

# Commonwealth Research and Technology (R&T) Strategic Roadmap

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Submitted by the Center for Innovative Technology  
on behalf of the  
Innovation and Entrepreneurship Investment Authority

December 14, 2017

## Table of Contents

Table of Contents.....	i
Executive Summary.....	1
Introduction .....	3
Development of the Roadmap.....	4
Updates to the November 2014 Roadmap.....	6
Regional Industry Priorities.....	6
VEDP Economic Development Priorities.....	7
Business Development Markets .....	7
Academia .....	8
Background .....	8
Strategic Plans and Six-Year Plans of Higher Education Institutions .....	9
University Research Priorities .....	10
Other Research and Development Assets .....	11
Capabilities of the Commonwealth’s R&D Assets .....	11
Research Assets Study .....	12
Intellectual Property .....	13
Capital Outlay.....	14
Summary .....	15
APPENDIX A: Regional Industry Priorities .....	A
APPENDIX B: Colleges and Universities.....	B
APPENDIX C: Research Institutes .....	C
APPENDIX D: Priority Platform Areas.....	D

## Executive Summary

Innovation is recognized as the premier path to economic expansion. Success in innovation requires an ecosystem to support these breakthroughs and entrepreneurship, research in strategically important industry sectors and technologies, and commercialization of research in those promising sectors. The Commonwealth Research and Technology (R&T) Strategic Roadmap identifies sectors in which Virginia has strength and that offer commercial promise, and in which the Commonwealth may invest to drive economic growth.

Virginia has many assets that drive innovation and economic development. The Commonwealth's public higher education system is repeatedly cited as among the best in the nation. Also prominent are research centers, the Commonwealth's workforce, and such innovation assets as MACH37™, the nation's first cyber security accelerator. Virginia was ranked #5 in Forbes' Best States for Business 2017<sup>1</sup>, up from #6 in 2016 and #7 in 2015<sup>2</sup>. Along with research assets and talent, regulatory environment, economic climate, and other criteria, economic leadership also requires smart investments in research and commercialization.

In 2011 the General Assembly directed the Center for Innovative Technology (CIT) to create the Commonwealth R&T Strategic Roadmap to help guide legislators in their funding decisions. The Roadmap provides a baseline: it identifies industry and research areas worthy of economic development and institutional focus and offers a framework for aligning key industry sectors within the state. It is a guide for investing funds allocated through the Commonwealth Research Commercialization Fund (CRCF), and, effective FY2017, through the Virginia Research Investment Fund (VRIF). The R&T Roadmap provides for regular review and, as such, reflects revisions to Virginia's strategic technology priorities, direction, and investments. The initial Roadmap was submitted in November 2011 and, per legislation, has since been submitted tri-annually. In interim years, CIT has conducted a higher level refresh to ensure that recommended industry sectors remain current. This year, CIT coordinated its development of the Roadmap with the Virginia Research Investment Committee (VRIC), which will assume responsibility effective January 1, 2018 for approving the assessment that is to be developed henceforth by the State Council of Higher Education for Virginia (SCHEV). In accordance with Code of Virginia 2.2-2221.2, CIT respectfully submits this tri-annual update.

Sources that provided input include colleges and universities, federal labs and other research organizations in Virginia, and the Virginia Economic Development Partnership (VEDP). Relevant reports prepared by or for the Commonwealth, the federal government, and industry also provided insights. Additionally, the Research and Technology Investment Advisory Committee (RTIAC) contributed to this examination of Virginia's strengths and priorities, as did two new and important resources uniquely available this year:

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<sup>1</sup> Forbes.com. (2017). *Best States for Business*. <https://www.forbes.com/best-states-for-business/list/>.

<sup>2</sup> Forbes.com (2016). *The Best and Worst States for Business 2016*.  
<https://www.forbes.com/pictures/582b1f12a7ea431d60195e28/best-states-6-virginia/#46f41ad914cb>.

## The Commonwealth Research and Technology Strategic Roadmap

- Growth and Opportunity (GO) Virginia regional Economic Growth and Diversification Plans
- VRIC's (ongoing) research-asset assessment study.

GO Virginia's nine Economic Growth and Diversification Plans provided the important regional data and perspective for this FY2018 Roadmap, while VRIC's study provided valuable empirical and other data to help understand and assess Virginia's technology and commercialization capabilities and opportunities.

The FY2018 Roadmap identifies the following sectors as research and technology strengths and opportunities that cut across regional and research assets and represent high-priority industries, subsectors, and research disciplines with promising out-year growth.

- **Advanced manufacturing**, with particular interest in advanced and engineered materials and power electronics
- **Communications**, with particular interest in next-generation broadband networks and wireless telecommunications
- **Cyber security and cyber-physical systems**, with particular interest in cloud-based and enterprise networks, critical infrastructure, authorization / authentication / identity management technologies, data and application encryption and key management, and mobile / device security
- **Energy**, with particular interest in clean energy, energy efficiency, and energy storage
- **Environment**, with particular interest in marine science and water technologies
- **Information technology**, with particular interest in data management and analytics, including related to the Internet of Things
- **Biosciences and medtech**, with particular interest in biopharma, diabetes technologies, cancer, neuroscience, including cognitive disorders and therapies, health IT, bioinformatics, personalized medicine, medical devices, and software
- **Transportation**, with particular interest in transportation logistics and intelligent systems
- **Unmanned systems and aerospace**, with unmanned systems including interest in air, space, ground, and water

Identifying and funding high-impact technologies will have widespread benefit to individual regions and to the Commonwealth as a whole. Investments targeted at the intersection of industry capabilities and direction, research strengths, and economic development can create a multiplier effect that increases the benefit of the CRCF, VRIF, and other industry / research growth initiatives.

Two of Virginia's strong and promising sectors, cyber security and data analytics, are considered priorities by regions and institutions across Virginia. Investments in these sectors will support growth in multiple industries important to the Commonwealth, including healthcare and biosciences, advanced manufacturing, education, energy, unmanned systems, and government.

## The Commonwealth Research and Technology Strategic Roadmap

Research requires specialized facilities and equipment; at Virginia's public universities, such infrastructure requests may be captured in the Commonwealth's budget for capital projects and capital outlay recommendations. Most capital projects requested by these institutions support objectives other than research. However, as in past years, the biennial [budget](#) and latest [Systemwide Capital Outlay Budget Recommendations for Higher Education in Virginia](#) include research facilities and / or equipment, or facilities that serve such purposes as research and teaching.

### Introduction

In accordance with Code of Virginia [Section 2.2-2221.2](#), CIT submits the Commonwealth Research and Technology Strategic Roadmap – a comprehensive framework the Commonwealth uses to identify research areas worthy of economic development and institutional focus.

Following assessments of the Commonwealth's strengths, priorities, and commercial opportunities, the R&T Roadmap identifies key industry sectors within the state that merit investment.

The Roadmap uses multiple perspectives to ensure a comprehensive view of the technology landscape. Research universities, entrepreneurs, federal laboratories, research institutes and consortia, and trade associations in Virginia, along with VEDP, were among sources that contributed to the Roadmap. In addition, information collected and reviewed to assess strengths and opportunities included industry reports prepared by the Commonwealth, the Administration's priorities, federal priorities and data, and investment community reports. Furthermore, this year CIT had a unique opportunity to draw from new resources:

- GO Virginia regional Economic Growth and Diversification Plans
- An assessment of the Commonwealth's research assets in higher education, federal labs, and the private sector (Research Assets Study), commissioned by SCHEV on behalf of the VRIC as provided for in the [2017 Appropriations Act, Item 255.A.2](#)

Since its introduction, the Roadmap has been a dynamic and ongoing initiative. Priorities and opportunities have continued to be assessed and cultivated in every region of the Commonwealth. In the years between the tri-annual updates required by legislation, CIT prepared higher-level refreshes of regional industry priorities prior to each CRCF request for proposals in order to reflect the changing landscape and opportunities.

The Roadmap highlights the commercially promising sectors that will drive economic growth in the Commonwealth. Grant review boards, legislators, and other officials can use the Roadmap to make informed investment decisions in research, technology, and economic development initiatives. In broad areas where Virginia is already strong, investments can help robust sectors excel. Where the Commonwealth has niche opportunities, investments also will make these sectors and Virginia more

competitive. Beyond this, the Roadmap will also help inform and align organizations across the state, including public and private universities.

Findings from the Roadmap guide industry sectors and disciplines eligible for awards from two technology research and commercialization programs: the CRCF and the VRIF. Effective January 1, 2018, however, awards from both programs may be made for research activities related to areas of focus other than those identified in the Roadmap, subject to a sufficient justification that it is in the Commonwealth's best interest to invest in the technology.

The assessment of statewide industry sectors and subsectors is a crucial step in identifying research areas worthy of institutional focus and Commonwealth investment. This assessment must consider well-defined regional priorities, statewide economic development initiatives, and industry strengths in light of the external climate and Virginia capabilities. The assessment also takes into account the potential for growth, commercialization, and job creation of various industries and research areas.

Regional industry priorities and those of academia, federal labs, and economic development professionals reflect many factors, with economic potential for revenue and job and company creation paramount. Cyber security, data analytics, advanced manufacturing, biosciences, and unmanned systems are among priorities. Federal science and technology (S&T) priorities also are a consideration, as research and development spending is often highest in those sectors, thus helping drive research, innovation, and economic development. Federal FY2019 research and development priorities identified in the FY2019 Administration Research and Development Budget Priorities memo<sup>3</sup> include autonomous and space-based systems; cyber security; such future computing capabilities as machine learning and quantum computing; clean energy, including fossil, nuclear, and renewable energy; biomedical innovation, including to prevent, treat, and defeat diseases; solutions for the aging population and drug addiction; and making healthcare more efficient and effective. Other federal priorities – including supporting early-stage, innovative research and incorporating STEM education, including computer science education, and workforce training opportunities into programs – reinforce priorities in the Commonwealth.

## Development of the Roadmap

An essential element of the Roadmap is that it provides a community-driven or bottom-up perspective on economic priorities. To develop the Roadmap, CIT collected, reviewed, and analyzed data from a multitude of sources. In line with the work plan presented to the VRIC in April 2017, CIT collected and reviewed information from public and private research universities, federal laboratories, and research institutes and consortia in Virginia. Materials included profiles that were prepared specifically to identify the institution's strengths and priorities, as well as information that was publically available, such as university strategic plans and six-year plans. Wherever possible, CIT drew from previously prepared,

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<sup>3</sup> Mulvaney, Mick. (2017). *FY 2019 Administration Research and Development Budget Priorities*. <https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2017/m-17-30.pdf>.

## The Commonwealth Research and Technology Strategic Roadmap

publically available information. CIT obtained and reviewed data from other sources, both inside and outside Virginia: reports prepared by the Commonwealth of Virginia, including the Virginia Commercial Space Flight Authority and commissions established to assess the aerospace, cyber security, and unmanned systems industries; the Administration; VEDP, including its Strategic Plan announced in December 2017; Virginia Catalyst (Virginia Biosciences Health Research Corporation, VBHRC); the GAP Funds investment team at CIT; members of the RTIAC; the federal government, including the aforementioned budget memo and National Science Foundation (NSF) statistics on research and development; and investment industry reports, including by PitchBook NVCA Venture Monitor and CB Insights. Empirical data is a valuable complement, and thus to augment this information, CIT additionally reviewed and analyzed the unique resources available for this iteration of the Roadmap: the Economic Growth and Diversification Plans prepared by each of the nine GO Virginia regions and the Phase I and Phase II reports of the Research Assets Study prepared for SCHEV on behalf of the VRIC by the consulting firm TEconomy Partners, LLC (TEconomy).

GO Virginia Economic Growth and Diversification Plans are the result of regional collaborations that included executives from business, local government, higher education, workforce, and economic development and planning, to identify a region's strengths, assets, and priorities, many of which are current and future strategic technology priorities. GO Virginia is an initiative to foster private-sector growth and job creation through state incentives for regional collaboration by business, education, and government. It was established in the 2016 Session of the General Assembly and brings together leaders to ensure the alignment of resources and the closing of skills gaps, and that each region finds success. The Plans help regions assess and develop solutions for their unique economic situations. Economic Growth and Diversification Plans are current as of this writing, having been completed and approved in Q1 FY2018.

The VRIC's Research Assets Study is well underway as of this writing, and the Roadmap has benefited from the data collection and assessment performed by TEconomy. Currently, Phase I is complete, and Phase II has been reported on and is nearly complete. The Study includes empirical data, including a review of patents, publications, and R&D expenditures at Virginia's colleges and universities. In addition, the Study reflects valuable in-person interviews that augment the empirical analyses. CIT coordinated information with TEconomy during the development of the Roadmap and the Study, which, to a degree, were done in parallel. (The Study will be completed in January 2018.) CIT's participation with the VRIC over the past year included briefings to the Committee on the Roadmap's background, processes, and resources; the plan of work for this submission; and a progress report. The information gathered in the above process has been distilled into this Roadmap and the technology sectors provided as a baseline to determine areas of focus for awards from the CRCF and VRIF programs.

The first use of this Roadmap was for the FY2018 CRCF request for proposals, which was issued on October 5, 2017. Technology sectors eligible for CRCF awards reflected early work in the Roadmap; data from most resources, whether final or in preliminary form, had been reviewed and analyzed prior to coordinating with the Secretary of Technology in September 2017 to identify the round's eligible sectors. Information on the process and resources was [presented](#) to the VRIC on November 7, 2017.

## Updates to the November 2014 Roadmap

Since the Roadmap's publication in November 2014, technology has advanced, priorities have been re-evaluated and, in some cases, revised, and some terminology has changed. This update to the Roadmap reflects these evolutions. For example, modeling and simulation, a standalone technology sector in the November 2014 Roadmap, is now considered a platform technology. That is, rather than being named as a separate technology sector, it is recognized as a fundamental aspect of many technology sectors, ranging from medicine to advanced manufacturing to unmanned systems. Another change is that nuclear physics is not named among the baseline sectors. While the Thomas Jefferson National Accelerator Facility (Jefferson Lab) brings unique capabilities to Virginia through its research and facilities, the sector's reach and collaborations are more limited than those named, as are its nearer term opportunities for commercialization through Commonwealth investment. Unmanned systems, cited as unmanned vehicles under advanced manufacturing in November 2014, is now a standalone sector. That reflects the prominence and economic opportunities afforded by drones and other unmanned systems, whether related to land, air, space, or water. Other subsectors named within advanced manufacturing, such as robotics and remote monitoring and sensing, are no longer called out, as they are fundamental to unmanned systems.

Other technologies are increasingly prominent and may be assessed for future Roadmaps. These include artificial intelligence, augmented reality, blockchain technology, machine learning, user behavior analytics, public safety communications technologies, food technologies, and agriculture.

## Regional Industry Priorities

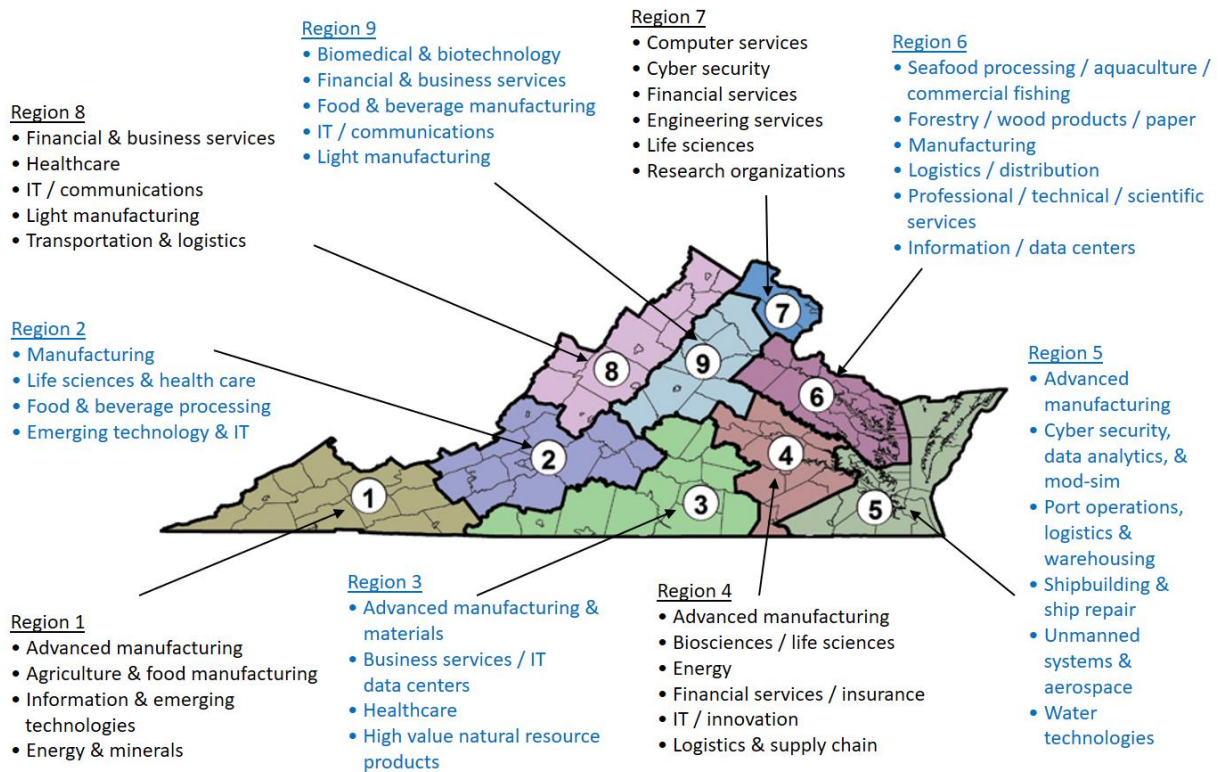
Virginia's nine regional Economic Growth and Diversification Plans provide information about regional strengths, industry priorities, and emerging opportunities. In the past, executives and senior members of Virginia's regional technology councils have had the lead role in identifying those priorities. In this update, GO Virginia regional plans provide a current and more comprehensive snapshot of each region's assets, strengths, and economic priorities.

In the months preceding this submission, a cross-section of regional leaders, including those from industry, established strategic priorities that were drawn from third-party assessments. Although not all regional priorities represent technology sectors, many do. Research and commercialization have an important role in driving success in many of these sectors. Several regions share priorities, and this leads to a beneficial multiplier effect: success in one region may benefit one or more other regions. Similarly, the multiplier effect also is achieved when technology sectors, such as cyber security, benefit numerous industries.

[Appendix A](#) provides a link to each regional Economic Growth and Diversification Plan published in 2017. A snapshot of priorities drawn from each Plan is in the [Summary](#) and the graphic below, which provides a sampling of cross-cutting and other regional priorities.



## Examples of Regional Priorities



## VEDP Economic Development Priorities

The mission of the Virginia Economic Development Partnership (VEDP) is to improve the quality of life and standard of living for Virginians by expanding the tax base and creating higher income employment opportunities. To fulfill this mission, VEDP focuses on cultivating new business investment, fostering international trade growth, and encouraging the expansion of existing industries, all with the aim of stimulating new job creation and capital investment in the Commonwealth. VEDP works with local and regional economic development organizations, state agencies, research assets in the Commonwealth, and other organizations to achieve its goals.

## Business Development Markets

VEDP directs its recruitment and outreach resources towards markets it expects will produce strong gains in employment, higher wages, and new capital investment. It works with local and regional partners to identify promising target markets. By mapping these markets to regional assets, VEDP can best meet the needs of business clients. In early December 2017, VEDP announced its new [strategic](#)

[plan](#), which includes targeted industry sectors and priorities. The plan includes marketing and outreach industry targets, which follow.

- **Advanced manufacturing**
  - Advanced materials
  - Aerospace
  - Automotive
  - Wood products
- **Corporate services**
  - Business process outsourcing / operations centers
  - Headquarters
- **Food and beverage processing**
- **Information / communications technologies**
  - Cyber security
  - Data centers
  - Software publishing
- **Life sciences**
- **Supply chain management**
- **Unmanned systems**

Additionally, VEDP’s newly released strategic plan identifies and discusses strategies to cultivate Virginia’s target industry growth clusters. Among them are information technology, including cyber security, and ensuring a coordinated effort and sound ecosystem for emerging disruptive technologies.

## Academia

### Background

The Roadmap identifies common themes among Virginia’s research universities with the goal of mapping university capabilities to regional and other strengths and priorities and market opportunities. This review provides insights into research areas that offer promise for commercialization and economic benefits to Virginia. For the purposes of this study, a “research university” is defined as one with more than \$3.0 million in annual science and engineering (S&E) R&D expenditures, as reported by NSF in its Fiscal Year 2016 Higher Education Research and Development Survey (HERD)<sup>4</sup>, the last year for which data is currently available. Virginia’s research universities, by this definition, from which input was sought are: the College of William and Mary (W&M), Eastern Virginia Medical School (EVMS), George Mason University (Mason), Hampton University (HU), James Madison University (JMU), Norfolk State University (NSU), Old Dominion University (ODU), the University of Virginia (U.Va.), Virginia

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<sup>4</sup> National Science Foundation. (2017). *Higher Education Research and Development Survey Fiscal Year 2016*. <https://ncesdata.nsf.gov/herd/2016/>.

Commonwealth University (VCU), Virginia Polytechnic and State University (Virginia Tech, VT), and Virginia State University (VSU). Input also was invited from George Washington University (GWU) on the basis of its research expenditures and impact on the Commonwealth from its Virginia Science and Technology campus, located in Loudoun County.

In order to identify and gauge strengths and priorities at these research universities, each institute was asked to identify its key areas. In some cases, relevant information was publically available. In other cases, institutions developed profiles. Responses were compiled and analyzed in order to identify common research priority areas. Additionally, CIT considered strategic plans and six-year plans produced by universities to understand focus areas for research and commercialization.

### **Strategic Plans and Six-Year Plans of Higher Education Institutions**

Universities' strategic plans focus on mission, vision, goals, and outcomes over a several-year period, addressing such topics as academic and research excellence, faculty, student life, effectiveness, regional impact, funding, and other priorities. Strategic plans may not identify and typically do not delve into specific research and / or technologies that support the plan.

The strategic plans reviewed for this Roadmap are multi-year plans; many are in or are approaching their final year. U.Va., VCU, and Virginia Tech are among the institutions whose strategic plans expire in 2018. New priorities may be reflected in these forthcoming documents, as well as in the plans of other institutions whose strategic plans expire in 2019 or soon after.

Virginia's public colleges and universities are required to develop six-year plans and adopt them biennially and amend or affirm them annually. Six-year plans were issued in early FY2018 and generally identify priority technology sectors. Synergies were expected and exist among the profiles provided by institutions, their six-year plans, and, if pertinent, strategic plans.

In recent years, interdisciplinary and pan-university research and research collaborations have been a focus, as well as partnerships with the private sector. Universities also have built partnerships with national laboratories, government, and other universities. These partnerships allow Virginia's institutions of higher education to perform research that is increasingly interdisciplinary, benefit from specialized equipment and instrumentation that is available elsewhere, and compete for funding that is awarded to large-scale interdisciplinary teams rather than individual investigators.

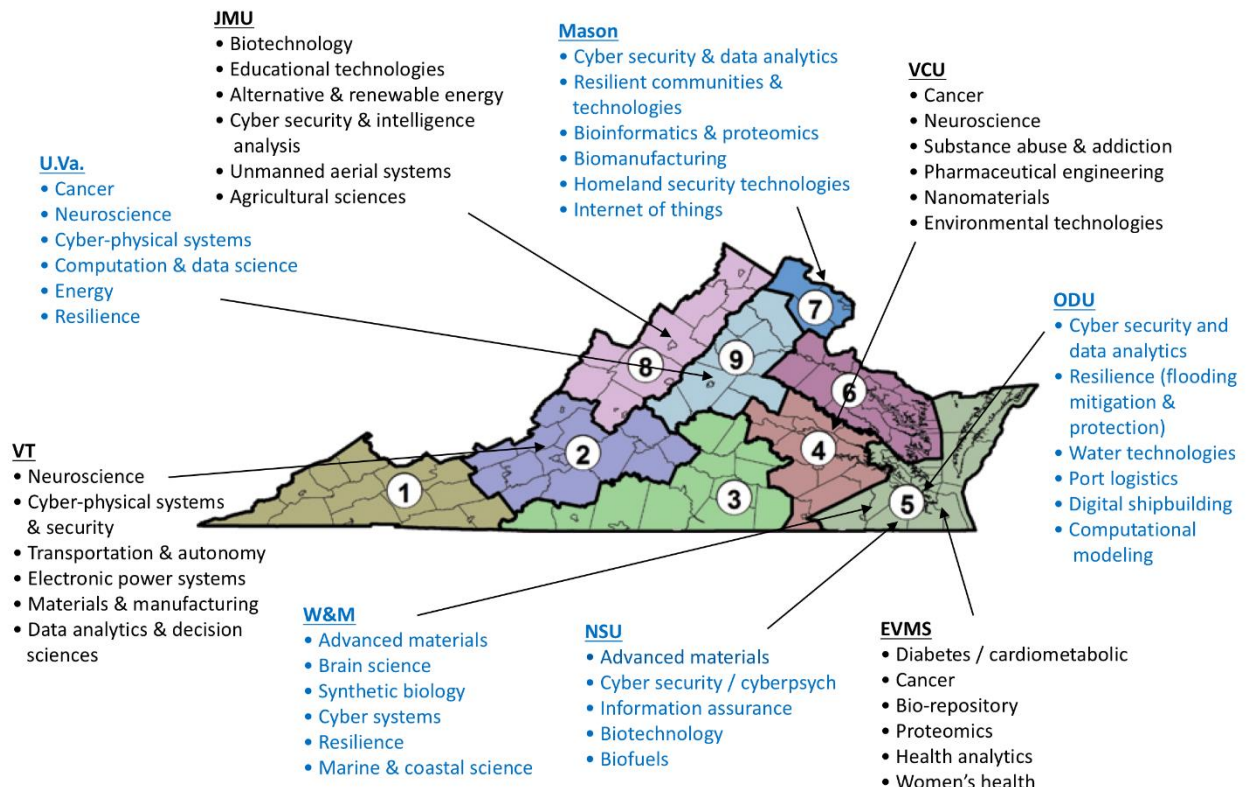
Virginia universities are increasingly focused on research commercialization, innovation, and entrepreneurship that span a multitude of sectors and include both students and faculty. These are common themes among the universities contributing to the Roadmap and include such initiatives as training, degree programs and concentrations in entrepreneurship; experiential learning programs such as student living / learning communities; business plan competitions; makerspaces; and clubs and mentoring.

## University Research Priorities

Collectively, the Commonwealth’s research universities have strengths and strategic interests in the technology sectors called out in this Roadmap as Virginia’s research and technology strengths and priorities. These include cyber security, cyber-physical systems, and data analytics; within biosciences and medtech: cancer, neuroscience, cardiometabolic disease, and medical devices; autonomous systems, advanced materials, and advanced manufacturing; and clean / renewable energy. In addition, cross-cutting opportunities in systems are of increasing interest to Virginia’s research universities. Many systems opportunities support smart communities, which is a Commonwealth priority and a growing area of interest worldwide. Interconnected communities, resilience, and sustainability cover such topics as pervasive communications and networks, autonomous systems, climate modeling and prediction, environmental technologies, water and food security, and sustainable infrastructure development. Research priorities at numerous Virginia institutions can be found on their websites and are highlighted in their [six-year plans](#), available on SCHEV’s website. Additionally, some strategic plans identify priorities; links to individual university’s plans are available in [Appendix B](#).

The graphic below provides a sampling of university strengths and priorities.

## Examples of University Priorities



## Other Research and Development Assets

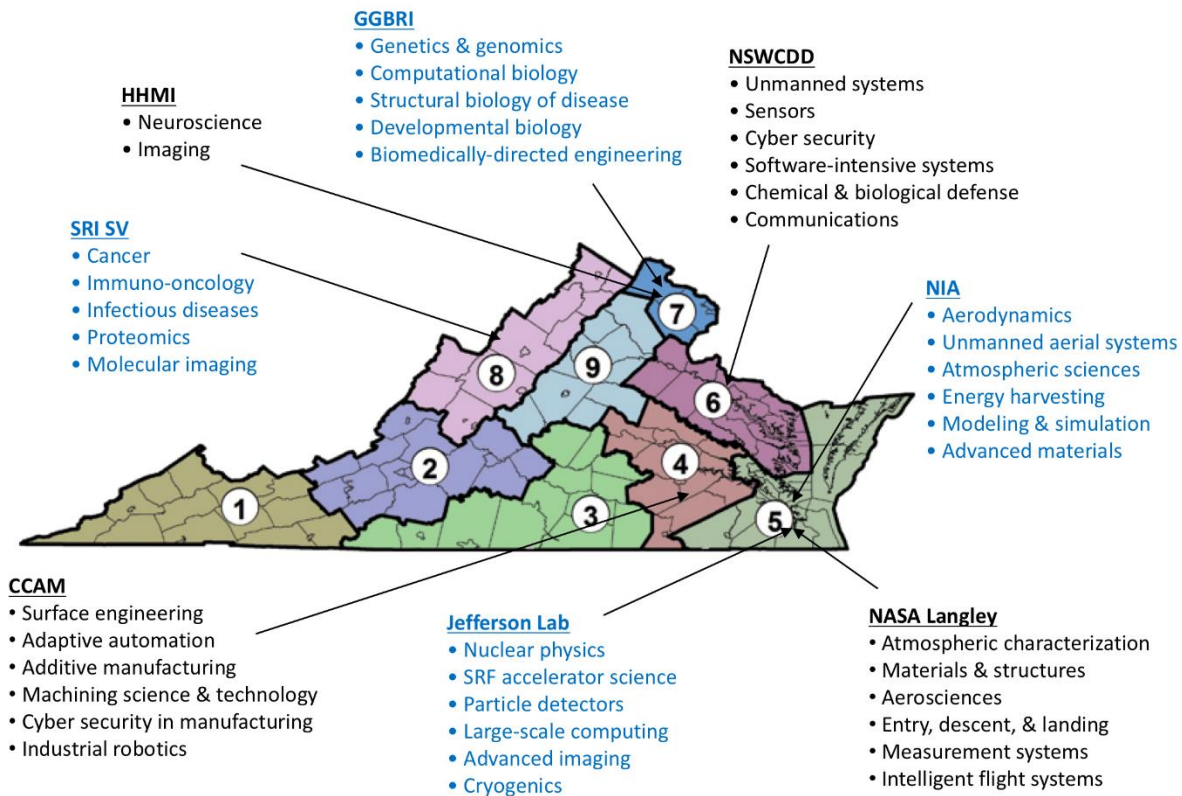
Virginia is home to research and development assets that augment the state’s capabilities in research, technology development, and education. The Roadmap reflects priorities of several R&D institutions in the Commonwealth. Three are federal laboratories – the Jefferson Lab, NASA Langley Research Center (NASA Langley), and the Naval Surface Warfare Center Dahlgren Division (NSWCDD, Dahlgren). Additional information was collected from other research organizations in Virginia: the Commonwealth Center for Advanced Manufacturing (CCAM), the National Institute of Aerospace (NIA), SRI Shenandoah Valley (SRI SV), as well as the Global Genomics & Bioinformatics Research Institute (GGBRI) and the Janelia Howard Hughes Medical Institute (HHMI).

## Capabilities of the Commonwealth’s R&D Assets

Commonalities and unique capabilities exist among the research institutes and federal labs of the Commonwealth; these capabilities also compliment other initiatives in industry and academia. Basic research is important among many, as is applied research. Similarly, the research institutes share an interest in innovation and commercialization. A common thread is the dedication to the development of life-changing technologies that will be key to advancing the innovation continuum and economy, and an increasing commitment to technology commercialization.

The synergies and diversity among key industry sectors represented by the research institutes and federal labs are shown in the graphic below and are a sampling of strengths and strategic priorities. Additionally, links to individual institute websites are available in [Appendix C](#).

## Examples of Research Institute Priorities



## Research Assets Study

The early phases of the research and innovation asset assessment being conducted in late-2017 for VRIC identified several areas for focused development around innovation-led growth opportunities across the ecosystem of Virginia’s universities, industries, and federal labs. TEconomy’s final report will be released in January 2018, and its preliminary findings indicate the presence of four high-level growth opportunities that the state can leverage (see below). A broader summary of TEconomy’s October 9, 2017 [Phase I presentation](#) to VRIC on the priority platform areas which support these growth opportunities appears in [Appendix D](#).

### 1) Cyber and Cyber-Physical Security

**Cyber and Cyber-Physical Security**, including “security by design” hardware and software; vulnerability assessment and testing solutions; real-time, massive-scale forensic network traffic and computer system activity analysis; advancements in encryption, access control, and identity management technologies; user-behavior analytics modeling; cloud and data center infrastructure security; and Internet of Things security.

## 2) **Integrated Networking, Communications Systems, and Data Analytics**

**Integrated Networking, Communications Systems, and Data Analytics**, including wireless and other point-of-access connectivity technologies; routing of high volumes of data-driven communications; rapid retrieval and processing of “big data” from data storage centers; rapid processing of large databases to drive endpoint analytics applications, such as machine learning; resilient, distributed infrastructure to support cloud-based services and software; and data center infrastructure automation.

## 3) **System of Systems Engineering**

**System of Systems Engineering**, across applications verticals related to advanced manufacturing, including aerospace, ship building, power electronics, and engineered materials; unmanned systems (aerial, ground, and naval); atmospheric, naval / ocean, and other environmental sensor systems; geospatial navigation technologies; and transportation systems.

## 4) **Life Sciences**

**Life Sciences**, including biopharmaceuticals tailored to specific genetic and metabolic biomarkers for treatment of disease; advanced diagnostic and testing technologies enabled by genetic sequencing, high throughput sample processing, advanced medical imaging, and novel testing materials development; medical devices, particularly those used in diagnostic sensing for clinical care and regenerative medicine focused on biocompatible and implantable materials; bioinformatics involving the integration of “big data” processing and predictive modeling for use in computational biology and healthcare applications; and commercial and industrial biotechnologies for use in industrial, agricultural, and other bioprocess engineering applications.

These findings followed TEconomy’s rigorous review of patent, publications, R&D expenditures, and other innovation ecosystem data along with numerous interviews throughout the Commonwealth on research and commercialization capabilities and priorities. The consultant’s Phase I and II reports and presentations are available at the [VRIC Meetings](#) webpage.

## **Intellectual Property**

Intellectual property (IP) agreements are a cornerstone of success in the research enterprise. Straightforward, win-win agreements that provide incentives for all parties can drive collaboration, commercialization, and other desirable outcomes. IP agreements, however, are influenced by an array of policies and perspectives. This includes the nature of the research and the individual policies among Virginia universities, research institutions, and industry.

For awards made under CRCF, the policy requires that an intellectual property agreement be executed, when IP is or may be jointly developed, before funding is disbursed. Universities or other parties that apply for CRCF funding are expected to use their respective existing approved IP policies and, as appropriate, to negotiate an agreement that has been accepted by and indicates the rights and

obligation of all parties. This continues the policy established in the 2011 Roadmap and implemented in the CRCF solicitations since the Fund's inception.

## Capital Outlay

The Commonwealth's Six-Year Capital Outlay Plan addresses the continuing and emerging infrastructure needs of the Commonwealth's public colleges and universities. Capital outlay encompasses large non-recurring expenses, which can include acquisition, construction, improvements to infrastructure, and equipment. It can also include improvements to real property leased for use by a public educational institution<sup>5</sup>. Although most capital projects requested by Virginia's public universities support objectives other than research, a few research facilities and / or equipment are included among infrastructure requests. Capital outlay projects in the initial and amended budgets for the FY2016-2018 biennium and several prior years are available on the Department of Planning and Budget's (DPB's) [Virginia Budget webpage](#).

Drawn from SCHEV's most recent analysis of capital outlay requests, announced in September 2017, a sampling of those receiving a Priority 1 status are identified in the graphic below; they include research and teaching laboratories. These requests may be a portion of what higher education institutions regard as future requirements. Priority 1 projects meet the Council's Fixed Asset Guidelines or are considered critical to supporting the capital outlay needs of Virginia's system of higher education. Also included in the Priority 1 group are projects that address the Americans with Disabilities Act, security issues, and infrastructure improvements for energy efficiency and mechanical, electrical, and plumbing (MEP) systems. This report, however, addresses space for research or research-related requirements.

The 2008 Special Session of the General Assembly established the Six-Year Capital Outlay Plan Advisory Committee to assist the Governor in the creation of the Six-Year Capital Outlay Plan<sup>6</sup>. Committee members include the Director of DBP and the Executive Director of SCHEV; CIT works with both organizations regarding capital outlay requests and Roadmap findings.

Additional information on capital outlay projects in the Commonwealth's budget is available at [www.dpb.virginia.gov](http://www.dpb.virginia.gov), and information on projects identified as Priority 1 by SCHEV and not in the budget as of this writing is available via the [2018-20 Systemwide Capital Outlay Budget Recommendations for Higher Education in Virginia](#) on the SCHEV website.

Examples of research-related capital outlay projects that are in the FY2016-2018 biennium budget or recently were categorized as Priority 1 by SCHEV staff are provided in the graphic below.

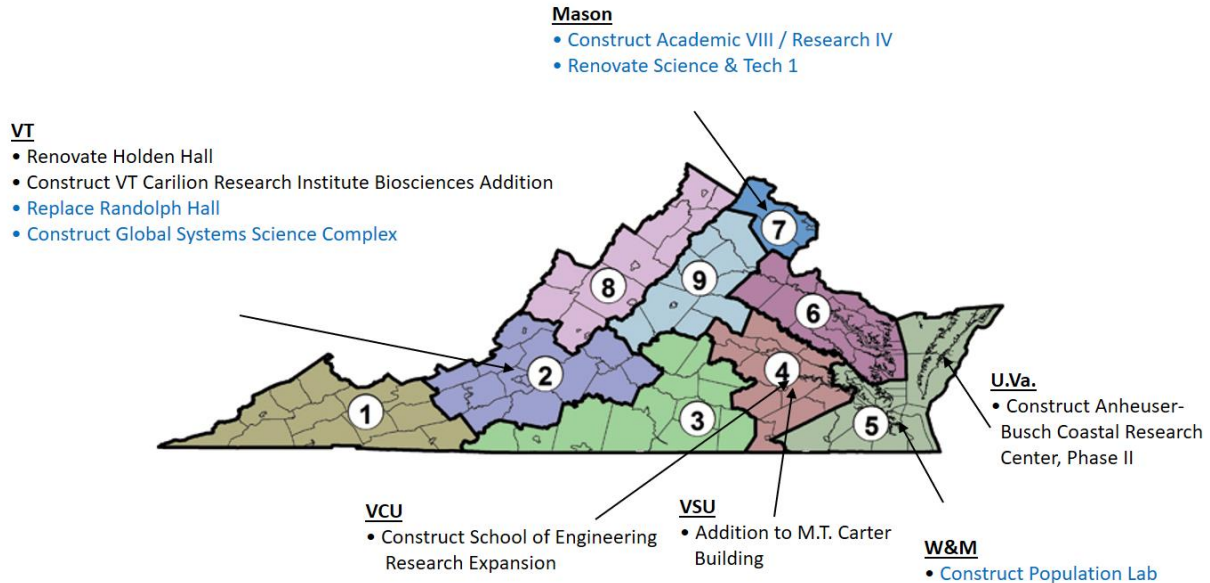
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<sup>5</sup>Commonwealth of Virginia Auditor of Public Accounts. (January 2014). *Review of Capital Outlay Funding and Cash Flow Processes*.

<sup>6</sup> Commonwealth of Virginia Auditor of Public Accounts. (January 2014). *Review of Capital Outlay Funding and Cash Flow Processes*.



## Examples of Research-Related Capital Outlay Projects and Requests



Black font = projects in the Commonwealth budget.

Blue font = projects categorized Priority 1 in 2017 by SCHEV staff. These are not in the state budget as of Dec. 13, 2017.

### Summary

This R&T Strategic Roadmap examined research strengths, priorities, and opportunities in the Commonwealth's private sector, universities, research institutes, and federal labs to identify and align key industry sectors within the state and, ultimately, assess which sectors present the Commonwealth with the most commercial promise. Information was gathered on regional assets, strengths and priorities, existing and projected research and commercialization capabilities, economic development priorities, and the external climate. A summary of high-level priorities among research universities, research institutes and GO Virginia regions is available [here](#).

The findings represent a high-level direction the Commonwealth may take for future investments in addition to research and technologies eligible for CRCF and VRIF awards. These opportunities follow:

- **Advanced manufacturing**, with particular interest in advanced and engineered materials and power electronics
- **Communications**, with particular interest in next-generation broadband networks and wireless telecommunications

## The Commonwealth Research and Technology Strategic Roadmap

- **Cyber security and cyber-physical systems**, with particular interest in cloud-based and enterprise networks, critical infrastructure, authorization / authentication / identity management technologies, data and application encryption and key management, and mobile / device security
- **Energy**, with particular interest in clean energy, energy efficiency, and energy storage
- **Environment**, with particular interest in marine science and water technologies
- **Information technology**, with particular interest in data management and analytics, including related to the Internet of Things
- **Biosciences and medtech**, with particular interest in biopharma, diabetes technologies, cancer, neuroscience, including cognitive disorders and therapies, health IT, bioinformatics, personalized medicine, medical devices, and software
- **Transportation**, with particular interest in transportation logistics and intelligent systems
- **Unmanned systems and aerospace**, with unmanned systems including interest in air, space, ground, and water

## APPENDIX A: Regional Industry Priorities

GO Virginia Region	Website	Economic Growth and Diversification Plan
Region 1	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/322.html">http://www.dhcd.virginia.gov/index.php/component/content/article/322.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%20G&amp;D%20Plan%2011.6.17%20revised.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%20G&amp;D%20Plan%2011.6.17%20revised.pdf</a>
Region 2	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/323.html">http://www.dhcd.virginia.gov/index.php/component/content/article/323.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%202%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%202%20G&amp;D%20Plan.pdf</a>
Region 3	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/324.html">http://www.dhcd.virginia.gov/index.php/component/content/article/324.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%203%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%203%20G&amp;D%20Plan.pdf</a>
Region 4	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/325.html">http://www.dhcd.virginia.gov/index.php/component/content/article/325.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%204%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%204%20G&amp;D%20Plan.pdf</a>
Region 5	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/326.html">http://www.dhcd.virginia.gov/index.php/component/content/article/326.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%205%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%205%20G&amp;D%20Plan.pdf</a>
Region 6	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/327.html">http://www.dhcd.virginia.gov/index.php/component/content/article/327.html</a>	Access Zip file from <a href="http://www.dhcd.virginia.gov/index.php/component/content/article/327.html">http://www.dhcd.virginia.gov/index.php/component/content/article/327.html</a>
Region 7	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/328.html">http://www.dhcd.virginia.gov/index.php/component/content/article/328.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%207%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%207%20G&amp;D%20Plan.pdf</a>
Region 8	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/329.html">http://www.dhcd.virginia.gov/index.php/component/content/article/329.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%208%20G&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%208%20G&amp;D%20Plan.pdf</a>
Region 9	<a href="http://www.dhcd.virginia.gov/index.php/component/content/article/330.html">http://www.dhcd.virginia.gov/index.php/component/content/article/330.html</a>	<a href="http://www.dhcd.virginia.gov/images/GoVA/Region%209%20E&amp;D%20Plan.pdf">http://www.dhcd.virginia.gov/images/GoVA/Region%209%20E&amp;D%20Plan.pdf</a>

## APPENDIX B: Colleges and Universities

Institution	Website	Strategic Plan
College of William & Mary	<a href="http://www.wm.edu/">http://www.wm.edu/</a>	<a href="http://www.wm.edu/about/administration/strategicplanning/plan/index.php">http://www.wm.edu/about/administration/strategicplanning/plan/index.php</a>
Eastern Virginia Medical School (EVMS)	<a href="http://www.evms.edu/">http://www.evms.edu/</a>	<a href="https://www.evms.edu/about_evms/leadership/evms_strategic_plan_2015-2018/">https://www.evms.edu/about_evms/leadership/evms_strategic_plan_2015-2018/</a>
George Mason University (Mason)	<a href="https://www2.gmu.edu/">https://www2.gmu.edu/</a>	<a href="https://strategicplan.gmu.edu/">https://strategicplan.gmu.edu/</a>
Hampton University (HU)	<a href="http://www.hamptonu.edu/">http://www.hamptonu.edu/</a>	Internal to Hampton University
George Washington University – Virginia Science & Technology Campus (GWU – S&T Campus)	<a href="https://www.virginia.gwu.edu/">https://www.virginia.gwu.edu/</a>	<a href="https://provost.gwu.edu/strategic-plan">https://provost.gwu.edu/strategic-plan</a>
James Madison University (JMU)	<a href="http://www.jmu.edu/">http://www.jmu.edu/</a>	<a href="https://www.jmu.edu/jmuplans/jmu-strategic-plan/index.shtml">https://www.jmu.edu/jmuplans/jmu-strategic-plan/index.shtml</a>
Norfolk State University (NSU)	<a href="https://www.nsu.edu/">https://www.nsu.edu/</a>	<a href="https://cm1.nsu.edu/Assets/websites/president/pdf/NSU-Strategic-Plan.pdf">https://cm1.nsu.edu/Assets/websites/president/pdf/NSU-Strategic-Plan.pdf</a>
Old Dominion University (ODU)	<a href="http://www.odu.edu/">http://www.odu.edu/</a>	<a href="https://www.odu.edu/about/planning/strategic-plan-14-19">https://www.odu.edu/about/planning/strategic-plan-14-19</a>
University of Virginia (U.Va.)	<a href="http://www.virginia.edu/">http://www.virginia.edu/</a>	<a href="http://planning.virginia.edu/current-strategic-plan">http://planning.virginia.edu/current-strategic-plan</a>
Virginia Commonwealth University (VCU)	<a href="https://www.vcu.edu/">https://www.vcu.edu/</a>	<a href="https://quest.vcu.edu/">https://quest.vcu.edu/</a>
Virginia Polytechnic and State University (Virginia Tech, VT)	<a href="http://www.vt.edu/">http://www.vt.edu/</a>	<a href="https://www.president.vt.edu/about-the-office/strategic-plan.html">https://www.president.vt.edu/about-the-office/strategic-plan.html</a>
Virginia State University (VSU)	<a href="http://www.vsu.edu/">http://www.vsu.edu/</a>	<a href="http://www.vsu.edu/strategicplan/">http://www.vsu.edu/strategicplan/</a>

Six-year plans are provided to SCHEV by Virginia’s public institutions of higher education. Current and prior plans are available at <http://www.schev.edu/index/institutional/planning-and-performance/current-six-year-plans---2017>,

## APPENDIX C: Research Institutes

Institution	Website
Commonwealth Center for Advanced Manufacturing (CCAM)	<a href="http://www.ccam-va.com/">http://www.ccam-va.com/</a>
NASA Langley Research Center (NASA Langley)	<a href="https://www.nasa.gov/langley">https://www.nasa.gov/langley</a>
National Institute of Aerospace (NIA)	<a href="http://www.nianet.org/">http://www.nianet.org/</a>
Naval Surface Warfare Center Dahlgren Division (NSWCDD, Dahlgren)	<a href="http://www.navsea.navy.mil/nswc/dahlgren/default.aspx">http://www.navsea.navy.mil/nswc/dahlgren/default.aspx</a>
SRI Shenandoah Valley (SRI SV)	<a href="http://www.sri.com/research-development/specialized-facilities/sri-shenandoah-valley">http://www.sri.com/research-development/specialized-facilities/sri-shenandoah-valley</a>
Thomas Jefferson National Acceleratory Facility (Jefferson Lab)	<a href="https://www.jlab.org/">https://www.jlab.org/</a>
Global Genomics & Bioinformatics Research Institute (GGBRI)	<a href="http://www.schev.edu/docs/default-source/VRIC/2017-05-24/ggbri-presentation.pdf">http://www.schev.edu/docs/default-source/VRIC/2017-05-24/ggbri-presentation.pdf</a>
Janelia Research Campus, Howard Hughes Medical Institute (HHMI)	<a href="https://www.janelia.org/">https://www.janelia.org/</a>

## **APPENDIX D: Priority Platform Areas**

*Findings from the Research Assets Study's Line-of-Sight Analyses*

### **Signature Innovation Platforms**

*Strengths in both industry and research institution measures*

- Cyber and cyber-physical security

### **Priority Innovation Platforms**

*Strong industry or research institution activities and moderate in other sector*

- Applied data analytics, image analysis, and decision support tools
- Electronics and optics materials / components
- Applied sensing and geospatial systems
- Wireless communications technologies and equipment

### **High Potential Innovation Platforms for Consideration**

*Strengths in both industry and research institution measures*

- Biopharmaceuticals, biochemistry, and biological analysis
- IT, networking, and data management
- Transportation systems and technologies
- Environmental sciences and technology

### **Middling and Niche Innovation Platforms**

- Diagnostic sensing and imaging medical devices
- Regenerative medicine devices
- Engineered materials for aerospace, naval, and defense applications
- Energy, power systems, and fuels
- Animal science and veterinary medicine