that the shift to a digital economy requires broadband infrastructure, increasing the amount of research performed necessitates labs and equipment to conduct research. West Virginia colleges and universities have identified critical lab and facility needs and should assess the funding mechanisms used in other states to support these

12 *A comprehensive description of the Research Challenge Fund can be found at: https://westvirginiaresearch.org/research-challenge-fund Retrieved April 14, 2021.*

investments. Other states support higher education capital projects periodically or on an annual basis via the issuance of bonds or state budget appropriations. For example, in Tennessee, state appropriations fund new construction and capital maintenance projects at higher education institutions. The Tennessee Higher Education Commission (THEC) prioritizes capital project requests based on Commission selection criteria, and the highest priority projects are recommended for inclusion in the Governor's budget.[13]

3.3.3 Innovation and Entrepreneurship

Innovation is the introduction of new products, new processes, new marketing methods, and new business models to the market.[14] Union Carbide's commercial process for making polyethylene was a process innovation. FedEx's hub-and-spoke model for package delivery was a business model innovation. Telsa's electric cars represent both a product innovation and a marketing innovation.

Companies create jobs in response to significant revenue growth, and revenue growth stems from strong customer demand for a new product or service. By contrast, a business strategy that is primarily focused on cost cutting (rather than innovation) is less likely to generate revenue growth and jobs.

For West Virginia to generate the higher rates of real GDP growth that it needs (double or triple West Virginia's 0.7% per year inflation-adjusted GDP growth rate from 2015-2019) will require more companies that are active innovators.

What types of behaviors should the Vision 2025 Plan encourage and incentivize among West Virginia companies and higher education institutions?

Vision 2025 goals for Innovation & Entrepreneurship include:

- Increase the number of industry-university R&D collaborations,
- Increase innovation activity, invention disclosures, and patenting by West Virginia companies, and
- Increase the number of SBIR/STTR awardees, the federal government's seed fund supporting the commercialization of early-stage technologies.

Industry-university R&D collaborations are beneficial to both companies and universities for several reasons. Both small and large companies require external scientific and technical expertise, from time to time, to overcome challenges involved in commercializing a new product. In addition to accessing faculty expertise, companies gain access to students, university facilities and specialized equipment. Both finding a solution to a technical challenge and identifying students to hire upon their graduation are valuable to companies.

From the university perspective, research projects with companies provide an opportunity for faculty to engage in commercially oriented projects, to see where there may be gaps between academic programs and industry needs, and to provide students with applied research experiences.

FIGURE 8. INNOVATION & ENTREPRENEURSHIP GOALS AND ACTIONS

GOALS	ACTIONS
◯ Increase number of industry-university R&D collaborations	◯ Pilot $350K WV R&D Voucher Program
◯ Increase innovation activity, invention disclosures, and patents	◯ Support FAST Program led by TechConnectWV and WV SBDC
◯ Increase number of SBIR/STTR awardees and awards	◯ Fund $1.1M for WV Entrepreneurship & Innovation Investment Fund (SBIR/STTR match)

13 *See Tennessee Higher Education Commission. 2020-21 Capital Projects Recommendation. https://www.tn.gov/content/dam/tn/thec/bureau/fiscal_admin/capital_outlay/capital-budget/captbudget/2020-21%20Capital%20Recommendation_TC.pdf*

14 *Organization for Economic Cooperation and Development (2021). Definition of Innovation. Accessed April 3, 2021. https://www.oecd.org/site/innovationstrategy/defininginnovation.htm*

Therefore, action one calls for West Virginia to pilot an R&D voucher program modeled on Maryland's Industrial Partnership Program and the Massachusetts Innovation Voucher Program. Maryland's R&D voucher provides up to $100,000 for a company to perform a research project with a faculty researcher at any public university in the state. Existing companies match the amount requested from the state 1:1 ($50,000 match for $50,000 R&D voucher), but startups are only required to match 1:9 ($10,000 match for $90,000 R&D voucher). The company submits a short proposal with a faculty researcher.[15] The Massachusetts Innovation Voucher Program subsidizes small company (fewer than 50 employees) access to specialized equipment and fabrication tools housed at public universities.

The second action recommends state support for the SBA Federal and State Technology (FAST) Partnership Program led by TechConnect WV and the WV Small Business Development Center (SBDC). FAST provides one year of program funding to provide outreach, technical assistance, and financial support to help increase SBIR/STTR applications and award rates.

The third action continues support for West Virginia small companies working to commercialize new technologies by requesting $1.1 million per year of State support for the West Virginia Entrepreneurship & Innovation Fund, the West Virginia's SBIR/STTR matching fund program. These matching funds are used by small high-tech businesses that have received Phase 1 or Phase 2 awards to cover unallowable SBIR/STTR project costs, such as costs related to protecting intellectual property or to provide gap funding in the period between SBIR/STTR phases (e.g., Phase 1 to Phase 2, Phase 2 to Phase 3).

3.3.4 High-Tech Companies

West Virginia needs more high-tech, high-growth potential companies, and many stakeholders (state government agencies, universities, industry trade associations, and high-tech parks) are actively working to support homegrown companies and to recruit new ones. The previous section discussed the Vision 2025 Plan for supporting more innovation activity among startups and existing companies. This section focuses on strategies to improve the recruitment of companies.

Vision 2025 goals for High-Tech Companies include:

- Attract more R&D-oriented federal operations with contracting activity,
- Ensure WV has the infrastructure, facilities, and access to specialized equipment appropriate for high-tech companies,
- Work with the WV DED to proactively recruit high-tech and R&D-based companies

West Virginia is home to several federal laboratories and R&D-oriented operations that the state has attracted. Some of these facilities generate significant contracting activity to meet their cybersecurity, enterprise solutions, and other mission-driven technical needs. The presence of these federal anchors have attracted high-tech companies to West Virginia. A good example is the expansion of Leidos in West Virginia. Leidos is an IT and engineering solutions company, which holds a $364 million, 10-year contract with the U.S. Department of Energy's National Energy Technology Laboratory in Morgantown and Pittsburgh, as well as a $109 million, five-year task order contract to manage the cybersecurity operations for the National Oceanic and Atmospheric Administration's Fairmont facility and three others (in Maryland, Colorado, and Washington, DC).[16] Leidos has approximately 300 people at its office in Morgantown.[17]

Action one is for government-industry-university stakeholders to support Opportunity Move, West Virginia's federal anchors strategy. The Opportunity Move Steering Committee is led by the WV DED, the WV High-Tech Foundation, and the WV

15 *The faculty member can be someone known to the company, or the company can request an introduction from HEPC to 2-3 faculty members with the requisite expertise.*
16 *Dahlia, John (2018). "Federal IT giant Leidos wins big using West Virginia-centric strategy," WV News. 17 December 2020. https://www.wvnews.com/statejournal/news/federal-it-giant-leidos-wins-big-using-west-virginia-centric-strategy/article_77923fbc-8d85-5d8e-8bb6-0ac88da6f6a3.html*
17 *Shaver, John M. (2020). "Leidos builds new software factory in Morgantown, WV while adjusting to remote working," WV News. 30 May 2020. https://www.wvnews.com/news/wvnews/leidos-builds-new-software-factory-in-morgantown-wv-while-adjusting-to-remote-working/article_d5653512-8cb9-516f-a0b4-a1effb4b1670.html*

Photo: Alex Wilson; West Virginia State University

Regional Technology Park. A second and related action is to invest in sites identified by the Opportunity Move Steering Committee. These could include regional high-tech parks, but also others (e.g., Beckley Airport site). The quality of infrastructure and facilities could factor into Opportunity Move decisions.

Third, continue WV DED and higher education collaboration on high-tech company recruitment and build a stronger business case for West Virginia as a location—especially in terms of workforce. The quick and proactive outreach by WV DED and the universities on the Virgin Hyperloop recruitment is an example of the positive impact of these collaborative efforts. Virgin Hyperloop is a proposed high-speed alternative transportation system that would move passengers and cargo between large cities. Demonstration work is currently being undertaken at select sites across the country and around the world.

Another is the launch of the Ascend West Virginia remote worker program. In March 2021, the State and WVU, with support from Brad and Alys Smith, launched Ascend West Virginia to attract high-tech workers who can work anywhere in the country and who would value and enjoy the lifestyle afforded by West Virginia.

FIGURE 9. HIGH-TECH COMPANIES GOALS AND ACTIONS

GOALS

- ◯ Attract more R&D-oriented federal operations with contracting activity
- ◯ Ensure WV has the infrastructure, facilities, and access to specialized equipment appropriate for high-tech companies
- ◯ Work with the WV DED to proactively recruit high-tech and R&D-based companies

ACTIONS

- ◯ Support Opportunity Move, the federal anchors strategy
- ◯ Invest in sites identified by Opportunity Move Steering Committee
- ◯ Leverage R&D Vouchers Program
- ◯ Continue collaboration on high-tech recruitments and WV business case development

3.3.5 Stakeholder Alignment

West Virginia has a large number of stakeholders who are fully vested and committed to realizing the vision for the role that S&T can play in developing West Virginia's economy. The S&T Plan helps to define how the S&T enterprise contributes to West Virginia's economy and to focus stakeholder attention on high-priority goals and actions. Collaboration starts with communication but grows from the experience of working together on defined projects.

Action one recommends the WV Science and Research Council organize two meetings a year for legislators and the executive branch with a curated agenda around one category of West Virginia S&T Plan goals. The agenda could be structured to answer a set of questions, such as: Why is this goal important to West Virginia's long-term growth and diversification? What actions has West Virginia taken to advance this goal? How are these programs or initiatives impacting the decisions and trajectories of West Virginia students, companies, startups?

In the same way that universities and the WV Department of Economic Development (DED) have partnered on the Virgin Hyperloop opportunity or the High Technology Foundation and the WV DED have partnered on Opportunity Move, action two identifies 2-3 projects a year for stakeholder collaboration and reporting on outcomes at Science and Research Council meetings.

3.4 Metrics

Circling back to the Bernstein quote about needing a good plan and not quite enough time to achieve great things, five years is a good timeframe for West Virginia to pilot the proposed actions and assess their initial impacts. The Vision 2025 Plan recommends two types of metrics: metrics to measure progress on goals and metrics to measure execution, or progress on actions.

- Metrics aligned to goals: Annual data to measure progress on Vision 2025 goals already exist and are collected by federal government agencies, WV HEPC, WV DED, and other stakeholders.
- Metrics aligned to actions: Action-level data can be collected at the program, institution, or grant level. These metrics can be used to assess action execution and to identify momentum or challenges encountered. They also measure contributions toward goals since the actions are strongly aligned with the Vision 2025 goals.

The table below shows the data sources for the metrics aligned to Vision 2025 goals.

The data collected on each of the goals will help STaR at WV HEPC track state-level impacts. However, the area where stakeholders have more control to influence near-term outcomes in the recommended set of actions. Table 2 presents the metrics for tracking progress on Vision 2025 actions.

FIGURE 10. STAKEHOLDER ALIGNMENT GOALS AND ACTIONS

GOALS	ACTIONS
◯ Industry-university-government stakeholders agree on role of S&T in WV economy	◯ Organize 2x meetings a year for industry, legislators and executive branch on S&T Plan topics
◯ Stakeholder collaboration on S&T goals and actions build trust	◯ Identify 2-3 projects a year for stakeholder collaboration; report on outcomes at Science and Research Council Meetings and in other venues and publications

TABLE 1. METRICS ALIGNED TO GOALS

STEM TALENT PIPELINE	
Goals	**Data Source**
Increase two-year and four-year STEM degree enrollment (in line with U.S. growth)	Institutions, WV HEPC
Increase research experiences and internships supported by federally funded grants and the Research Challenge Fund	Institutions, WV HEPC
Increase STEM degrees conferred (in line with U.S. growth)	Institutions, WV HEPC
RESEARCH ENTERPRISE	
Goals	**Data Source**
Increase number of PhDs (to support research activity)	Institutions, WV HEPC
Increase research expenditures in target platforms (in line with U.S. growth)	Institutions, NSF HERD
INNOVATION & ENTREPRENEURSHIP	
Goals	**Data Source**
Increase number of industry-university R&D collaborations (# of companies and amount of industry-sponsored research, sub-awards to industry, # of licenses and amount of licensing, amount generated by equipment use fees)	Institutions
Increase innovation activity, invention disclosures, and patents awarded	Institutions, USPTO
Increase number of SBIR/STTR awardees (# of awardees, # and amount of awards by phase)	SBIR/STTR Award Database
HIGH-TECH COMPANIES	
Goals	**Data Source**
Attract more R&D-oriented federal operations with contracting activity	WV HTF, WV DED
Ensure WV has the infrastructure, facilities, and access to specialized equipment appropriate for high-tech companies	WV HTF, WV RTP
Work with the WV DED on proactive recruitment of high-tech companies	WV DED
STAKEHOLDER ALIGNMENT	
Goals	**Data Source**
Re-establish good communication among stakeholders	WV HEPC
Collaborate on big opportunities and work together on tough challenges	WV HEPC

TABLE 2. METRICS ALIGNED TO ACTIONS

STEM TALENT PIPELINE

Plan Actions	Metrics
• Expand K-12 STEM opportunities for teachers and students • Partner with HSTA, First2Network, etc., to prepare and retain STEM college students • Partner with companies and federal labs to increase internships	• # of students or teachers served • longitudinal tracking of degree pursued to first job • # of companies and organizations offering internships • # of students participating • longitudinal tracking of staying in field and job placements

RESEARCH ENTERPRISE

Plan Actions	Metrics
• Re-establish $4.5M funding model for Research Challenge Fund (to seed work on larger competitive grants, provide PhD scholarships, etc.) • Win large capacity-building grants (NSF EPSCoR, NASA EPSCoR, NIH IDEA, etc.) • Increase federal R&D grants and contracts in target platforms • Identify critical lab and facility needs and assess funding mechanisms in other states	• # of seed projects • # of funded projects that become basis for major grants • # of PhD scholarships • # and size of proposals submitted • # and size of projects awarded • # and size of proposals submitted • # and size of projects awarded • prioritized list and estimated cost • identified funding mechanisms used in other states

INNOVATION & ENTREPRENEURSHIP

Plan Actions	Metrics
• Pilot $350K WV R&D Voucher System • Support FAST Program led by TechConnectWV and WV SBDC • Fund $1.1M for WV Entrepreneurship & Innovation Fund (SBIR/STTR match)	• # of companies that submit expression of interest • # of companies-faculty PIs that apply • # of awards made • Products commercialized, students hired • # of SBIR/STTR applications by phase • # of unique SBIR/STTR applicants, # of applications by phase, # of awards by phase

HIGH-TECH COMPANIES

Plan Actions	Metrics
• Support Opportunity Move, the Federal anchors strategy • Invest in sites identified by Opportunity Move Steering Commmittee • Continue collaboration on high-tech recruitments and WV business case development	• # of federal labs or operations attracted, # of jobs created • Opportunity Move site recommendations • priority needs identified with estimated cost • amount of investment secured for relocation project • # of projects pursued jointly • # of successes • reasons cited by companies if decided to locate in another state

STAKEHOLDER ALIGNMENT

Plan Actions	Metrics
• Organize 2x meetings a year for legislators and executive branch on WV S&T Plan topics • Identify 2-3 projects a year for stakeholder collaboration; report on outcomes at Science and Research Council Meetings and in other venues and publications	• # meetings • # attendees from industry, university, government • Rating of value from participants on a scale of 1 to 4, where 1=not at all valuable, 4=extremely valuable • # of projects undertaken • Needs identified, action required, stakeholder participants, outcomes • Ratings of value from participants on a scale of 1 to 4, where 1=not at all valuable, 4=extremely valuable • Success shared at event and/or publication (yes/no; date and name of venue or publication)

4. Megatrends and S&T Platforms SWOT Analysis

4.1 Megatrends

As a small state, West Virginia does not generate sufficient levels of demand and investment within its state borders to drive the economic growth rates needed to raise household incomes. Consequently, West Virginia companies and other S&T actors need to be externally focused and aiming to leverage much larger out-of-state markets, investment dollars, and partners.

RTI performed research and analysis, including interviews with representatives from major companies and federal laboratories located in West Virginia, to identify the most important trends impacting their technology and workforce needs. Three were identified as important to the West Virginia Vision 2025 strategic planning effort:

1. Digitalization: the convergence of digital technologies across a broad swath of industry sectors,
2. Robotics and automation: the increasing use of robotics and automation to increase scale and efficiency, and
3. Sustainability and Resource Scarcity: the increasing adoption of sustainability goals by companies which impact consideration of feedstocks, process efficiencies, recycling, and conservation of scarce resources.

These mega trends represent a strong demand-pull factor and were used as one criterion in identifying S&T platforms in West Virginia's Vision 2025 Plan. Each megatrend is briefly described below.

4.1.1 Digitalization

Digitalization, the convergence of digital technologies across a broad swath of industry sectors, is driving significant changes across the U.S. and global economy. From finance to healthcare to manufacturing, employees are now spending a large part of their workday using tools that require digital skills. Federal government agencies are also incorporating aspects of digitalization to better serve constituents. Particularly, they are asked to build a 21st century digital government that deliver better digital services to the American people as part of the Digital Government Strategy. Recent analysis indicates that the share of jobs requiring high and medium digital skills rose significantly while the share of jobs requiring low digital skills declined from 2002 to 2016.

4.1.2 Robotics and Automation

Automation refers to the application of technology and robotics to routine, replicable processes currently performed by humans. Companies and federal government agencies are interested in automation technologies to increase efficiency and scale, as well as to reduce human error, all of which can improve quality and reduce cost. The impact of robotics and automation can be seen across all manufacturing industries, with the highest applications in the electrical and electronics industry, automotive industry, and metals and machinery industry. While increasing adoption of robotics and automation has shifted employment from manufacturing to service sector industries in industrialized countries, a great deal of automation is also underway in the service sector. Service sector application include

self-checkout at retail establishments, automated teller machines at banks, warehousing (order fulfillment, materials handling, or supply chain activities), email marketing, and automated customer service enabled by verbal recognition software and chatbots.

4.1.3 Sustainability and Resource Scarcity

As concern over greenhouse gas emissions, climate-related weather phenomena, and resource scarcity have grown, global companies have responded by incorporating sustainability goals and outcomes into their business strategies. According to a recent survey, 43 percent of the world's largest 250 companies report annually on UN Sustainability Development Goals.[18] To meet these goals, large companies are actively focused on process and product innovation. For example, representative of chemical manufacturers Dow, Covestro, and Solvay all use the "circular economy" framework to guide internal R&D activity and external technology scouting activity. The circular economy framework seeks to maximize product value and eliminate waste by improving how chemicals and downstream products, such as plastics, are designed, manufactured, and used. These corporate sustainability goals and metrics are factoring into the drive to increase production efficiencies, limit waste, and develop greener products. Virgin Hyperloop is another example of a company focused on using less energy to go faster and emphasizing greener and cleaner infrastructure to achieve this goal.

18 *In 2015, the United Nations adopted a set of sustainable development goals (SDGs) to be achieved by 2030. One of these goals include ensuring sustainable consumption and production patterns.*

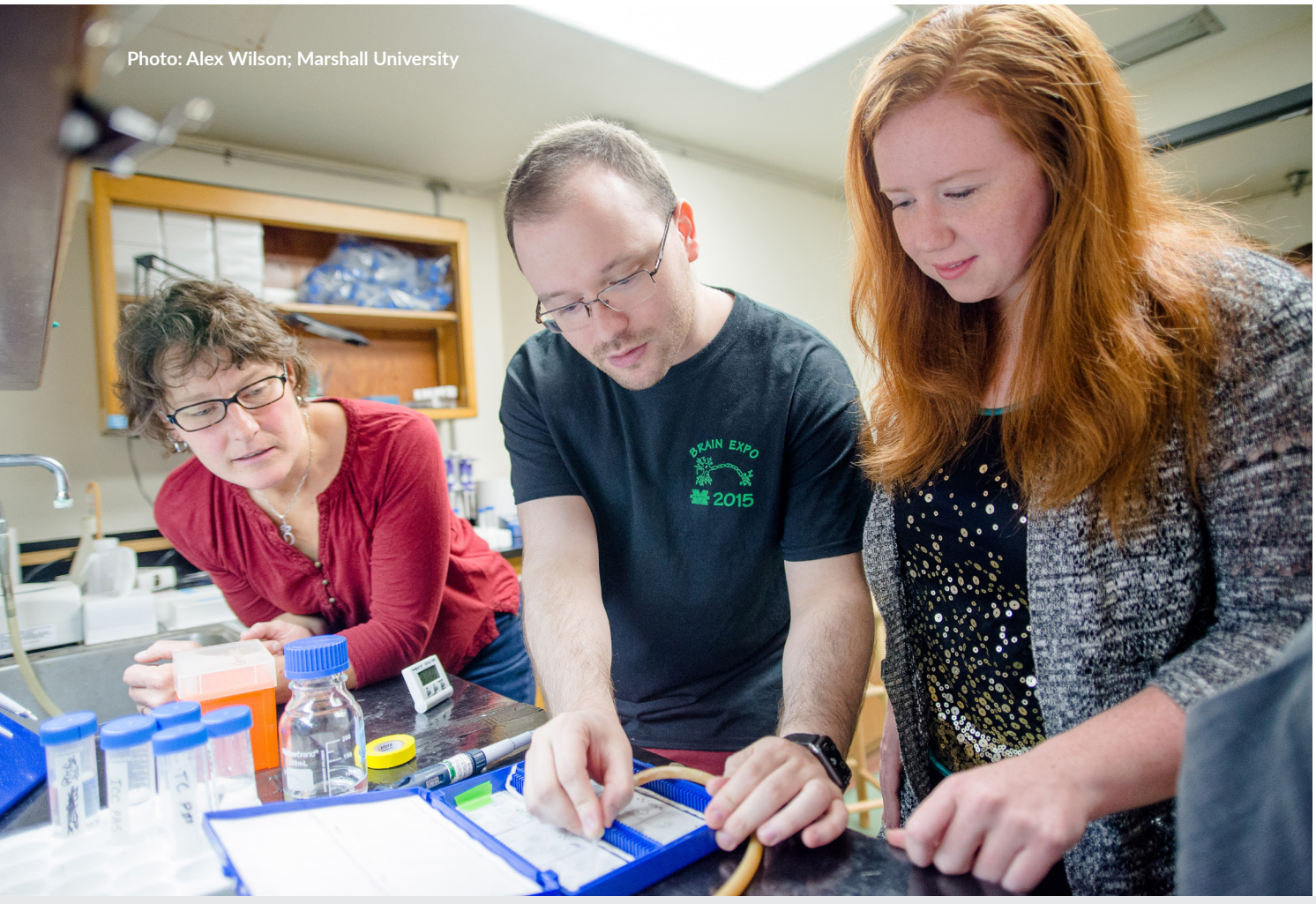


Photo: Alex Wilson; Marshall University

4.2 S&T Platforms SWOT Analysis

The RTI team used a strengths, weaknesses, opportunities, and threats (SWOT) analysis to identify high-priority S&T platforms. The S&T platforms meet two or more of the following criteria:

- Large and growing university-based research and educational activities,
- Strong alignment with state target industries and workforce needs,
- Active patenting and innovation activity, and
- Leverage megatrends affecting a wide swath of industries

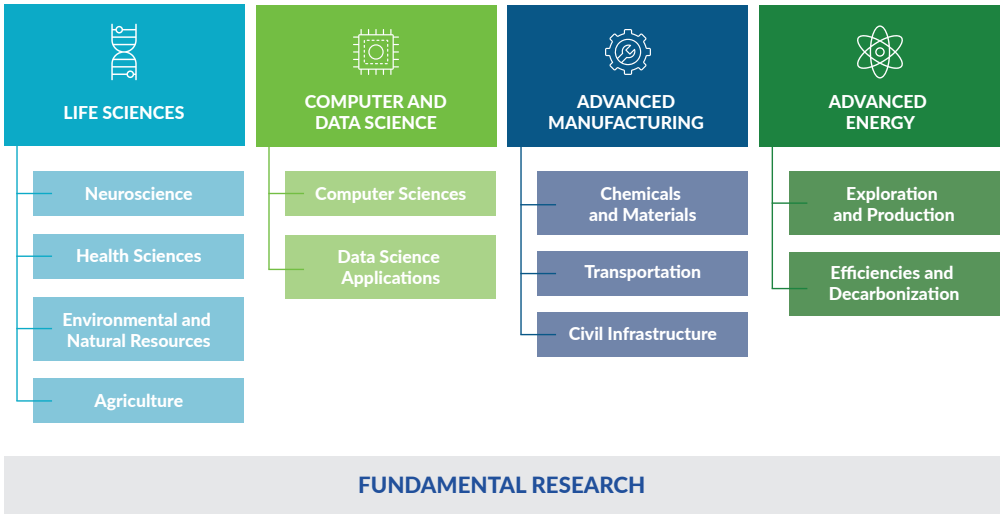
Data supporting these criteria were identified as internal strengths or weaknesses of West Virginia or as external opportunities posed by megatrends (private sector and federal government demand) and external threats posed by neighboring states that are making significant investments to enhance competitiveness.

4.2.1 Life Sciences

Life Sciences includes the Health Sciences, Environmental and Nature Conservation, and Agriculture. Healthcare is West Virginia's largest industry sector by employment, and Health Sciences accounts for the most R&D expenditures at WVU and Marshall University, anchored by the two medical schools and the Rockefeller Neuroscience Institute. West Virginia's challenge is that there are no major pharmaceutical, medical device, or health tech companies in WV outside of Mylan Pharmaceuticals, which is consolidating its manufacturing activity in Pennsylvania.[19] Vision 2025 actions to spur more research collaboration, innovation, and SBIR/STTR award activity will help seed new activity.

West Virginia needs more clinical trials infrastructure, and the West Virginia Clinical and Translational Science Institute has launched the Principal Investigators' Academy to train WVU researchers in clinical trials processes and procedures and provide mentoring of early-career researchers.[20] Other neighboring states and regions have a major focus and head start on not only health-related research and clinical trials (e.g., Cleveland, Cincinnati, Pittsburgh, Baltimore, etc.), but also innovation and startup activity.

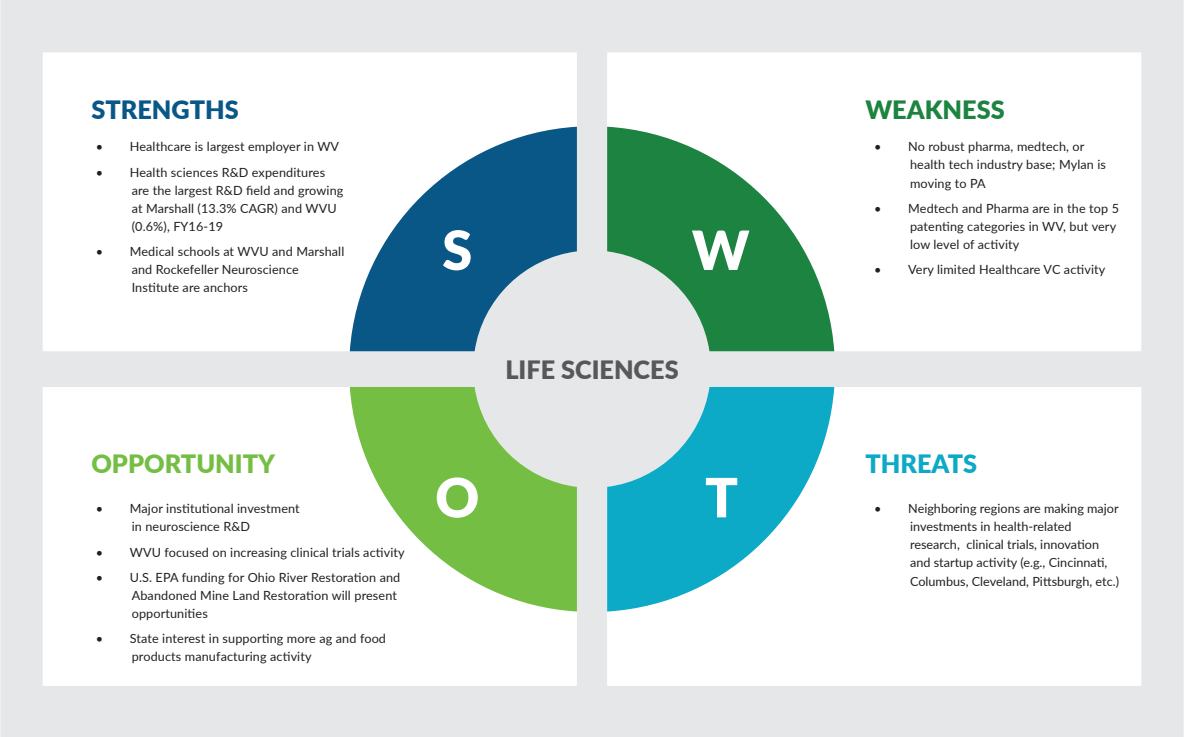
FIGURE 11. S&T PLATFORMS FOR VISION 2025: WEST VIRGINIA S&T PLAN



19 *https://www.post-gazette.com/business/career-workplace/2020/12/11/Mylan-s-Morgantown-West-Virginia-plant-restructuring-Viatris-Upjohn/stories/202012110134*

20 *https://www.hsc.wvu.edu/news/story?headline=new-training-program-designed-to-enhance-clinical-trials-in-west-virginia*

FIGURE 12. LIFE SCIENCES SWOT ANALYSIS



Within the life sciences sector, West Virginia also has environmental consulting and small-scale agriculture. The environmental consulting focuses on the environmental impact of new energy projects, mining remediation activities, and water quality. One future opportunity for West Virginia could come from U.S. Environmental Protection Agency funding for an Ohio River Restoration Initiative (modeled after the Great Lakes Restoration Initiative) and the Abandoned Mine Land restoration program proposed by the Biden administration.

In terms of agriculture, the vast majority of West Virginia farms are small, family-owned farms. However, West Virginia is actively recruiting high-value, larger scale agriculture and food companies, some of which incorporate remote sensing, data analytics, and AI. Existing small farms span beef and dairy, poultry and eggs, soybeans, apples and cider, maple syrup, forest products, and lavender. WVU and West Virginia State University are the state's two land-grant universities. They can contribute to West Virginia's agriculture and food and beverage manufacturing sectors through technical assistance and specialized workforce training and production.

4.2.2 Computer and Data Science

Computer science uses mathematics to program systems to run more efficiently. Data science uses statistics, mathematics, computer science, and information science to develop insights from data across a range of research areas and disciplines. Artificial intelligence and machine learning are examples of data science applications.

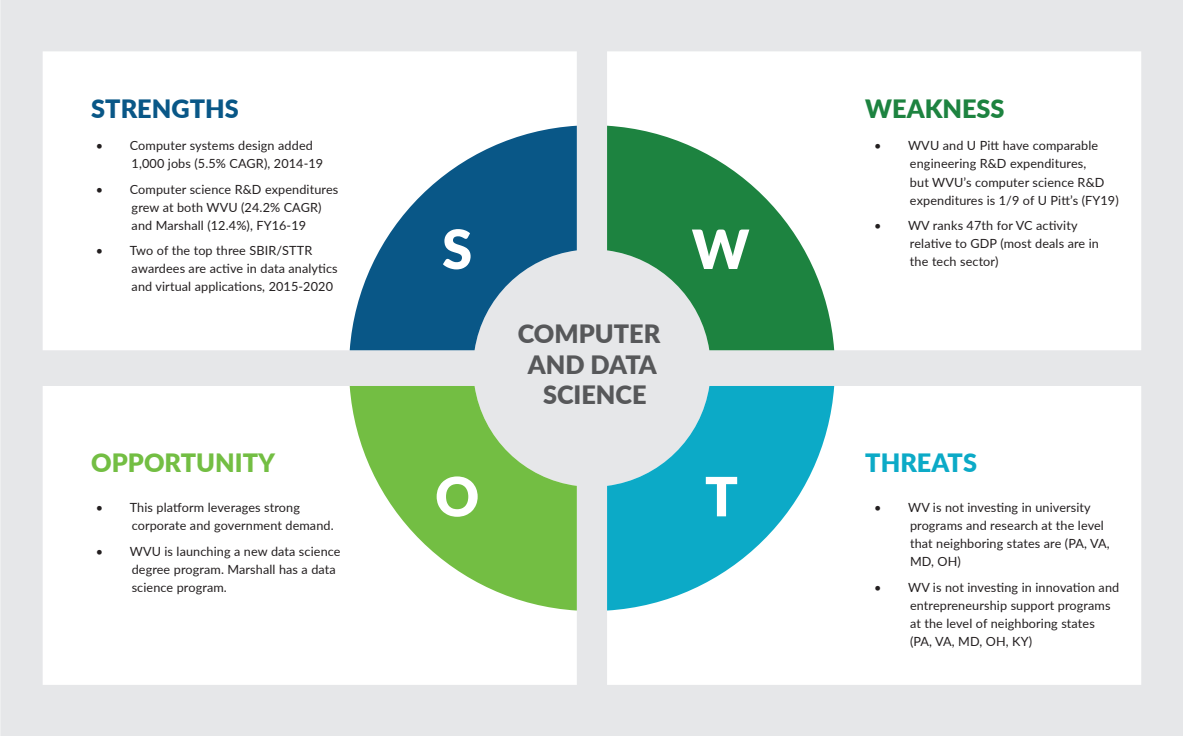
While West Virginia's total high-tech sector employment (5.6%) is half of the national average (9.9%), computer systems design was West Virginia's third largest high-tech industry segment in 2019 (and likely higher, since many of the companies in the Management of Companies and Enterprises segment are also likely to be computer systems related). The industry added 1,000 jobs from 2014-19

(5.5% CAGR). Computer science R&D expenditures at WVU and Marshall University are low but grew by 24.2% CAGR at WVU and 12.4% CAGR at Marshall from FY16-19. Computer science is one of the top two research areas with corporate co-authors (outside of health) at WVU. Marshall and WVSU also had one publication with industry in computer science in the last five years.

Two of West Virginia's top three SBIR/STTR awardees are active in data analytics and virtual applications: NextGen Federal Systems and TMC Technologies. Although West Virginia has very limited VC activity, the majority of deals are concentrated in Business-to-Business (B2B) and Business-to-Customer (B2C) tech applications and IT. As shown in the megatrends analysis, digitalization and robotics and automation are impacting every industry sector, from agriculture to manufacturing to health care. Interviews with faculty pointed to data science applications across every research field and industry and government lab interviews supported strong demand and investment.

To this point, the State of West Virginia has not invested enough in computer science research activity, and this is a clear S&T platform in which to focus Vision 2025 investment and activity. Although WVU's engineering R&D expenditures are comparable to University of Pittsburgh's, WVU's computer science R&D expenditures were 1/9 of University of Pittsburgh's in 2019. The state governments of Ohio, Pennsylvania, Maryland, and Virginia are all investing heavily in computer science and data science research and education activity.

FIGURE 13. COMPUTER AND DATA SCIENCE SWOT ANALYSIS



4.2.3 Advanced Manufacturing

Manufacturing is WV's third largest industry sector in terms of GDP and fourth largest sector in terms of employment. Within manufacturing, the largest segments include chemicals and polymers, primary and fabricated metals, and transportation equipment (i.e., aerospace and automotive components manufacturing). Of these three, the plastics portion of chemicals and polymers manufacturing and both aerospace and automotive components manufacturing within transportation equipment added employees from 2014-2019.

Manufacturing draws on STEM graduates of both two-year technical and four-year degree programs. For example, West Virginia chemical manufacturers hire community college graduates for operator positions, as well as graduates from chemistry, mechanical engineering, industrial engineering, and civil engineering. Manufacturing drives and supports other economic activity in West Virginia, such as repair and maintenance operations, engineering and technical consulting services, and downstream consumer goods manufacturing.

The Dow plant in South Charleston manufacturers active pharmaceutical ingredients (APIs) for Mylan and P&G.

The state is working to increase manufacturing contracts with the Department of Defense and leverage partnerships with Office of Economic Adjustment's AIM Higher Consortium to help manufacturers to adopt advanced AI, machine learning, robotics, and additive manufacturing technologies. In the short term, to stay competitive West Virginia needs to be able to meet the demand for STEM workers for expanding companies, while introducing STEM students to the technologies that global companies are adopting.

FIGURE 14. ADVANCED MANUFACTURING SWOT ANALYSIS

4.2.4 Advanced Energy

Coal and gas extraction remain the state's top industry contributor to GDP, but rank 8th in terms of direct employment. Shale gas-related pipeline construction will create short term jobs, but the ethane cracker for transforming the gas into usable products is being constructed in Pennsylvania. West Virginia has significant academic and private sector engineering and technical consulting activities related to exploration and production. Many of West Virginia's top patent assignees and patenting categories are related to exploration and production activities, such as Civil engineering (e.g., J.H. Fletcher), Measurement (e.g., Mustang Sampling), and Analysis of Biological Materials (e.g., Mustang Sampling).

WVU's Center for Innovation in Gas Research/Utilization and the U.S. Department of Energy's National Energy Technology Laboratory conduct research on domestic energy resources.[21] WVU has research focused on production efficiencies and decarbonization. These include hydrogen, biofuels, and storage research. For example, two WVU Chemical Engineering faculty members received an ARPA-E award focused on the conversion of renewable energy to liquids for storage. WVU also has one of 31 DOE-funded Industrial Assessment Centers that provide faculty-led energy audits for small and medium-sized manufacturers to save energy, increase productivity, and reduce waste.

Increased federal funding opportunities for renewables, energy efficiency, and decarbonization technologies are anticipated and infrastructure spending is also likely to emphasize sustainability and energy efficiency. Private sector renewables R&D and innovation activity is hampered by limited demand and incentives for renewable energy technology adoption in West Virginia.[22] No SBIR/STTR awardees or VC deals were identified in energy over the 2015-2019 time period.

FIGURE 15. ADVANCED ENERGY SWOT ANALYSIS

21 *WVU's co-publications with industry are in Geochemistry and Geophysics (e.g., SINOPC, Schlumberger), Chemical Engineering (e.g., GE, Chevron), and Petroleum Engineering (e.g., Halliburton).*

22 *The state repealed its renewable portfolio standards in 2015, and there no requirements for utilities to increase the amount of alternative energy sources used.*

Appendix 1: Science and Research Council Members

Sarah Armstrong Tucker, PhD, West Virginia's Chancellor for Higher Education

*Juliana Serafin, PhD, Senior Director of Science & Research, STaR Division: Science, Technology and Research

*Anne Barth, Executive Director, TechConnect

Clayton Burch, State Superintendent of Schools, West Virginia Department of Education

*John "Jack" Dever, PhD, Chief Technology Office and Executive Vice President, MATRIC

Ed Gaunch, Cabinet Secretary, West Virginia Department of Economic Development

Laura Gibson, PhD, Senior Associate Vice President for Health Sciences Research and Graduate Education, West Virginia University

*Fred King, PhD, Vice President for Research, West Virginia University

*John Maher, PhD, Vice President for Research, Marshall University

Maura McLaughlin, PhD, Professor of Physics and Astronomy, West Virginia University

Colleen Nolan, PhD, Dean and Professor of Biology, Shepherd University

Michael Norton, Professor of Chemistry, Marshall University

Rachel Roberts, Site Logistics Leader and Manufacturing Production Leader, Dow Inc.

Uma Sundaram, MD, Vice Dean for Research and Graduation Education, Joan C. Edwards School of Medicine, Marshall University

*Jose Ulises Toledo, PhD, Vice President for Research and Public Service, West Virginia State University

Note: ** denotes WV S&T Plan working group members. Other WV S&T Plan working group members who are not members of the Science and Research Council include:*
**Kelsey Staggers, Manager, Business Development, West Virginia Department of Economic Development*
**Suzanne Strait, Associate Director of Science and Research, West Virginia Higher Education Policy Commission*
**Annette Carpenter, Finance and Administration Manager, West Virginia Higher Education Policy Commission*

Appendix 2: List of Stakeholder Interviews

Industry

Manufacturing

Dean Cordle, President and CEO, AC&S, Inc.
Don Wardius, PhD, Senior Manager, Technology Development & University Engagement, Covestro (formerly Bayer)
Tim O'Neal, Site Director, Dow
Jack Dever, PhD, CTO and Executive Vice President, Mid-Atlantic Technology, Research and Innovation Center (MATRIC)
Craig Thomas, Manufacturing Excellence Leader, Solvay
Eric Thompson, Executive Lead of Manufacturing, Operations & Technology, Aurora Flight Sciences (Boeing)

Engineering/Scientific R&D Services

Brian Joseph, President and CEO, Touchstone Research Laboratory, CFOAM Ltd. (SBIR award recipient)
Kristen Hammer, Business Development Manager, Virgin Hyperloop
Kelsey Kirby, WV Project Development, Virgin Hyperloop

IT Solutions/Computer Systems Design

Chetan Desai, Chief Operating Officer, NextGen Federal Systems (SBIR award recipient)
Randy Hefner, Vice President, TMC Technologies (SBIR award recipient)
Scott Zemerick, TMC Technologies (SBIR award recipient)

Data Analytics

Liam Bowers, CEO and Co-Founder, Blue Stone Analytics

Distinguished Alumni

Brad Smith, Executive Chairman, Intuit
John Chambers, Chairman Emeritus, Cisco / CEO, JC2 Ventures

Early-Stage Capital

Sarah Biller, Executive Director, Vantage Ventures
Michelle O'Connor, Investment Manager, West Virginia Jobs Investment Trust
Guy Peduto, Director, INNOVA Commercialization Group

Non-Profit

Anne Barth, Executive Director, TechConnect West Virginia
James "Jim" Estep, President, High Technology Foundation
Tracy Miller, CEO/Executive Director, Mid-Atlantic Aerospace Complex
Matt Ballard, Director, West Virginia Regional Technology Park
Kevin DiGregorio, PhD, Executive Director, Chemical Alliance Zone
Mary Hunt, Senior Program Manager, Benedum Foundation

Higher Education – Administration

West Virginia Higher Education Policy Commission

Sarah Armstrong Tucker, PhD, West Virginia's Chancellor for Higher Education
Juliana (Julie) Serafin, PhD, Senior Director, STaR Division: Science, Technology and Research

West Virginia University

Fred King, PhD, Vice President for Research
Sheena Murphy, PhD, Associate Vice President for Research
Laura Gibson, PhD, Senior Associate Vice President for Research and Graduate Education, Associate Dean for Research, School of Medicine
Stephen Hoffmann, PhD, Vice President of Clinical Programs, Professor of Pulmonary and Critical Care Medicine
Dave Satterfield, Director of Asset Development, Office of Research and Economic Development, Associate Professor, School of Music
Danny Twilley, Assistant Dean, Remote Worker Program and the Brad & Alys Smith Outdoor Economic Development Collaborative, and Javier Reyes, Vice President for Start-Up West Virginia

WVU Rockefeller Neuroscience Institute

Peter Konrad, PhD, Executive Director, Integrative Neuroscience and Clinical Innovation, Professor and Vice Chair of the Department of Neurosurgery, Ruby Chair for the study of Neuroscience and Neurosurgery

Marshall University

Eric Blough, Associate Dean of Academic and Curricular Affairs, Professor of Pharmacy
David A. Dampier, PhD, Interim Dean, College of Engineering and Computer Sciences
John Maher, PhD, Vice President for Research
Charles C. Somerville, PhD, FLS, Dean, College of Science

West Virginia State University

Jose Ulises Toledo, PhD, Vice President for Research
Sharon Warren Cook, PhD, Provost

Higher Education – Faculty

Hota GangaRao, PhD, Wadsworth Distinguished Professor, Civil and Environmental Engineering and Director, Constructued Facilities Center, WVU
Amy Hessl, PhD, Professor of Geography, WVU
John Hu, PhD, Statler Chair in Engineering for Natural Gas Utilization, WVU
Xingbo Liu, PhD, Professor, Mechanical and Aerospace Engineering, WVU
Maura McLaughlin, PhD, Eberly Distinguished Professor of Physics and Astronomy, WVU
Randy Nelson, PhD, Professor and McQuain Chair for Neurological Research, Director of Basic Science Research, WVU
Gary Rankin, PhD, Professor and Chair, Pharmacology (WV-INBRE Principal Investigator), Marshall University
Boyd Rorabaugh, PhD, Professor and Chair, Department of Pharmaceutical Science and Research, Marshall University
Shikha Sharma, Phd, Professor of Geology and Director, IsoBioGeM (Isotopic and Biogeochemical Characterization of Geological Materials) Laboratory, WVU
Earl Scime, PhD, Jefimenko Professor of Physics and Astronomy, WVU
Richard Thomas, PhD, Professor of Forest Ecology and Climate Change, WVU
Dorthy Vesper, PhD, Professor of Geology, WVU
Jingxin Wang, PhD, Professor of Wood Science & Technology, Associate Director for Research, Director of Renewable Materials and Bioenergy Research Center, WVU
James Wood, PhD, Director, WVU Energy Institute
Nicolas Zegre, Associate Professor of Forest Hydrology and Director of the Mountain Hydrology Laboratory, WVU

STEM K-12 Pipeline

Sue Ann Heatherly, Senior Education Officer, Green Bank Observatory, Lead PI, NSF INCLUDES First2Network (first generation college students in STEM)
Cathy Morton, EdD, MSEd, Director of Health Sciences and Technology Academy

Federal Labs

Frank Indiviglio, Deputy Director, High Performance Computing, NOAA High Performance Computing Facility
Wesley Deadrick, PhD, NASA Katherine Johnston Independent Verification and Validation Facility

Other EPSCoR Programs

Majid Jaridi, PhD, Director, NASA EPSCoR and NASA Spacegrant Consortium

State Government

Mike Graney, Deputy Secretary, West Virginia Department of Commerce
Joseph Hatton, Deputy Commissioner, West Virginia Department of Agriculture
Samantha Smith, Manager, Business Development, West Virginia Department of Economic Development

Appendix 3: West Virginia Economy

FIGURE 3-1

West Virginia new business creation and real GDP growth lagged behind the U.S. during the most recent economic expansion, while population declined.

Change in Key Economic Indicators: West Virginia vs. the U.S., 2015-2019

West Virginia	$72.3BN Real GDP Growth Rate 2014-19: 0.7% State Growth Rank: 45	1,792,147 Population Growth Rate 2014-19: -0.6% State Growth Rank: 50	51,549 Businesses Growth Rate 2014-19: 0.7% State Growth Rank: 44
U.S.	$19,091.7BN Real GDP Growth Rate 2014-19: 2.5%	260.2M Population Growth Rate 2014-19: 0.9%	9.9 M Businesses Growth Rate 2014-19: 1.8 %

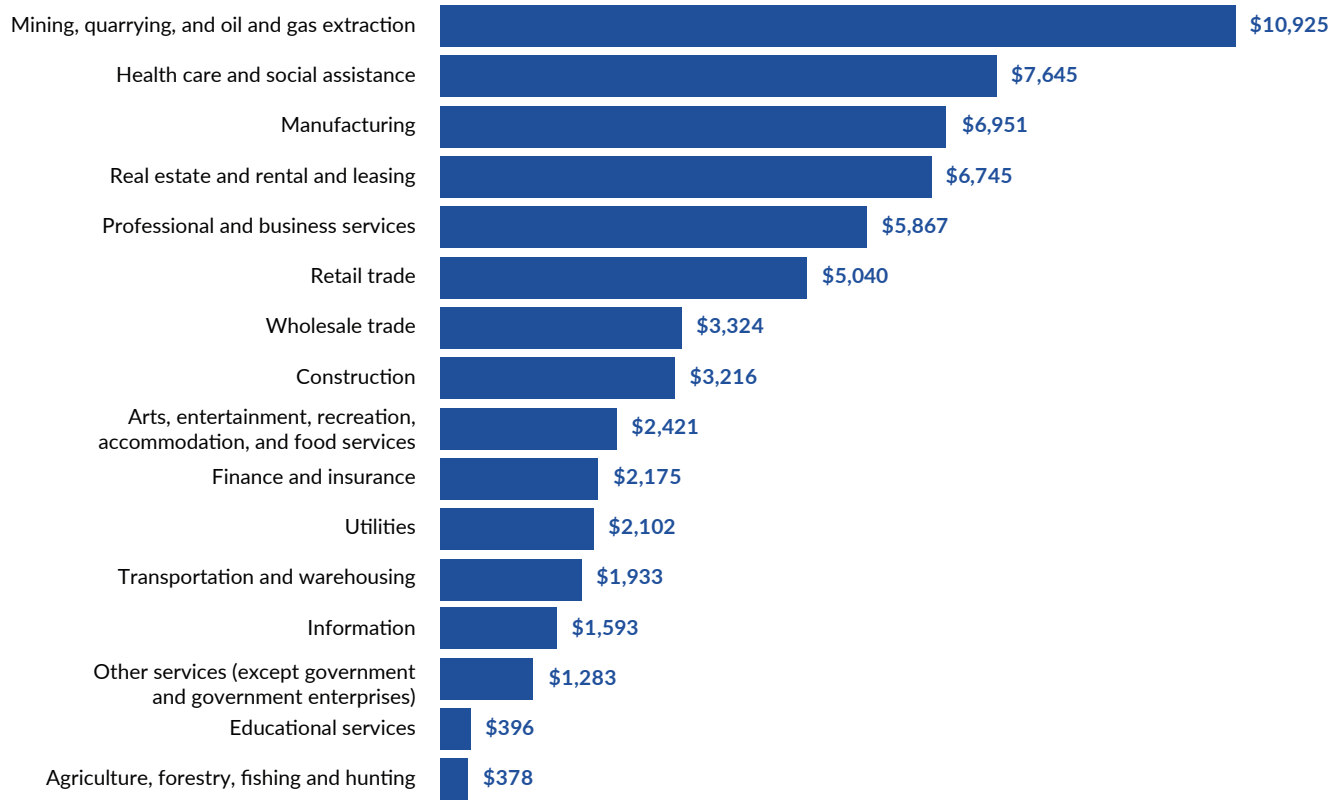
Note: *Red is negative growth; light blue is < 1% CAGR; blue is national average.*

Source: *U.S. Bureau of Economic Analysis, U.S Bureau of Labor Statistics, U.S. Census Bureau*

FIGURE 3-2

West Virginia's top 5 industries in terms of contribution to GDP are mining and extraction, health care and social assistance, manufacturing, real estate, and professional and business services.

West Virginia GDP by Industry Sector, 2019
$ Million

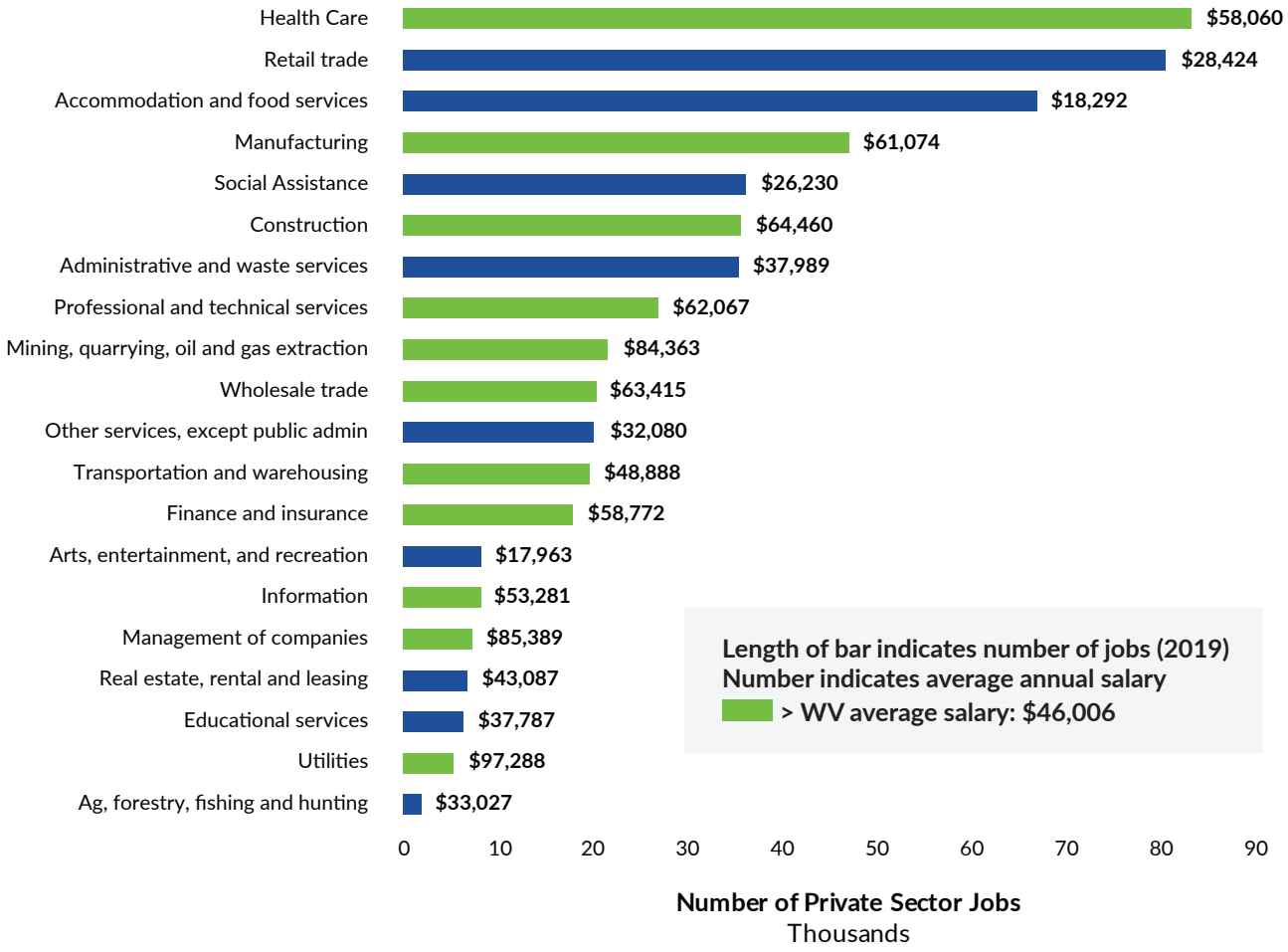


Source: *U.S. Bureau of Economic Analysis*

FIGURE 3-3

The top 5 industry employers differ from the top 5 ranking by GDP contribution. Only health care and manufacturing rank in the top 5 for both. Three of the top 5 industries by employment have very low average salaries: retail, accommodation and food service, and social assistance.

West Virginia Employment by Industry Sector, 2019

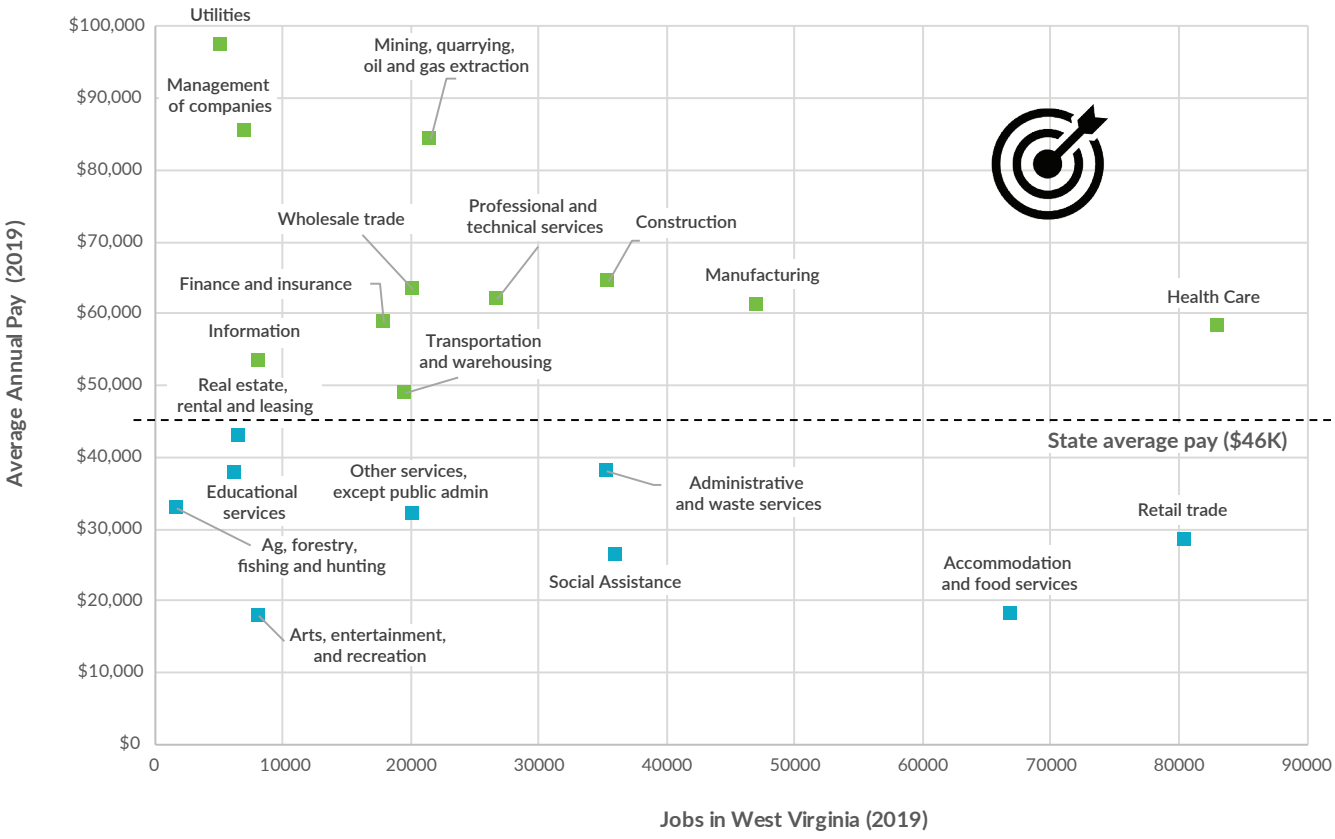


Source: *U.S. Bureau of Economic Analysis*

FIGURE 3-4

West Virginia needs more employment in high-wage industries, indicated by their location in the top right quadrant. Currently, only manufacturing and health care are located in this quadrant.

West Virginia Industry Sector Employment and Average Salary, 2019

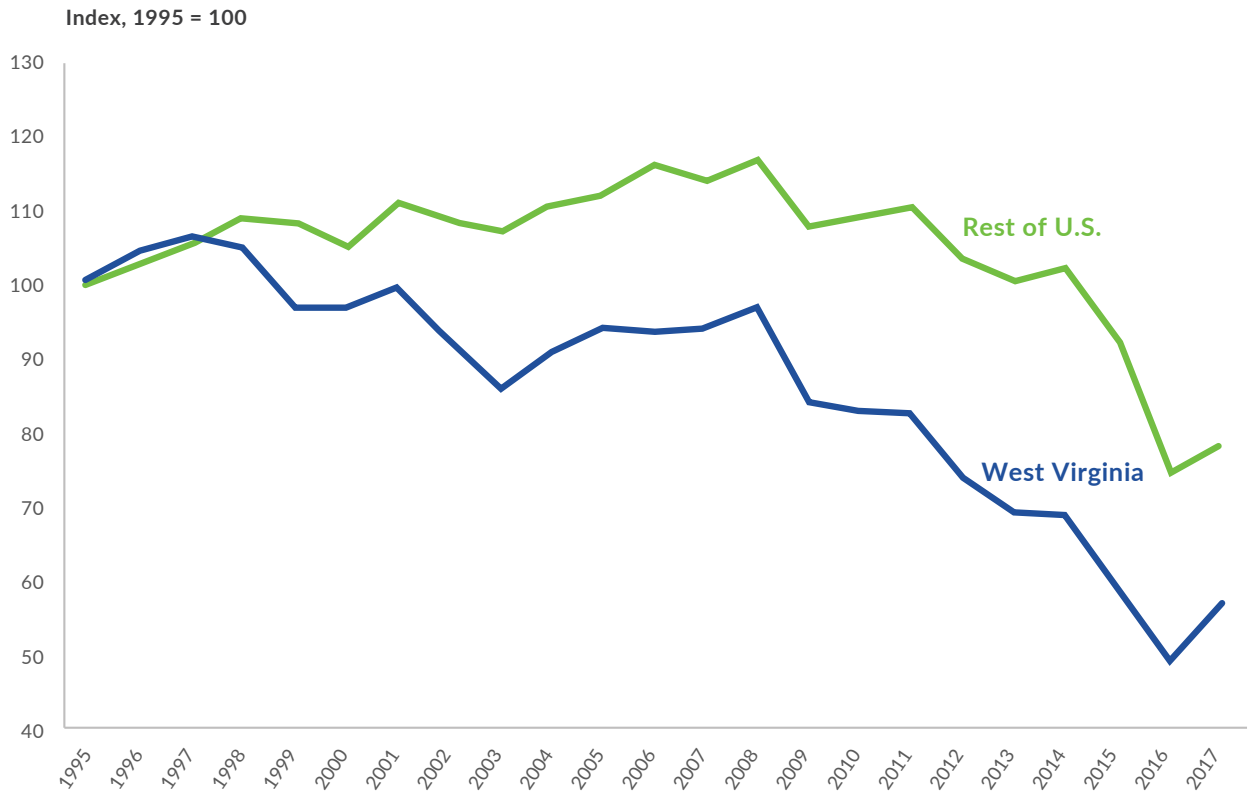


Source: *U.S Bureau of Labor Statistics*

FIGURE 3-5

Mining pays higher-than-average salaries, but the trend in U.S. and West Virginia coal production is negative.

West Virginia Annual Coal Production, West Virginia vs. Other U.S. States



Source: *Energy Information Administration*

FIGURE 3-6

West Virginia manufacturing employment declined slightly overall. Transportation equipment, plastics products, furniture, and beverage manufacturers added 100+ jobs from 2014-2019.

Change in West Virginia Manufacturing Employment, 2014-2019

NAICS	INDUSTRY TITLE	TOTAL JOBS (2019)	CHANGE (2014-19)	CAGR (2014-19)
336	Transportation equipment manufacturing	6,125	1,283	4.80%
326	Plastics and rubber products manufacturing	3,521	215	1.30%
337	Furniture and related product manufacturing	1,341	180	2.90%
312	Beverage and tobacco product manufacturing	509	147	7.10%
324	Petroleum and coal products manufacturing	714	82	2.50%
327	Nonmetallic mineral product manufacturing	2,826	40	0.30%
332	Fabricated metal product manufacturing	4,561	-671	-2.70%
334	Computer and electronic product manufacturing	792	-415	-8.10%
321	Wood product manufacturing	4,762	-401	-1.60%
311	Food manufacturing	3,057	-246	-1.50%
333	Machinery manufacturing	1,937	-211	-2.00%
331	Primary metal manufacturing	4,350	-200	-0.90%
325	Chemical manufacturing	9,039	-195	-0.40%
322	Paper manufacturing	455	-148	-5.50%
339	Miscellaneous manufacturing	1,014	-83	-1.60%
335	Electrical equipment and appliance mfg.	598	-63	-2.00%
323	Printing and related support activities	1,113	-56	-1.00%
315	Apparel manufacturing	114	-1	-0.20%
32-33	**Manufacturing**	**46,980**	**-794**	**-0.30%**

Source: *U.S Bureau of Labor Statistics, Quarterly Census of Employment and Wages*

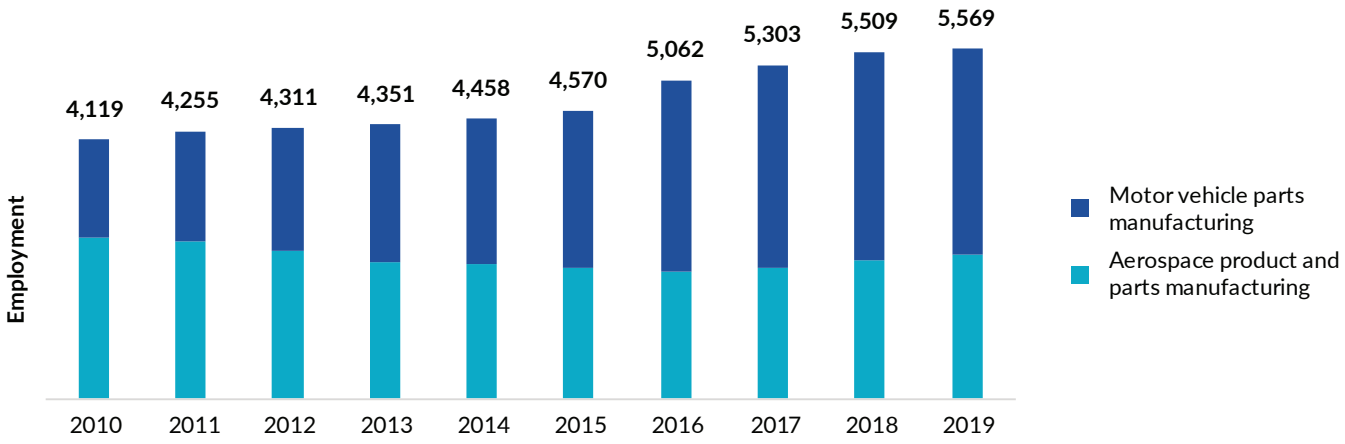
FIGURE 3-7

Automotive and aerospace parts manufacturing drove transportation equipment manufacturing employment growth.

Change in West Virginia Transportation Equipment Manufacturing Employment, 2014-2019

NAICS	INDUSTRY TITLE	TOTAL JOBS (2019)	CHANGE (2014-19)	CAGR (2014-19)
336	**Transportation equipment manufacturing**	**6,125**	**1,283**	**4.80%**
3363	Plastics and rubber products manufacturing	3,521	215	1.30%
3364	Furniture and related product manufacturing	1,341	180	2.90%

West Virginia Automotive and Aerospace Parts Manufacturing Employment, 2010-2019

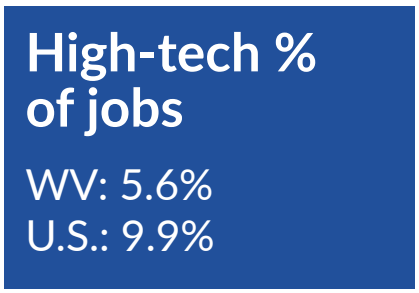


Source: *U.S Bureau of Labor Statistics, Quarterly Census of Employment and Wages*

FIGURE 3-8

The West Virginia high-tech industry's share of total employment is half that of the U.S. Increasing the number of high-tech companies and jobs is desirable, because they leverage larger national and international markets and pay higher-than-average salaries.

High-Tech Share of Total Employment, 2019



Source: *U.S Bureau of Labor Statistics*

The U.S. Bureau of Labor Statistics defines high-tech industries as those employing a higher share of STEM workers.

- 27 industries whose STEM occupations are 2.5x the average:
  - 13 goods-producing industries (STEM share > 18.5%)
  - 14 services-producing industries (STEM share > 14.7%)

- Pay higher median salaries for every occupation group (even non-STEM) than non-high-tech industries.
  - **9.9%** of total U.S. employment (**includes federal government** employment as a high-tech sector)
  - **18%** of U.S. output
  - **82.8%** of high-tech employment in **services** in 2016 (up from 71% in 1996)

- Export-oriented: demand from companies and government agencies outside of West Virginia and globally

FIGURE 3-9

Within the high-tech sector, computer systems/software/data processing, aerospace parts manufacturing, engineering and technical consulting services lead West Virginia job growth.

Change in WV High-Tech Industry Sector Employment, 2014-2019

NAICS	INDUSTRY TITLE	TOTAL JOBS (2019)	CHANGE (2014-19)	CAGR (2014-19)
5415	Computer systems design and related services	4,319	1,007	5.50%
5511	Management of companies and enterprises	7,085	714	2.20%
3364	Aerospace product and parts manufacturing	2,282	143	1.40%
5112	Software publishers	145	127	86.50%
5413	Architectural and engineering services	4,824	122	0.80%
5182	Data processing, hosting and related services	1,052	120	3.70%
2211	Power generation and supply	3,913	42	0.30%
5416	Management and technical consulting services	3,393	27	0.30%
5173	Wired and wireless telecommunications carriers	2,420	-743	-5.00%
2111	Oil and gas extraction	2,130	-671	-5.30%
3251	Basic chemical manufacturing	2,226	-254	-2.10%
5417	Scientific research and development services	1,346	-252	-3.10%
3345	Electronic instrument manufacturing	666	-200	-5.00%
3344	Semiconductor and electronic component mfg.	108	-141	-12.80%
3333	Commercial and service industry machinery	252	-113	-5.60%
5179	Other telecommunications	254	-43	-3.00%
3353	Electrical equipment manufacturing	373	-20	-0.40%
5191	Other information services	79	-2	0.20%

Source: *U.S Bureau of Labor Statistics, Quarterly Census of Employment and Wages*

FIGURE 3-10

Employment for nine high-tech industries were not included because the data was suppressed. Employment data are suppressed when there are too few business establishments comprising an industry segment to protect the identity of reporting companies.

West Virginia Suppressed High-Tech Industry NAICS, 2014-2019

NAICS	INDUSTRY
3254	Pharmaceutical and medicine manufacturing
3332	Industrial machinery manufacturing
3341	Computer and peripheral equipment mfg.
3342	Communications equipment manufacturing
3343	Audio and video equipment manufacturing
3346	Magnetic media manufacturing and reproducing
4861	Pipeline transportation of crude oil
4862	Pipeline transportation of natural gas
5174	Satellite telecommunications

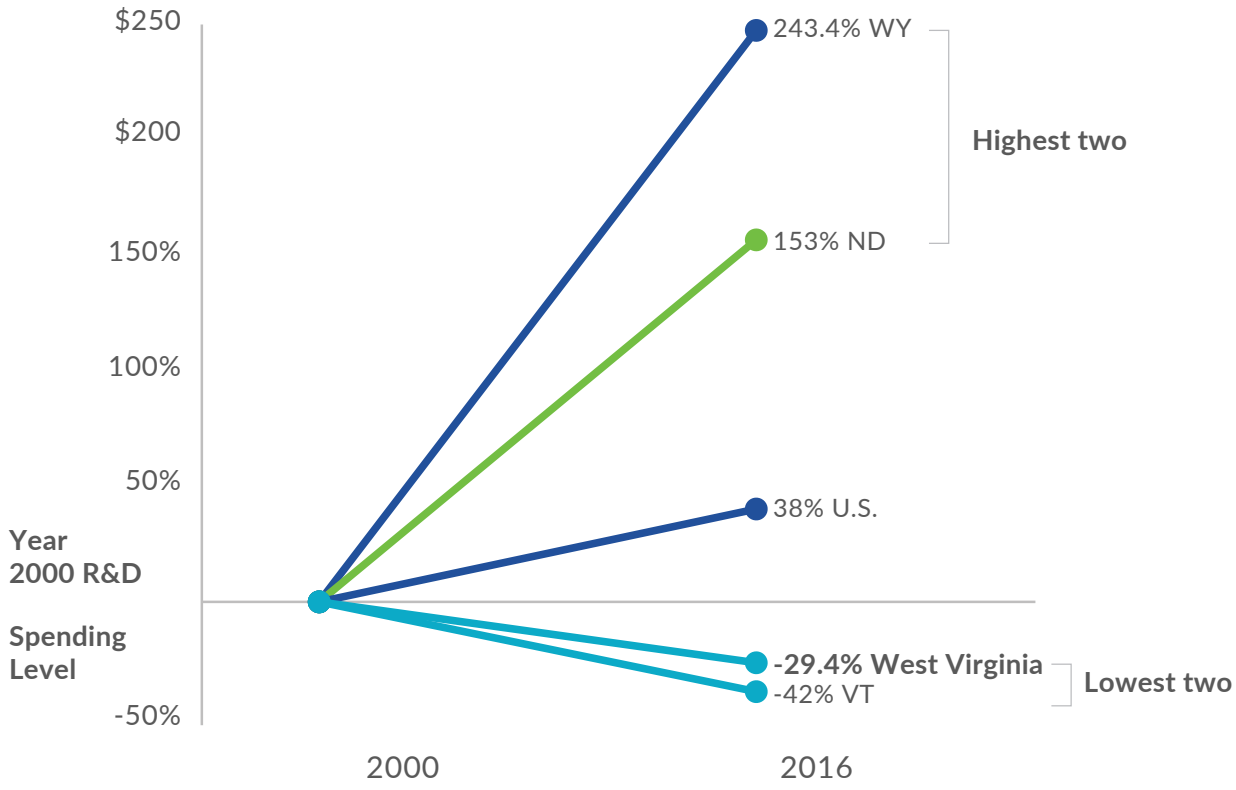
Source: *U.S. Bureau of Labor Statistics, Quarterly Census of Employment and Wages*

Appendix 4:
West Virginia Research Enterprise

FIGURE 4-1

Total R&D spending in West Virginia (industry, academic, and federal) declined by -29.6 in real terms over the last 15 years, the most of any state except Vermont.

Percent change in R&D spending 2000 to 2016 (Adjusted for inflation to 2016 dollars)

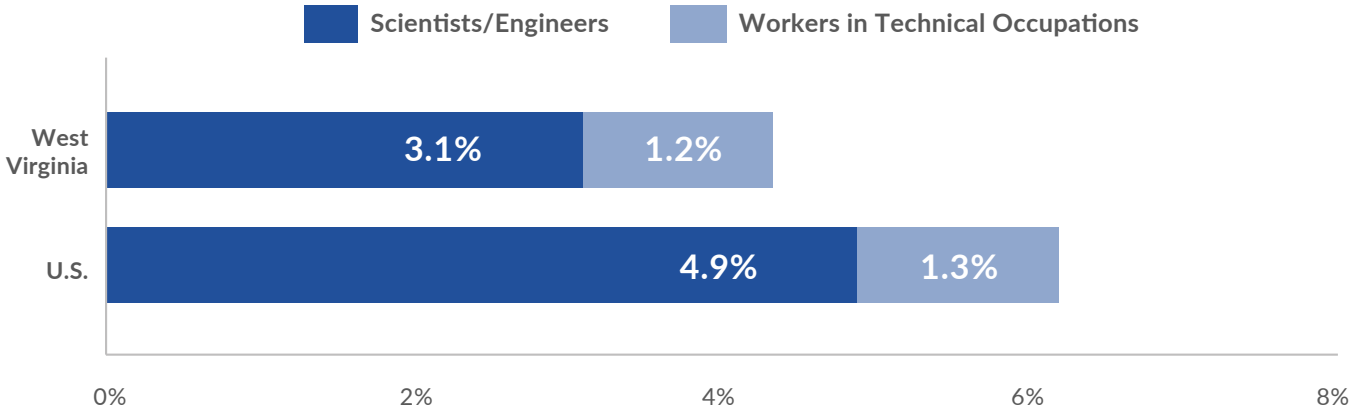


Source: *NSF, National Center for Science and Engineering Statistics, National Pattern of R&D Resources*

FIGURE 4-2

The percentage of West Virginia jobs that require scientists/engineers and workers in technical occupations is 4.3%, which lags behind the U.S. average of 6.2%.

Jobs in S&E as a percent of all jobs in 2018



Source: *U.S Bureau of Labor Statistics, Occupational Employment Statistics Survey*

FIGURE 4-3

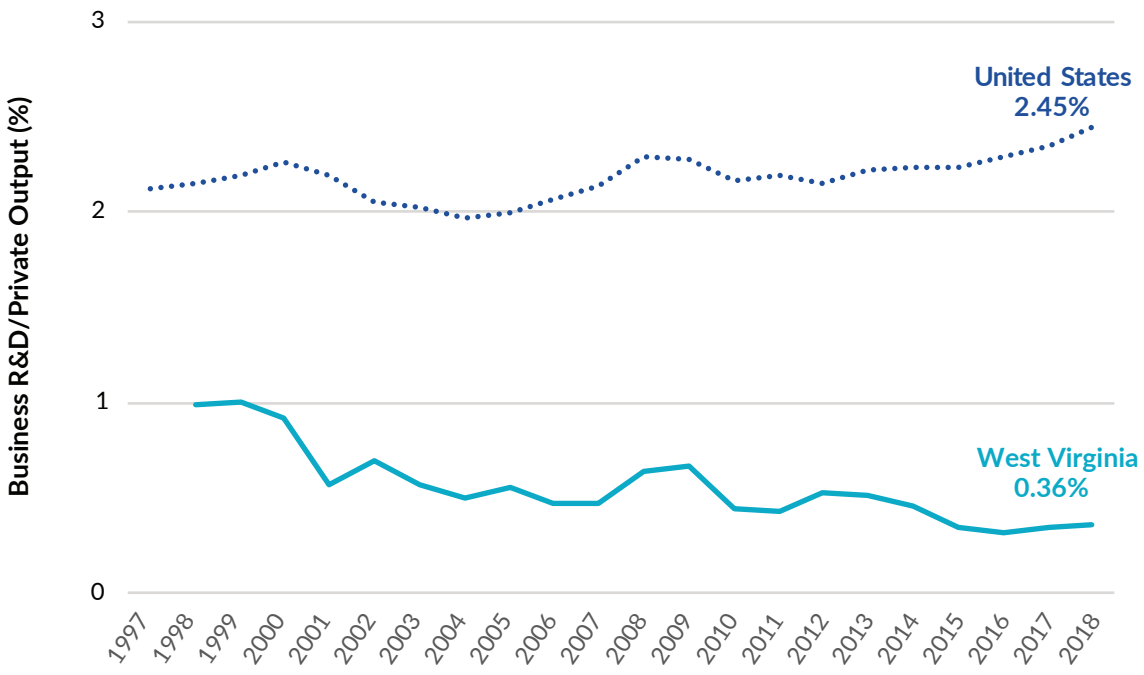
West Virginia business R&D expenditures (BERD) as a percentage of private sector output have declined from 1.0% to 0.36% over the past two decades compared to 2.45% for the U.S.

WV Business R&D Expenditures: 1998, 2008, 2018

BERD

WV: 0.36% (rank 45th)
U.S.: 2.45%

	1998	2008	2018
Total business R&D expenditures ($M)	$335	$334	$238
Business R&D expenditures as a percentage of private output	1.00%	0.64%	0.36%
Rank	33rd	39th	45th

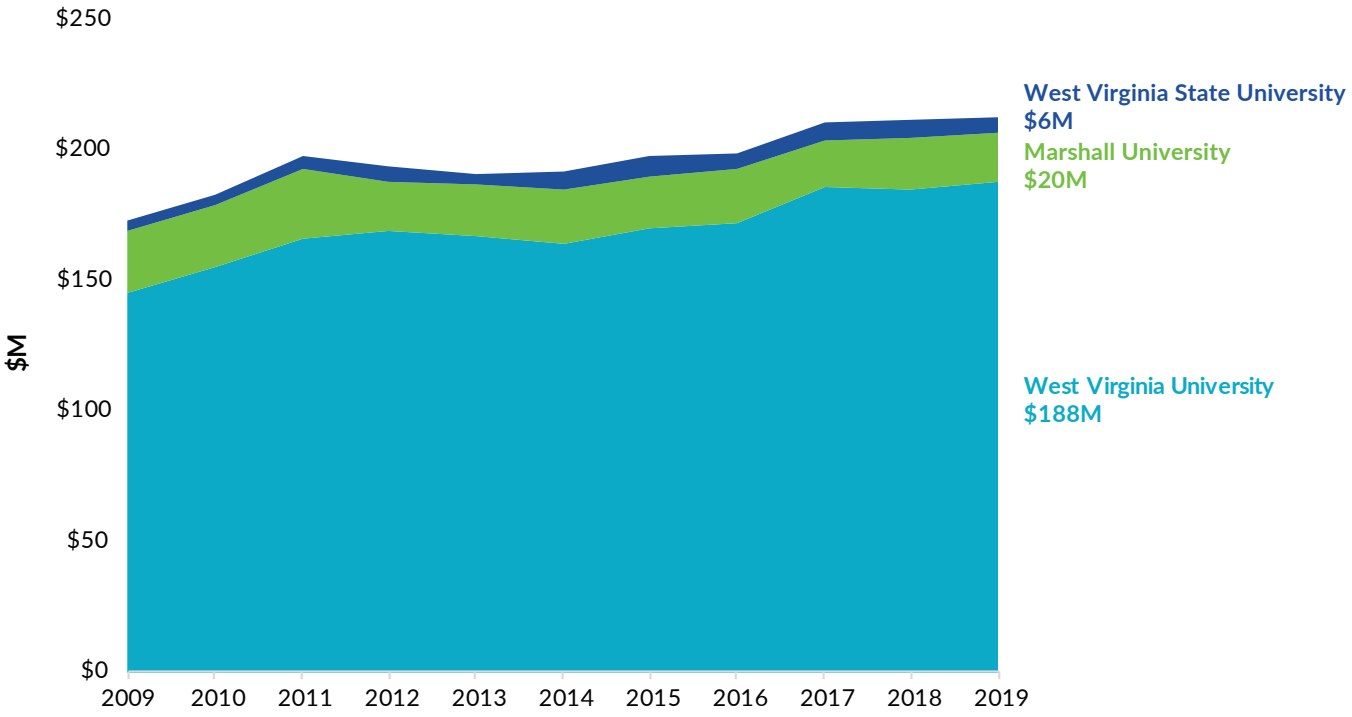


Source: *NSF, National Center for Science and Engineering Statistics, Business Enterprise Research and Development Survey*

FIGURE 4-4

West Virginia academic R&D expenditures grew 2.3% CAGR over the last 10 years, compared to 3.5% CAGR for all U.S. institutions.

University R&D Expenditures in West Virginia, FY2009-2019



Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-5

Life Sciences is the largest R&D field at all three of the institutions: WVU, Marshall, and WVSU. WVU ranks among the top 100 institutions nationally for Geosciences, Atmospheric, and Ocean Sciences; Engineering; and Physical Sciences R&D.

Three-Year Average R&D Expenditures and Ranking by Institution and R&D Field, FY2016-2019

	WVU			Marshall			WVSU		
	Rank		Avg	Rank		Avg	Rank		Avg
	FY16	FY19	FY17-19	FY16	FY19	FY17-19	FY16	FY19	FY17-19
Life sciences	103	105	$106.0 M	203	201	$15.2 M	275	276	$5.6 M
Engineering	95	84	$38.9 M	225	272	$1.2 M	323	377	$0.2 M
Physical sciences	113	100	$14.0 M	234	311	$0.7 M	419	402	$0.3 M
Geosciences, atmospheric sciences, and ocean sciences	58	71	$8.3 M	402	314	$0.1 M			$0.0 M
All non-S&E fields	128	137	$9.4 M	245	263	$1.9 M		498	$0.0 M
Social sciences	123	162	$2.9 M	341	483	$0.0 M			$0.0 M
Psychology	164	132	$2.1 M	249		$0.0 M			$0.0 M
Computer and information sciences	208	192	$1.5 M	339	347	$0.2 M	356		$0.1 M
Sciences NEC			$0.8 M			$0.0 M			$0.0 M
Mathematics and statistics	111		$2.2 M	356		$0.0 M		371	$0.0 M

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-6

While Life Sciences R&D expenditures grew at all three universities, this growth was driven by different subfields: by Biological and Biomedical Sciences at WVU and WVSU and by Health Sciences at Marshall.

Breakdown of Life Sciences R&D Expenditures by Institution and R&D Subfield, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
All life sciences	**5.70%**	**$104.40**	**0.80%**	**$15.70**	**4.80%**	**$5.40**	**4.00%**
Health sciences	6.80%	$60.70	0.60%	$10.80	13.30%	$0.10	
Biological and biomedical sciences	5.60%	$18.90	11.00%	$4.80	-8.50%	$1.60	20.70%
Agricultural sciences	1.40%	$14.30	-5.60%			$3.10	-3.60%
Natural resources and conservation	6.70%	$9.60	-3.60%			$0.50	
Life sciences NEC	-3.80%	$1.00	2.90%	$0.10	141.60%	$0.20	-25.90%

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-7

Engineering is the second largest R&D field at WVU and grew by 8.9% CAGR from FY16-19, exceeding the U.S. CAGR of 5.1%. Engineering R&D declined at Marshall and WVSU.

Breakdown of Engineering R&D Expenditures by Institution and R&D Subfield, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR (FY16-19)	FY19 $M	CAGR (FY16-19)	FY19 $M	CAGR (FY16-19)	FY19 $M	CAGR (FY16-19)
All engineering	**5.10%**	**$42.50**	**8.90%**	**$1.20**	**-21.70%**	**$0**	**-45.90%**
Mechanical engineering	5.90%	$15.60	11.80%				
Electrical, electronic, and communications	5.30%	$6.60	-2.60%				
Engineering NEC*	-0.60%	$6.10	31.10%				
Civil engineering	2.50%	$5.20	5.50%	$1.20	-20.30%		
Chemical engineering	3.40%	$5.10	19.60%				
Industrial and manufacturing	32.60%	$2.40	-6.30%				
Metallurgical and materials	0.80%	$1.30	-5.90%		-69.10%		
Aerospace, aeronautical, and astronautical	9.80%	$0.10					
Bioengineering and biomedical	10.20%						-45.90%

Note: **not elsewhere classified (NEC)*

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-8

Physical Sciences R&D expenditures at WVU and WVSU grew at CAGRs that exceeded the CAGR for all U.S. institutions (4.3%).

Breakdown of Physical Sciences R&D Expenditures by Institution and R&D Subfield, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
All physical sciences	**4.30%**	**$14.30**	**14.80%**	**$0.70**	**-24.30%**	**$0.20**	**17.50%**
Physics	3.00%	$8.70	7.80%		-83.00%	$0.10	
Chemistry	3.50%	$5.60	30.70%	$0.70	6.60%	$0.20	4.40%
Astronomy and astrophysics	5.70%	<$0.1					
Physical sciences NEC*	10.00%	<$0.1					
Materials science	14.60%	<$0.1					

Note: **not elsewhere classified (NEC)*

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-9

All Geological, Geosciences, Atmospheric, and Ocean Sciences R&D expenditures decreased at WVU and Marshall. The smaller Geosciences, Atmospheric, and Ocean Sciences not elsewhere classified (NEC) subfield grew by 11.3% CAGR at WVU.

Breakdown of All Geosciences, Atmospheric Sciences, and Ocean Sciences R&D Expenditures by Institution and Subfield, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
All geosciences, atmospheric sciences, and ocean sciences	**1.00%**	**$10.00**	**-8.40%**	**$0.20**	**-29.90%**	**$0**	
Geological and earth sciences	-2.00%	$7.90	-11.90%				
Geosciences, atmospheric, and ocean sciences NEC*	3.90%	$2.20	11.30%	$0.20	-30.50%		
Atmospheric science and meteorology	0.10%						
Ocean sciences and marine sciences	0.90%						

Note: **not elsewhere classified (NEC)*

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-10

Social Sciences R&D expenditures declined at WVU and Marshall in contrast to strong U.S. growth.

Breakdown of Social Sciences R&D Expenditures by Institution and Subfield, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
All social sciences	**5.80%**	**$2.40**	**-12.70%**	**$0.00**	**-80.10%**	**$0.00**	
Economics	5.00%	$0.90	-5.10%	$0.00		$0.00	
Social sciences NEC*	5.80%	$0.80	-19.70%	$0.00		$0.00	
Sociology, demography, and population studies	6.50%	$0.60	-7.00%	$0.00	-100.00%	$0.00	
Political science and government	5.20%	$0.00	-43.20%	$0.00		$0.00	
Anthropology	8.80%	$0.00		$0.00		$0.00	

Note: **not elsewhere classified (NEC)*

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-11

Starting from a small base, computer science R&D expenditures grew much faster at WVU (24.2% CAGR) and Marshall (12.4% CAGR) than for all U.S. institutions (8.3% CAGR).

Computer and Information Sciences R&D Expenditures by Institution, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
Computer and information sciences	**8.30%**	**$1.20**	**24.20%**	**$0.10**	**12.40%**	**$0.00**	**-100.00%**

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

Although WVU and University of Pittsburgh have comparable R&D expenditures in engineering, WVU has 1/9 the computer science R&D expenditures at University of Pittsburgh.

WVU vs. University of Pittsburgh R&D Expenditures ($1,000) and Rankings by R&D Field, FY2019

RANKS OUT OF 646 ACCREDITED UNIVERSITIES	Engineering		Physical sciences		Geosciences, atmospheric sciences, and ocean sciences		Computer and information sciences	
	Rank	Expenditures	Rank	Expenditures	Rank	Expenditures	Rank	Expenditures
West Virginia U	84	$42,516	100	$14,339	71	$10,049	192	$1,150
Marshall U	272	$1,158	311	$684	314	$164	347	$78
West Virginia State	377	$34	402	$235	N/A	$0	N/A	$0
U of Pittsburgh	77	$46,075	49	$30,196	57	$13,185	65	$9,734

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-12

Sciences, not elsewhere classified (NEC) R&D Expenditures grew 27.6% CAGR at WVU compared to a decline for all U.S. institutions.

Sciences, Not Elsewhere Categorized R&D Expenditures by Institution, FY2016-2019

	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
Sciences, NEC*	-5.30%	$0.50	27.60%	$0.20		$0.00	

Note: *not elsewhere classified (NEC)*

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-13

Mathematics and Statistics R&D Expenditures declined at WVU and Marshall in contrast to growth at all U.S. institutions.

Mathematics and Statistics R&D Expenditures by Institution, FY2016-2019

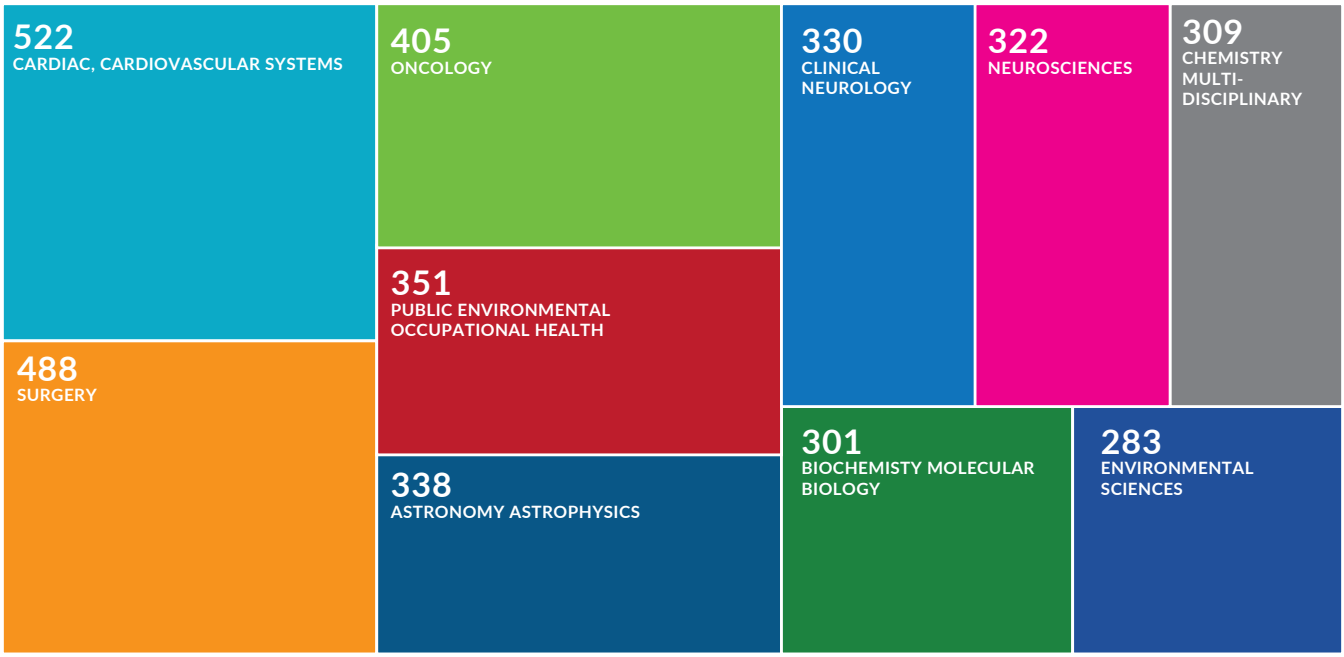
	U.S.	WVU		Marshall		WVSU	
	CAGR	FY19	CAGR	FY19	CAGR	FY19	CAGR
	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)	$M	(FY16-19)
Mathematics and statistics	4.10%	$0.60	-17.90%	$0.00	-100.00%	$0.00	

Source: *NSF, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey*

FIGURE 4-14

The Health Sciences are strongly represented in West Virginia's top 10 research areas. Other research areas with strong publications activity are Astronomy & Astrophysics, Biochemistry & Molecular Biology, Chemistry, and Environmental Sciences.

West Virginia Web of Science Publications: Top 10 Research Areas, 2015-2019



Source: *Web of Science*

FIGURE 4-15

Analysis of publications with industry collaborators shows the strongest activity at WVU for both health and non-health industry collaborators.

Count of West Virginia Academic Publications with Industry Collaborators by Institution, 2015-2019

	WVSU	Marshall	WVU
Industry Collaborators	3	19	239
Non-Health	3	2	79
Total Documents*	169	1,701	11,971

Note: **The term "documents" is used because the data includes not only peer-reviewed publications but conference proceedings and other types of publications.*

Source: *Clarivate Analytics, InCites*

FIGURE 4-16

Geochemistry & Geophysics and Computer Science are the top two research areas with corporate co-authors at WVU.

WVU Publications with Non-Health Industry Collaborators, 2015-2019

RESEARCH AREA	DOCUMENTS	CORPORATE CO-AUTHORS
GEOCHEMISTRY & GEOPHYSICS	13	SINOPEC (6), Schlumberger (4), PetroChina, Shell, etc.
COMPUTER SCIENCE	11	Microsoft (3), IBM (2), etc.
ENGINEERING, CHEMICAL; ENERGY & FUELS	5	GE, Chevron, Conoco Phillips, Ford, Statoil
GEOSCIENCES, MULTIDISCIPLINARY	5	Southwest Research Institute (2), Lockheed, Schlumberger
TELECOMMUNICATIONS	5	Nokia (2), Telefonica, NEC, Huawei
ENGINEERING, ELECTRICAL & ELECTRONIC; COMPUTER SCIENCE	4	Huawei, Bosch, IBM, Tencent
ENGINEERING, PETROLEUM	3	Halliburton (3), ExxonMobile
ENVIRONMENTAL SCIENCES	3	SkyTruth & Google Earth, Mycogen Seeds, Showa Denko
GEOLOGY	3	Statoil (2), Chevron
MATERIALS SCIENCE	3	GE Global Research Ctr (2), UES, DuPont
PHYSICS, APPLIED	3	BAE, Azimuth, Toyota
ENERGY & FUELS	2	Ford, GE Global Research Ctr
ENGINEERING, ELECTRICAL & ELECTRONIC; OTHER	2	SpaceTech, GM
OPTICS	2	BAE Systems (2)
PHYSICS, FLUID & PLASMAS	2	Samsung, Lockheed Martin

Source: *Clarivate Analytics, InCites*

FIGURE 4-17

Computer Science, Engineering, and Plant Sciences are the top two research areas with non-health industry collaborators at WVSU and Marshall.

WVSU and Marshall University Publication with Non-Health Industry Collaborators, 2015-2019

RESEARCH AREA	WVSU	MARSHALL UNIV	CORPORATE CO-AUTHORS
PLANT SCIENCES; BIOTECHNOLOGY	1		Syngenta Beijing
ENGINEERING, ELECTRICAL & ELECTRONIC	1		Broadcom
COMPUTER SCIENCE, INFORMATION SYSTEMS	1		Broadcom
COMPUTER SCIENCE, INTERDISCIPLINARY APPS		1	Huawei US R&D Center
ENGINEERING, MECHANICAL		1	BAIC Motor Corporation

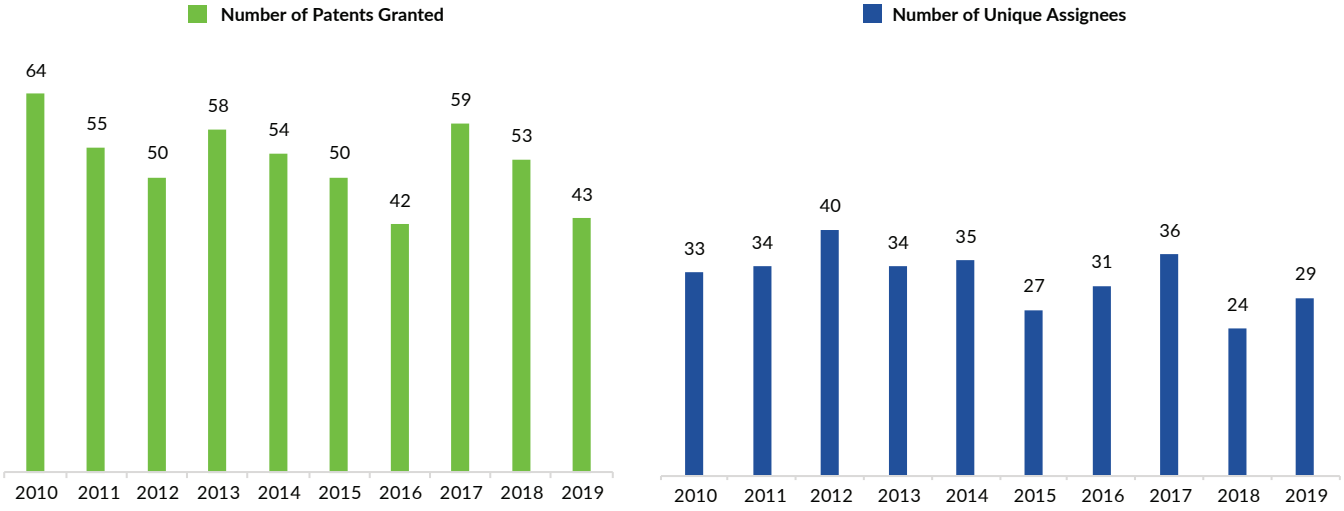
Source: *Clarivate Analytics, InCites*

Appendix 5: West Virginia Innovation & Entrepreneurship

FIGURE 5-1

The number of West Virginia patent assignees (e.g., companies, universities, etc.) and patents awarded fluctuate from year-to-year. However, three-year averages indicate a slight decline over the past 10 years: 36 assignees and 54.3 patents (2011-13) vs. 30 assignees and 51.7 patents (2017-19).

West Virginia Patents Granted and Unique Assignees, 2010-2019



Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-2

Civil Engineering, Measurement, Medical Technology, Pharmaceuticals, Electrical Machinery, and Chemical Engineering are West Virginia's top fields for patenting.

West Virginia Patents Granted Ranked by World Intellectual Property Organization Category, 2015-2020

CATEGORY	# OF PATENTS
Civil engineering	43
Measurement	43
Medical technology	34
Chemical engineering	34
Pharmaceuticals	30
Electrical machinery, apparatus, energy	25
Analysis of biological materials	23
Metals, metallurgy	20
Computer technology	19

Note: *The sum of awards by category is greater than the total number of patents awarded.*

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-3

The top West Virginia patent assignee in the Civil Engineering category was J.H. Fletcher & Co. with 7 patents.

Count of Patents Granted to West Virginia Patent Assignees: Civil Engineering, 2015-2020

ORGANIZATION	# OF PATENTS
J.H. Fletcher & Co.	7
No Assignee (Individuals)	6
Seneca Industries Inc.	4
West Virginia University	3
American Muscle Docks & Fabrication LLC	3
4D TECH SOLUTIONS, INC.	2
Terra Response, LLC	2
Caterpillar Global Mining Highwall Miners LLC	2
Pine Tree Gas, LLC	2
Trinity Solutions	1
Wright-Mix Material Solutions, LLC	1
West Virginia High Technology Consortium Foundation	1
Highwall Mining Innovations, LLC	1
Terrasimco Inc.	1
Royal Vendors, Inc.	1
Well Safe, LLC	1
KSD Enterprises, LLC	1
NG Innovations, Inc.	1
Simonton Building Products, Inc.	1
Intelligent Solutions, Inc.	1
Merco Inc.	1
Grand Total	**43**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-4

The top West Virginia patent assignee in the Measurement category was Mustang Sampling with 21 patents.

Count of Patents Granted to West Virginia Patent Assignees: Measurement, 2015-2020

ORGANIZATION	# OF PATENTS
Mustang Sampling, LLC	21
West Virginia University	5
Advanced Technology Applications, LLC	3
Terra Response, LLC	2
Walhonde Tools, Inc.	2
Precision Samplers Inc..	1
Sophie Lin, Trustee of the John Michael Payne Family Trust	1
PZM Diagnostics, LLC	1
Becker Mining America, Inc.	1
Kanawha Scales & Systems, Inc.	1
The General Hospital Corporation	1
Automatic Timing & Controls, Inc.	1
Aridea LLC	1
4D TECH SOLUTIONS, INC.	1
No Assignee (Individual)	1
Grand Total	43
KSD Enterprises, LLC	1
NG Innovations, Inc.	1
Simonton Building Products, Inc.	1
Intelligent Solutions, Inc.	1
Merco Inc.	1
Grand Total	**43**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-5

The top West Virginia patent assignee in the Medical Technology category was West Virginia University with 8 patents.

Count of Patents Granted to West Virginia Patent Assignees: Medical Technology, 2015-2020

ORGANIZATION	# OF PATENTS
West Virginia University	8
Zone 2 Surgical, Inc.	3
Mylan Pharmaceuticals Inc.	5
Fred Herz Patents, LLC	2
Omnia Medical, LLC	2
Darco International, Inc.	2
No Assignee (Individuals)	2
Vascular Access Technologies, Inc.	2
The General Hospital Corporation	1
Barix Medical Corp..	1
Emmetropia, Inc.	1
Charleston Area Medical Center, Inc.	1
Marshall University Research Corporation	1
Oridion Medical 1987 Ltd.	1
Austin Lulit Lift Systems, Inc.	1
SlipStream, LLC	1
Grand Total	**34**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-6

The top West Virginia patent assignee in the Chemical Engineering category is WVU with 14 patents, followed by Conn-Weld Industries, Inc., with 5 patents.

Count of Patents Granted to West Virginia Patent Assignees: Chemical Engineering, 2015-2020

ORGANIZATION	# OF PATENTS
West Virginia University	14
Conn-Weld Industries, Inc.	5
NG Innovations, Inc.	4
Marshall University Research Corporation	3
Advanced Technology Applications, LLC	3
Cabot Corporation	1
Bodygard, LLC	1
Freedom Industries, Inc.	1
International Maritime Security Network, LLC	1
Dewar of Virginia, Inc.	1
Grand Total	**34**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-7

The top West Virginia patent assignee in the Pharmaceuticals category was the Rockefeller Neuroscience Institute with 8 patents, followed by Mylan Pharmaceuticals and WVU with 7 patents each.

Count of Patents Granted to West Virginia Patent Assignees: Pharmaceuticals, 2015-2020

ORGANIZATION	# OF PATENTS
Rockefeller Neuroscience Institute	8
Mylan Pharmaceuticals	7
West Virginia University	7
Cognitive Research Enterprises, Inc.	6
Marshall University Research Corporation	2
University of Pittsburgh of the Commonwealth System of Higher Education	1
Temple University of the Commonwealth System of Higher Education	1
Grand Total	**30**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-8

The top West Virginia patent assignee in the Electrical Machinery, Apparatus, Energy category was WVU with 10 patents followed by Advanced Technology Applications with 3 patents.

Count of Patents Granted to West Virginia Patent Assignees: Electrical Machinery, Apparatus, Energy, 2015-2020

ORGANIZATION	# OF PATENTS
West Virginia University	10
Advanced Technology Applications, LLC	3
NG Innovations, Inc.	2
Marshall University Research Corporation	2
Conn-Weld Industries, Inc.	1
SGA Polymers, LLC	1
No Assignee (Individual)	1
Bodygard LLC	1
Tabor Machine Company, LLC	1
Mustang Sampling, LLC	1
Main Law Cafe	1
Cabot Corporation	1
Grand Total	**25**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-9

The top West Virginia patent assignee in the Analysis of Biological Materials category is Mustang Sampling with 12 patents.

Count of Patents Granted to West Virginia Patent Assignees: Analysis of Biological Materials, 2015-2020

ORGANIZATION	# OF PATENTS
Mustang Sampling, LLC	12
West Virginia University	3
No Assignee (Individuals)	2
Rockefeller Neuroscience Institute	2
PZM Diagnostics, LLC	1
Aridea LLC	1
Expression Pathology, Inc.	1
Marshall University Research Corporation	1
Grand Total	**23**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-10

The top West Virginia patent assignee in the Metals, Metallurgy category is WVU with 8 patents, followed by Huntington Alloys with 6 patents.

Count of Patents Granted to West Virginia Patent Assignees: Metals, Metallurgy, 2015-2020

ORGANIZATION	# OF PATENTS
West Virginia University	8
Huntington Alloys, Inc.	6
Superior Fibers, LLC	2
Constellium Valais SA	1
Terrasimco Inc.	1
J.H. Fletcher & Co.	1
Special Metals Corporation	1
Grand Total	**20**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-11

The top West Virginia patent assignee in the Computer Technology category is WVU with 11 patents.

Count of Patents Granted to West Virginia Patent Assignees: Computer Technology, 2015-2020

ORGANIZATION	# OF PATENTS
West Virginia University	11
Aces and Eights Corporation	2
No Assignee (Individuals)	2
Mylan Inc.	1
Aspinity, Inc.	1
Geostellar, Inc.	1
Intelligent Solutions, Inc.	1
Grand Total	**19**

Source: *U.S. Patent & Trademark Organization, PatentsView*

FIGURE 5-12

The value of West Virginia SBIR/STTR awards fluctuates, but three-year averages indicate growth over time. In 2018, West Virginia had 9 awards and ranked 42nd nationally.

West Virginia SBIR/STTR Awards ($M), 2010-2019

Source: *NSF, National Center for Science and Engineering Statistics, State S&E Indicators*

FIGURE 5-13

Touchstone Research Laboratory and NextGen Federal Systems are West Virginia's top SBIR/STTR award recipients with 10+ awards each. NextGen has grown rapidly to 112 employees.

West Virginia SBIR/STTR Awardees by Company Size and Count by Phase, 2015-2019

Company	Type of technology	# of Employees	Phase 1	Phase 2
Touchstone Research Laboratory	Composites, carbon foam	42	10	5
NextGen Federal Systems	Environmental sensing, weather forecasting data analytics	112	7	3
TMC Technologies	Portable virtual aircraft test system	85	2	0
Stephens & Cross Research	Guided rocket inductive link	2	1	0
Progenesis Technologies	Bioengineered bacteria to create biopolymer	N/A	1	1
ExesaLibero Pharma	Inhibitor for prevention of arthritis-induced bone erosion	N/A	1	0
4D Tech Solutions	Intelligent Electronic Speed Controller	14	1	1
Modulation Therapeutics	Radiopharmaceutical for metastic uveal melanoma	N/A	0	1
Knobley Technical Associates	Advanced solid rocket motor technology for tactical Missiles	16	0	1
Total		**271**	**23**	**12**

Note: *Employment is self-reported by companies and from most recent SBIR/STTR award.*

Source: *SBIR/STTR Award Database*

FIGURE 5-14

DOD and NASA are lead funders of West Virginia SBIR/STTR Phase 1 Awards.

West Virginia SBIR/STTR Phase 1 Awardees by Federal Funder, 2015-2019

(median=$124,956, mean=$127,168)

Company	Phase 1 Awards	DOD	NASA	NIH	DOE
Touchstone Research Laboratory	10	6	3		1
NextGen Federal Systems	7	6	1		
TMC Technologies	2		2		
Stephens & Cross Research	1	1			
Progenesis Technologies	1			1	
ExesaLibero Pharma	1			1	
4D Tech Solutions	1		1		
Total	**23**	**13**	**7**	**2**	**1**

Source: *SBIR/STTR Award Database*

FIGURE 5-15

DOD is the lead funder of West Virginia SBIR/STTR Phase 2 Awards.

West Virginia SBIR/STTR Phase 2 Awardees by Federal Funder, 2015-2019

(median=$999,999, mean=$1,142,031)

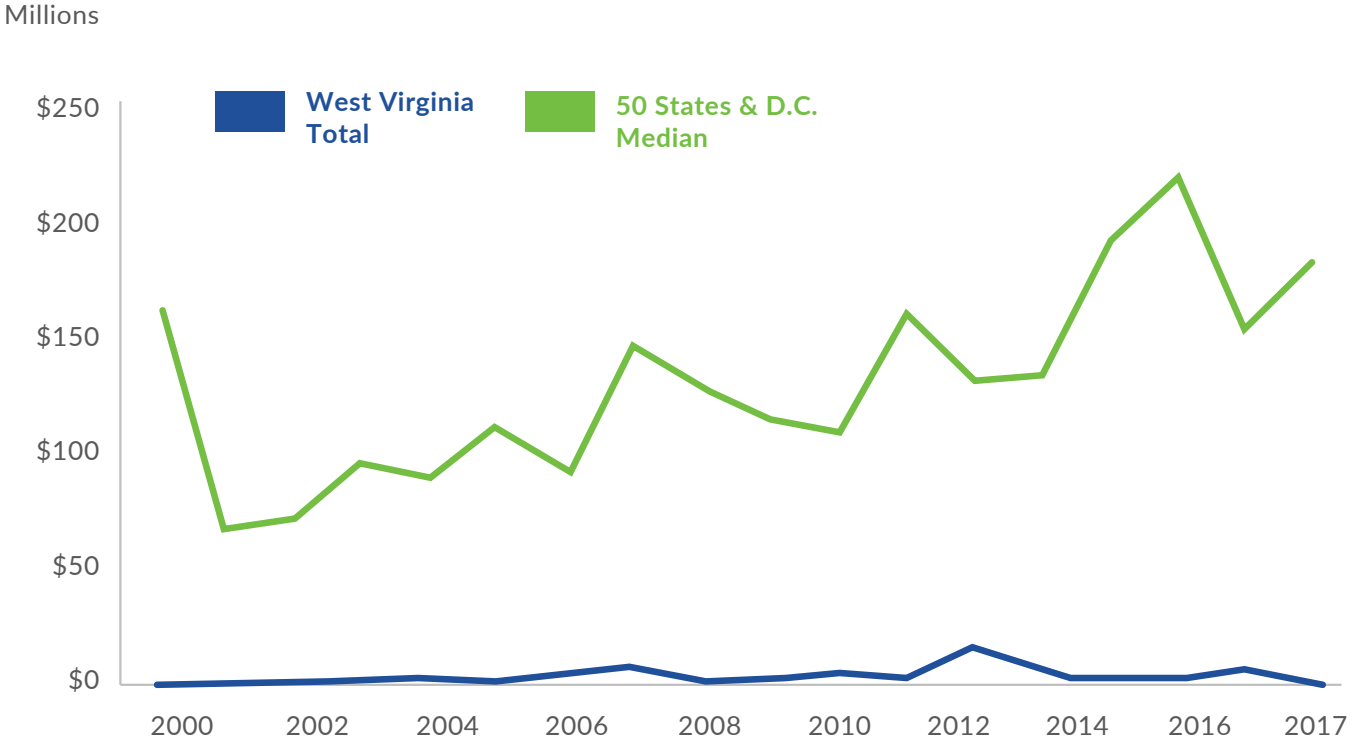
COMPANY	PHASE 2 AWARDS	DOD	NASA	NIH	DOE
Touchstone Research Laboratory	5	3	1		1
NextGen Federal Systems	3	3			
Progenesis Technologies	1			1	
Modulation Therapeutics	1			1	
Knobley Technical Associates	1	1			
4D Tech Solutions	1		1		
Total	**12**	**7**	**2**	**2**	**1**

Source: *SBIR/STTR Award Database*

FIGURE 5-16

West Virginia ranks 47th nationally for VC investment relative to the size of its economy.

West Virginia VC Investment vs. U.S. Median VC Investment: 2000 to 2017 (adjusted for inflation to 2017 dollars)



Source: *NSF, National Center for Science and Engineering Statistics, State S&E Indicators*

FIGURE 5-17

The B2B and IT sectors lead VC deal activity in West Virginia in terms of total number of companies and deals. B2C and Energy have seen the largest deals. Information about Healthcare deals have not been reported.

West Virginia Venture Capital Deals by Sector and Size ($M), 2015-2019

	B2B	IT	Energy	Healthcare	B2C	Materials
Average ($M)	$1.80	$1.60	$1.90	N/A	$10.00	
Median ($M)	$0.60	$1.20	$0.90	N/A	$10.00	
# of companies	5	3	3	3	1	0
# of deals	7	6	3	5	2	0
Largest deal ($M)	$7.00	$3.50	$24.80	N/A	$15.00	
Largest deal (Company)	Geostellar	Core10	Nacelle Logistics		VEEPIO	

Source: *Pitchbook Venture Capital and Private Equity Database*

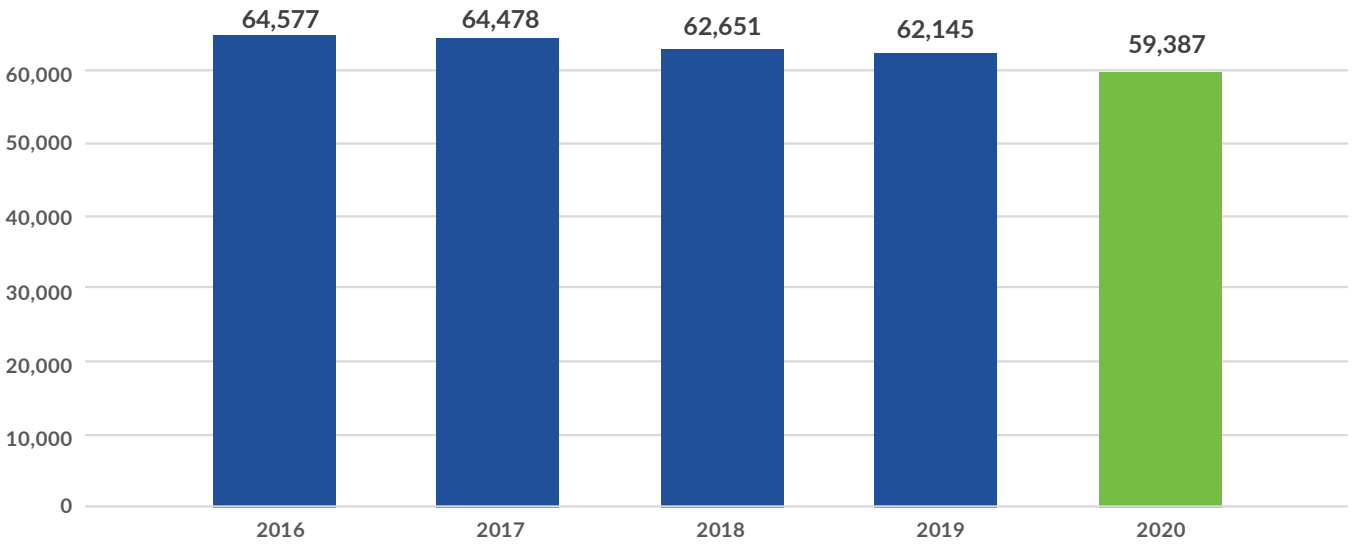
Appendix 6: West Virginia STEM Talent Pipeline

FIGURE 6-1

Total enrollment in West Virginia has decreased -8.0% since Fall 2016.

Total Headcount Enrollment, Fall 2016-Fall 2020

Total Headcount Enrollment: 59,387
Headcount decreased 4.4 percent since Fall 2019 and 8.0 percent since Fall 2016



Source: *Higher Education Policy Commission, Enrollment Report*

FIGURE 6-2

West Virginia STEM bachelor's degrees are growing at a faster rate compared to all bachelor's degrees conferred over the last 5 years.

West Virginia STEM Bachelor's Degrees vs. All Bachelor's Degrees Conferred, by Institution, Academic Year 2015-2020

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	5-year CAGR
WVSU STEM	22	22	25	26	33	33	8.40%
WVSU All	432	416	357	370	360	365	-3.30%
WVUIT STEM	81	77	80	84	97	101	4.50%
WVUIT All	152	147	156	153	162	165	1.70%
Marshall STEM	204	197	207	224	268	308	8.60%
Marshall All	1590	1600	1454	1549	1661	1628	0.50%
WVU STEM	1236	1317	1369	1369	1431	1423	2.90%
WVU All	4437	4550	4524	4519	4561	4649	0.90%

Source: *RTI analysis of WV HEPC degrees conferred data and the U.S. Department of Homeland Security STEM-designated degree program list.*

FIGURE 6-3

STEM master's degrees grew at West Virginia State University and Marshall University, but declined at WVU over the last 5 years.

West Virginia STEM Master's Degrees vs. All Master's Degrees Conferred, by Institution, Academic Year 2015-2020

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	5-year CAGR
WVSU STEM	6	10	4	9	6	8	5.90%
WVSU All	11	22	11	32	38	61	40.90%
Marshall STEM	78	96	179	134	160	94	3.80%
Marshall All	729	812	912	904	867	792	1.70%
WVU STEM	256	259	248	242	216	186	-6.20%
WVU All	1649	1481	1522	1479	1481	1340	-4.10%

Source: *RTI analysis of WV HEPC degrees conferred data and the U.S. Department of Homeland Security STEM-designated degree program list.*

FIGURE 6-4

West Virginia STEM research doctoral degrees are growing at a faster rate compared to all research doctoral degrees conferred over the last 5 years.

West Virginia STEM Doctoral Degrees vs. All Doctoral Degrees Conferred, by Institution, Academic Year 2015-2020

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	5-year CAGR
Marshall STEM	4	1	2	2	7	5	4.60%
Marshall All	18	19	20	19	26	16	-2.30%
WVU STEM	48	69	57	56	63	63	5.60%
WVU All	183	210	183	190	194	199	1.70%

Note: *Professional doctorate degrees, such as a Doctor of Education (EdD), Doctor of Nursing Practice (DNP), and Doctor of Public Health (DrPH), are a separate degree category and not included in the data presented in the table.*

Source: *RTI analysis of WV HEPC degrees conferred data and the U.S. Department of Homeland Security STEM-designated degree program list.*