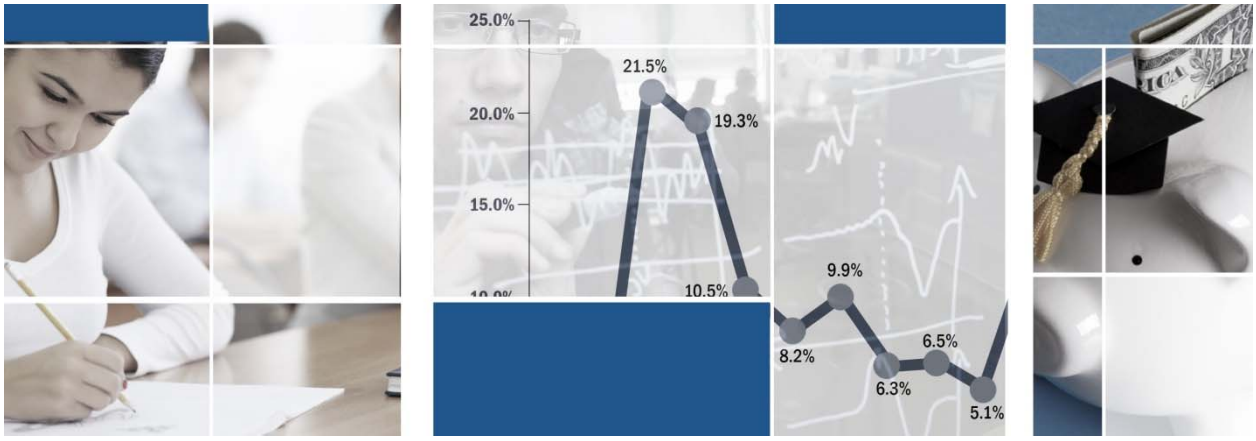
February 2017



Virginia Areas of Research Strength

Staff Report

STATE COUNCIL OF HIGHER EDUCATION FOR VIRGINIA

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Executive Summary

Academic research in Virginia is a $1.4 billion enterprise annually. Significant investments at federal labs and by the private sector contribute to a robust research ecosystem. The entities charged with administering the Virginia Research Investment Fund (VRIF) have expressed interest in developing a full understanding of the scope and depth of research in Virginia. Pending legislation would provide an opportunity for the Virginia Research Investment Committee (VRIC) to participate in the update of the Commonwealth's Research and Technology Strategic Roadmap (R&T Roadmap) in 2017 and to continue in future years to refine that document to ensure that, in addition to providing reflective information on the current status of research, it provides actionable intelligence about future directions for Virginia's research enterprise. During that process, VRIC members will develop the full understanding they seek.

Against that longer-term backdrop, this brief report examines the strengths of Virginia's research ecosystem through the analysis of two major indicators: academic research expenditures and both academic and total patent awards. Additional indicators include start-up growth and peer-reviewed publications. Virginia and national trends for these indicators are also explored. Finally, the industries listed in the VRIF statutes (a subset of the industries in the R&T Roadmap) are mapped to the areas of strength to reveal potential foci for the Round 1 competition for VRIF funding.

Institutions of higher education must compete nationally to secure funding. Therefore, higher education research expenditures indicate areas of expertise with the muscle to win funding in a highly competitive environment. Because intellectual property must be protected prior to commercialization, patent awards are one indication of the areas of research that have commercial potential.

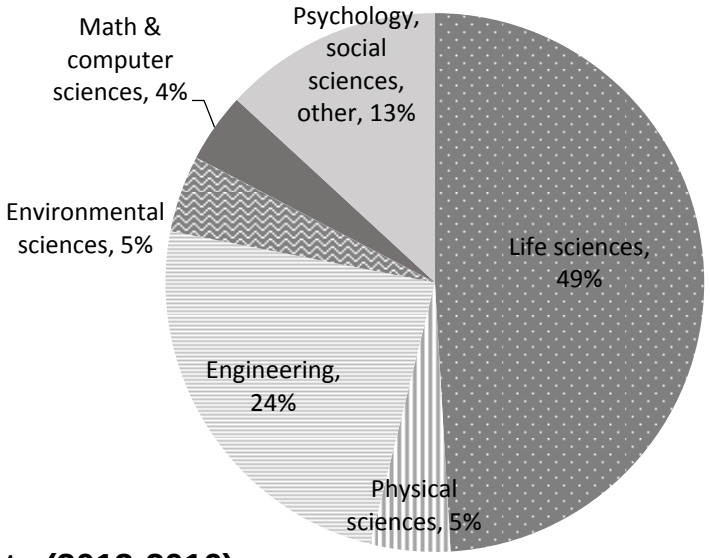
The graphic on the next page (Figure 1) illustrates the intersection between Virginia's areas of academic research strength and areas ripe for commercialization, with an overlay of the industries listed in the VRIF statutes. Potential areas of collaboration between institutions and the private sector are also revealed.

The remainder of the report provides more in-depth information on the indicators and national and Virginia trends including peer-reviewed publications, which confirm the areas of expertise revealed by expenditures and patent awards, and start-up growth which shows the strength of Virginia's innovation ecosystem.

In conclusion, staff suggest that the committee consider investing VRIF funds at the intersection of three vectors: university research strength and expertise; commercial potential; and the larger research ecosystem in Virginia.

Figure 1: Intersection of Virginia's Research Strengths and Areas with Commercial Potential

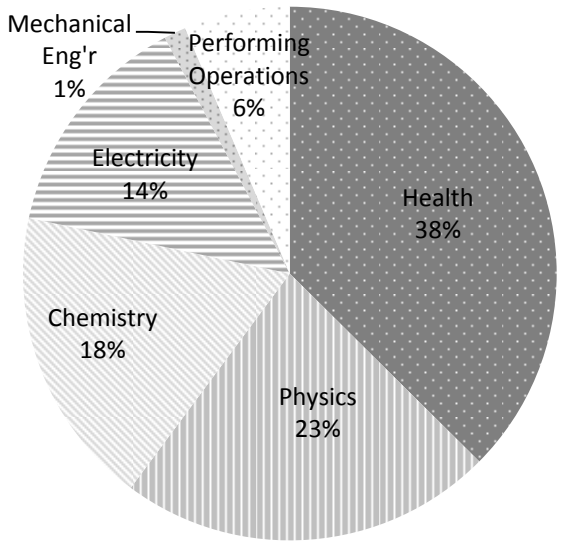
R&D Expenditures at Virginia Institutions ($1.4 billion)



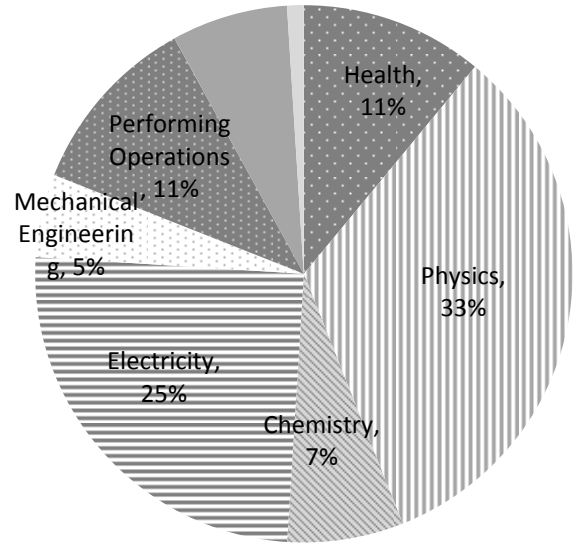
Statutory Focus Areas

Life Sciences
(includes health, physics, chemistry & electricity)
IT – Data Analytics
(includes health, physics, chemistry & electricity)
Cybersecurity
(includes health, physics, chemistry, electricity & computer science/math)

Academic Patents (2013-2016)



All Patents (2013-2016)



Background

Academic research in Virginia is a $1.4 billion enterprise annually. Significant additional investments at federal labs and by the private sector contribute to a robust research ecosystem. The entities charged with administering the Virginia Research Investment Fund (VRIF) have expressed interest in developing a full understanding of the scope and depth of research in Virginia. Pending legislation would provide an opportunity for the Virginia Research Investment Committee (VRIC) to participate in the update of the Commonwealth's Research and Technology Strategic Roadmap (R&T Roadmap) in 2017 and to continue in future years to refine that document to ensure that, in addition to providing reflective information on the current status of research, it provides actionable intelligence about future directions for Virginia's research enterprise. During that process, VRIC members will develop the full understanding they seek.

This brief report analyzes the following information:

- National trends
- Higher education R&D expenditures, which indicate general research areas of expertise
- Patents awarded and assigned to Virginia entities, which indicate research areas that have potential for commercialization
- Start-up growth, which shows the strength of Virginia's innovation ecosystem
- Peer-reviewed publications, which confirm areas of expertise revealed by expenditures and patent production

Sources of information include:

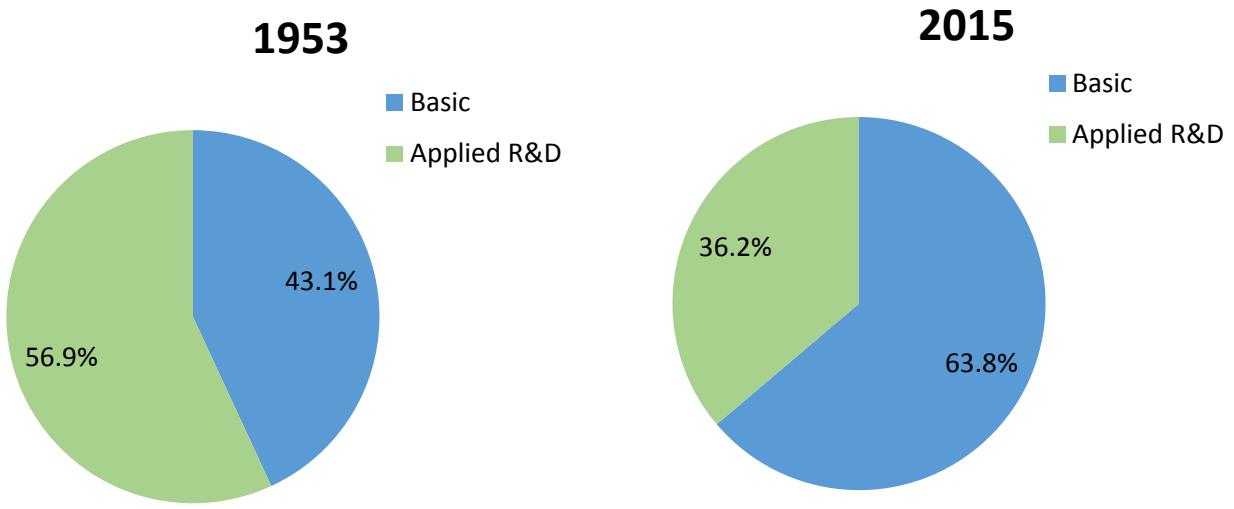
- National Science Board, Science and Engineering Indicators 2016
- National Science Foundation, Higher Education Research and Development Survey, FY2015
- U.S. Patent and Trademark Office, "U.S. Colleges and Universities – Utility Patent Grants 1969-2012" and the USPO patent database and other reports
- Kauffman Foundation's 2016 Index of Growth Entrepreneurship
- Reed Elsevier and Council of State Government's April 2015 Report, "America's Knowledge Economy: A State-by-State Review"
- CIT's Commonwealth Innovation and Entrepreneurship Measurement System (IEMS)

Historical Higher Education Trends

Basic vs. Applied Research Expenditure Trend – National

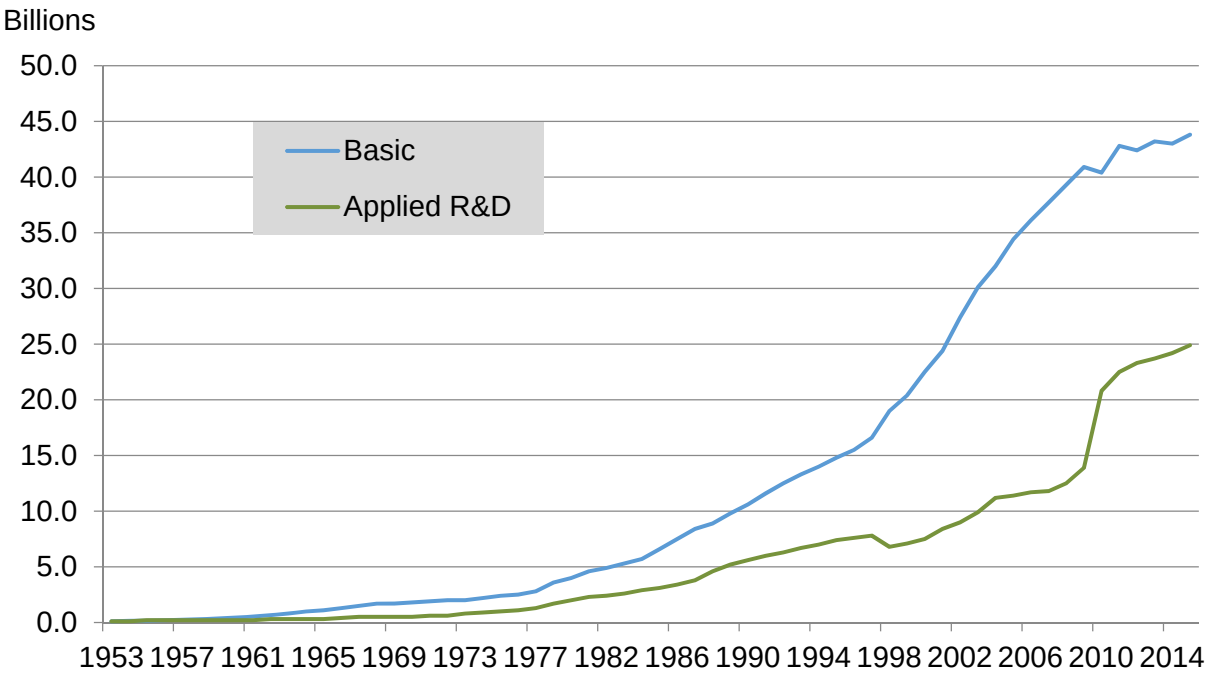
Nationally, in 1953, expenditures for applied research outpaced basic research 57% to 43%. By 2015, the proportions were reversed, with 64% of all academic research expenditures focused on basic research and 36% on applied research. (Figure 2)

Figure 2: Basic and Applied Research – Proportional Spending



Expenditures for both types of research increased over that timeframe, but basic research expenditures increased much more steeply until the recession in 2008, when the American Recovery and Reinvestment Act (ARRA) focused new funding on applied research. (Figure 3)

Figure 3: Basic and Applied Research – Increase in Spending



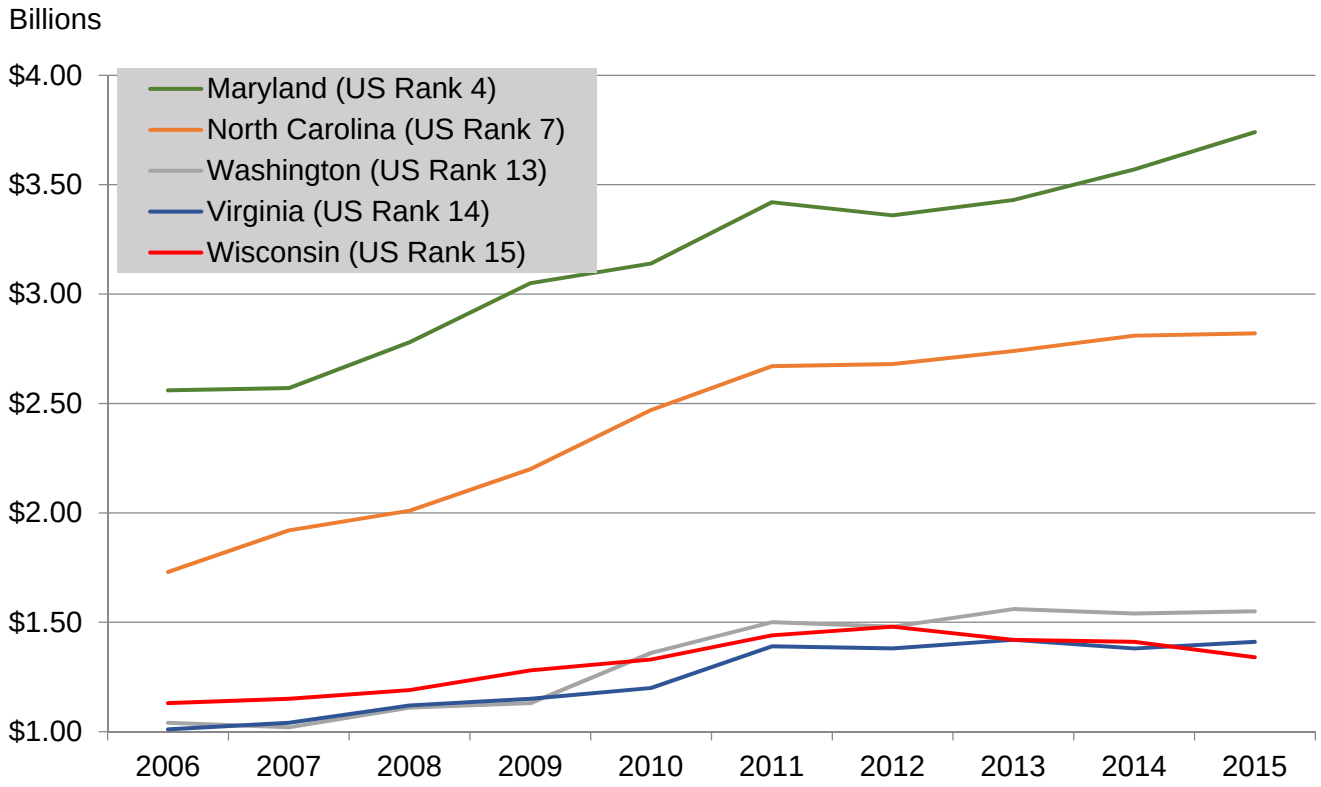
Comparative Research Expenditure Trend – VA, MD, NC, WI, WA

The Virginia Plan for Higher Education calls for Virginia to be the best-educated state by 2030. The plan includes six initiatives with six corresponding targets. Recognizing that public investment in research at colleges and universities spurs development of scientific and medical discoveries, new medicines and treatments, and all types of innovations and inventions, which lead to patents, licenses, and the commercialization of results, Initiative 6 of that plan promotes

economic development through research and sets a target to increase Virginia's research expenditures as a percentage of national totals by 30% by 2030. This goal focuses on increasing the total share of research funding compared to other states. In federal fiscal year 2014, Virginia ranked 14th nationally in annual expenditures on research and development in higher education. The Commonwealth's total share of expenditures compared to the national total was 2.05%. The target is to increase this share to 2.75% by 2030, an increase of almost $1 billion.

Virginia has been competing with Washington and Wisconsin for the 13th rank. In terms of attracting new businesses for economic development, Virginia competes with North Carolina and Maryland. Figure 4 illustrates the progress of Virginia in improving our rank relative to those four states.

Figure 4: Virginia's Rank Relative to Competing States



Academic Utility Patent Award Trend – National & Virginia Compared to Selected Other States

Utility patents are issued for inventions and, therefore, serve as an indicator of innovation. Nationally, the percentage of utility patents awarded that were assigned to academic institutions grew steadily from 0.83% to just under 2% over the past 25 years, but has held steady at that rate recently. Virginia outpaces the national average.

A comprehensive study issued by the U.S. Patent Office examined data through 2012. The report, U.S. Colleges and Universities – Utility Patent Grants 1969-2012," found:

- In 1985, 0.83% of the total utility patents awarded were assigned to U.S. academic institutions.
- The percent share of utility patents issued to U.S. academic institutions has held steady recently at just under **2%**.
- In 2012, Virginia's 7 research universities combined were awarded 60 patents; **3.5%** of the total 1,691 utility patents for Virginia in that year.

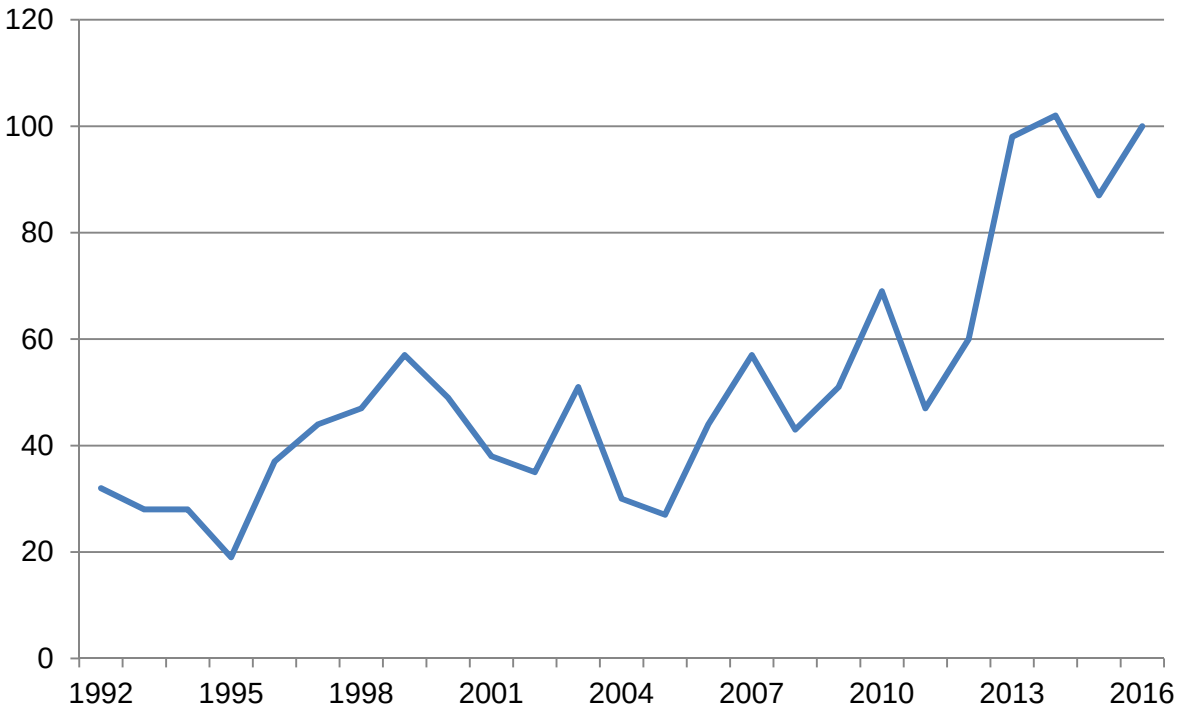
Data for 2012 also show the University of California has been the top academic institution receiving utility patents each year during the period 1992 through 2012. Massachusetts Institute of Technology has been the second most prolific patenting university each year since 2005.

- University of California System - 361 patents
- Massachusetts Institute of Technology - 216 patents
- University of Wisconsin System - 167 patents
- University of Texas System - 141 patents
- California Institute of Technology - 136 patents

Academic Utility Patent Award Trend – Virginia

In 1992, 32 utility patent awards were assigned to Virginia's seven research institutions. By 2016, the total had jumped to 100.

Figure 5: Virginia Utility Patent Award Trend



Virginia's Strength in Commercializing Research Through Small Businesses

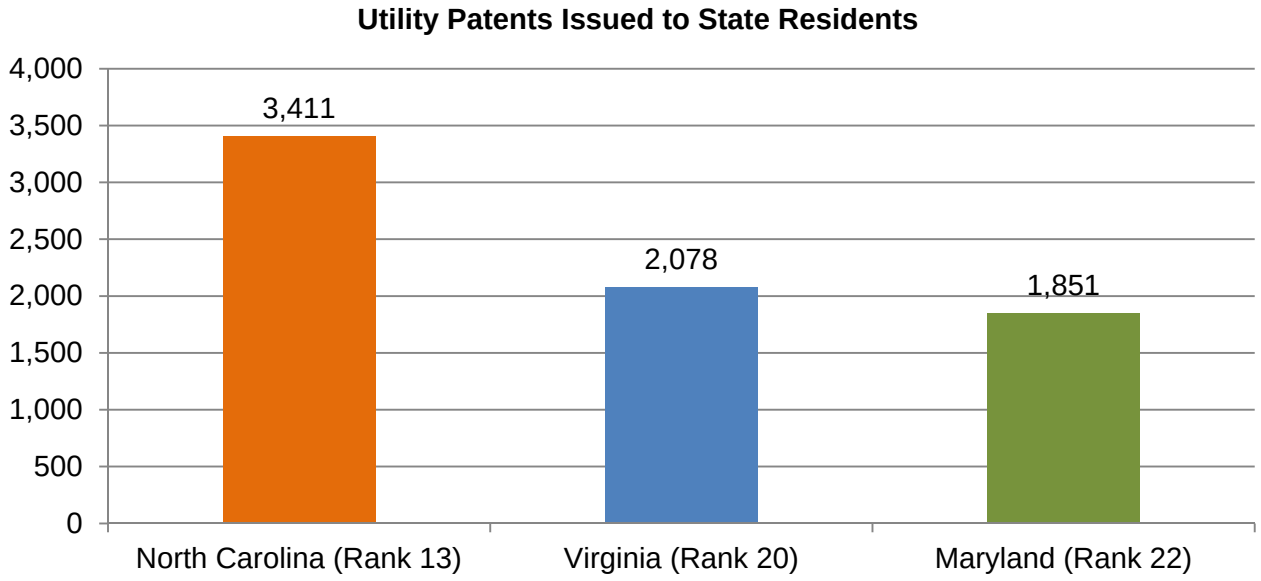
Virginia Utility Patent and SBIR Grant Award Strengths

Virginia is significantly stronger than neighboring states of North Carolina and Maryland in the commercialization of research through small businesses, as indicated by Small Business Innovation Research (SBIR) grant awards.

The National Science Foundation publishes state profiles of science and engineering indicators and then ranks states.* Comparing utility patents issued to residents of Virginia, North Carolina, and Maryland reveals that North Carolina ranks 13th nationally, while Virginia and Maryland rank 20th and 22nd, respectively.

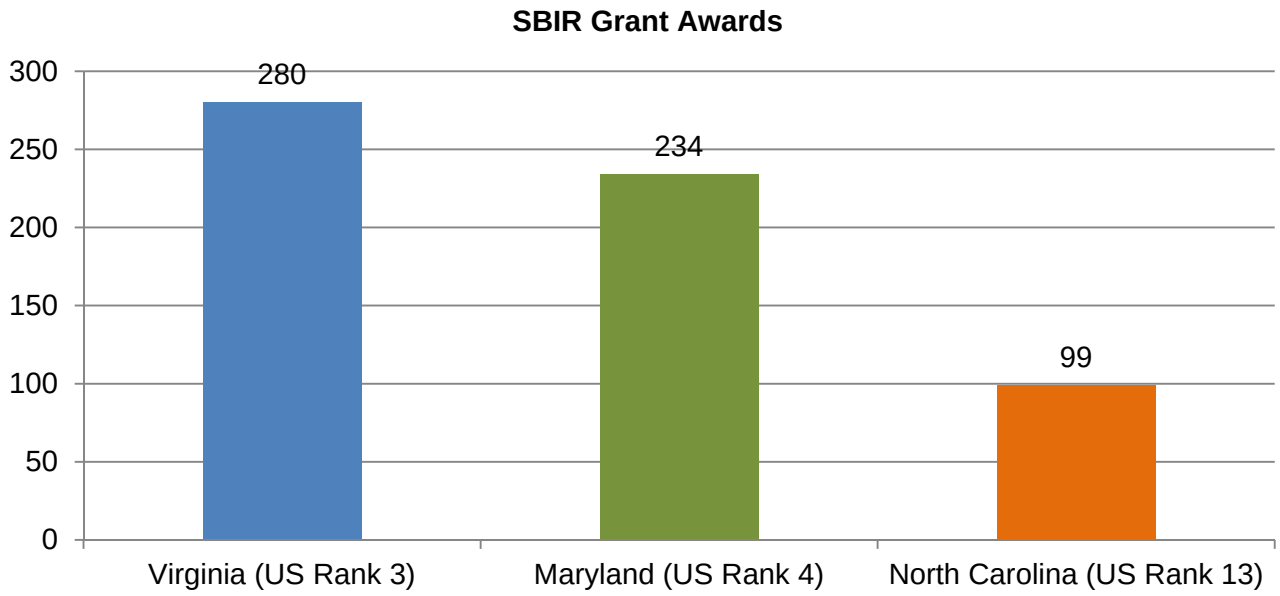
Examining the number of SBIR grant awards, North Carolina ranks 13th, which is not unexpected given their rank of 13th in utility patent awards. However, Virginia's rank jumps to 3rd nationally in the number of SBIR grant awards, significantly outperforming North Carolina. Maryland ranks 4th. This does not mean that North Carolina is not following through on the commercialization of their patents; it indicates only that they are perhaps choosing other avenues. (Figures 6 & 7)

Figure 6: Utility Patents Issued to State Residents



* While NSF has published the FY2015 financial expenditure data, the state profiles have not yet been updated.

Figure 7: SBIR Grant Awards



Virginia Start-Up Strength

The Kauffman Foundation publishes the Kauffman Index of Growth Entrepreneurship. This index focuses on how much U.S. entrepreneurial businesses are growing.

Virginia ranked 1st of the 25 largest states in both 2015 and 2016.

The report measures the following indicators:

- Rate of start-up growth (increase in employment 5 years after founding)
- Share of scale-ups (firms that started small but grew to employ 50 or more people within 10 years; % of all employers younger than 10 years)
- High-growth company density (businesses with at least $2 million revenue that reach three years of annual revenue growth greater than 20%)

National Trends – Areas of Research

The National Science Board report, Science and Engineering 2016 Indicators, revealed that:

- Between 1996 and 2014:
  - Biotechnology patents accounted for the largest share (18.2%) of U.S. university patents
  - Pharmaceuticals (15.1%)
  - Measurement (7.8%)
- Since 2009,there has been an upward trend for:
  - Pharmaceuticals
  - Biotechnology
  - Medical technology
  - Organic fine chemistry
- Computer technology and semiconductor patents rose steadily over the past 15 years.

Virginia Strengths – Areas of Research

Utility Patent Awards Assigned to Virginia Entities

The U.S. Patent Office categorizes patents by major sections, such as Human Necessities, Physics, Chemistry, etc. Each of those sections is further subdivided into subsections, classes, and subclasses. Most patents are classified in more than one section. The primary section classification was used for purposes of this report. Utility patents issued between 2013 and 2016 are included.

Figure 8 illustrates the major sections and the corresponding subsections of research that have generated patents assigned to academic institutions in Virginia.

Figure 9 illustrates the same sections and subsections of research that have generated patents assigned to any entity in Virginia.

Areas of patent overlap indicate indicate opportunities for collaboration between the private or federal sector and academic institutions.

Figure 8: Academic Utility Patents by Area of Research

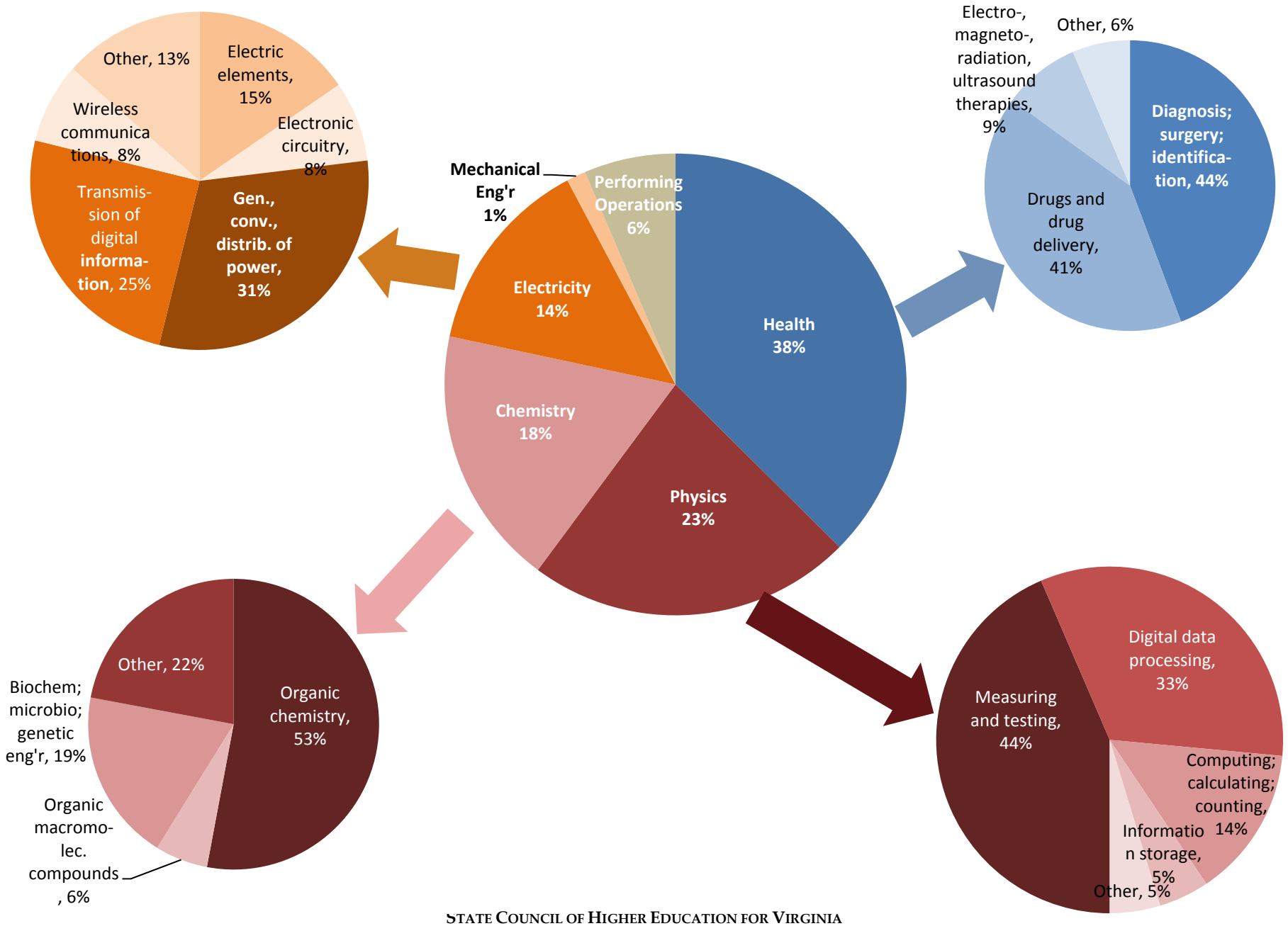
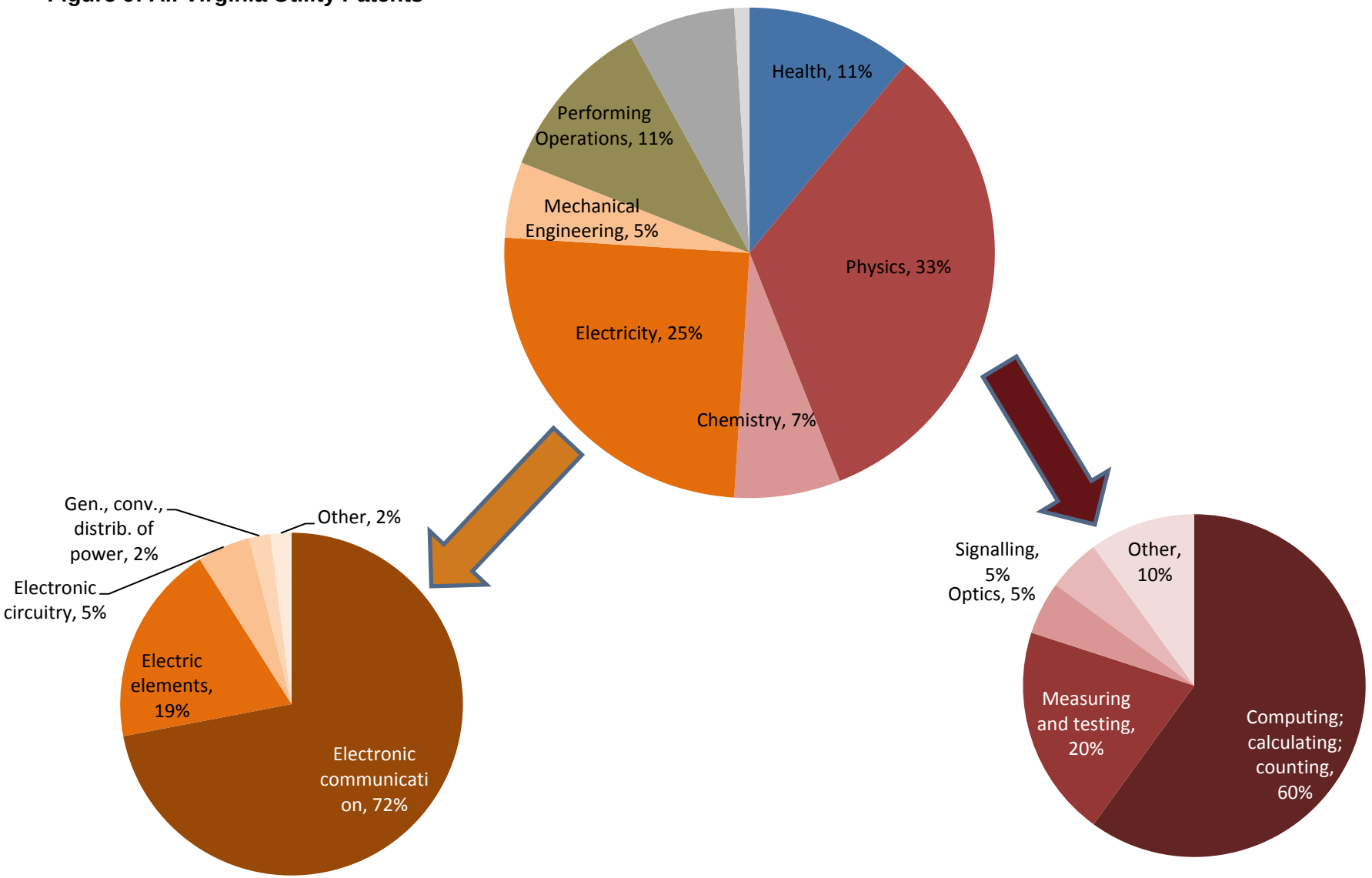


Figure 9: All Virginia Utility Patents



Peer-Reviewed Journal Articles and Citations of Peer-Reviewed Publications

Reed Elsevier and the Council of State Government issued a report in April 2015, entitled "America's Knowledge Economy: A State-by-State Review."

The report stated that Virginia has a comparative advantage in medicine, with journal articles in the field of medicine cited **11% more** than the U.S. average.

Within engineering, the **top three states** in terms of relative volume of peer-reviewed publications were New Mexico, Idaho, and Virginia.

Both the production of patents (illustrated above) and the research expenditures (examined below) confirm that these are areas of strength for Virginia.

Academic Research and Development Expenditures

In FY2015, Virginia ranked 14th nationally in academic expenditures for research and development. Areas of strength include life sciences and engineering. Each of those fields of research include multiple subfields.

Figure 10 illustrates expenditures in the major areas of research. Figures 11 through 15 examine expenditures in subfields of the major areas. Further, institutions vary in their areas of strength. The figures in the Appendix illustrate institution-level expenditures in subfields of research.

Figure 10: FY2015 Expenditures for Research and Development

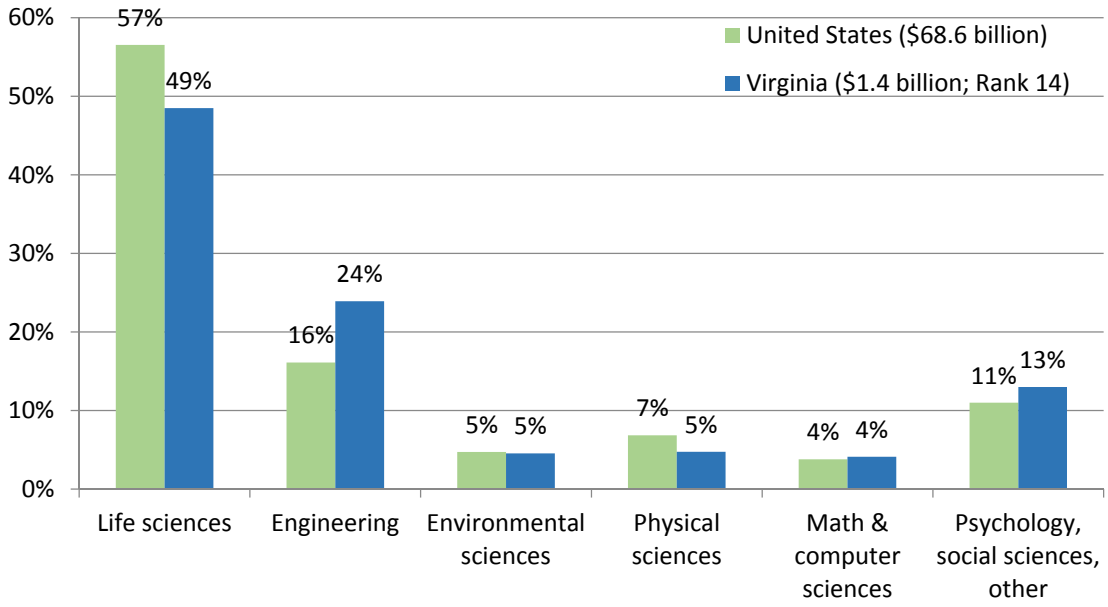


Figure 11: FY 2015 Expenditures in Life Sciences by Subfield

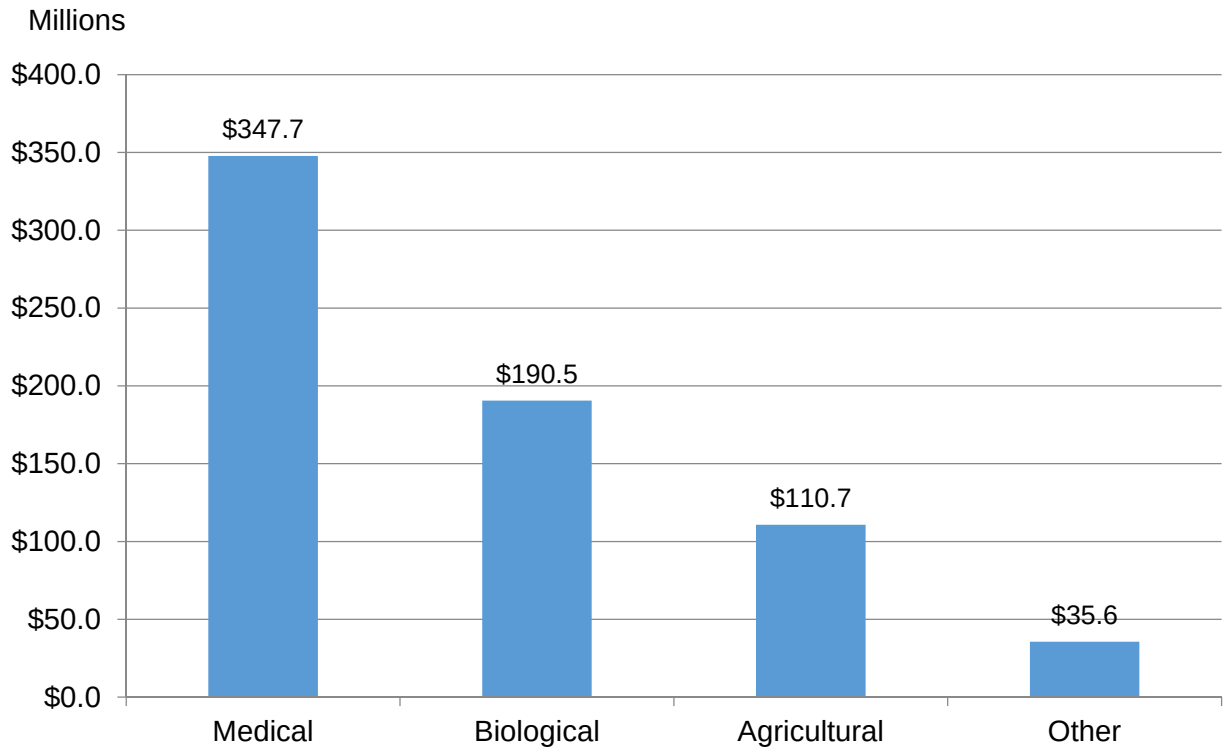


Figure 12: FY2015 Expenditures in Engineering by Subfield

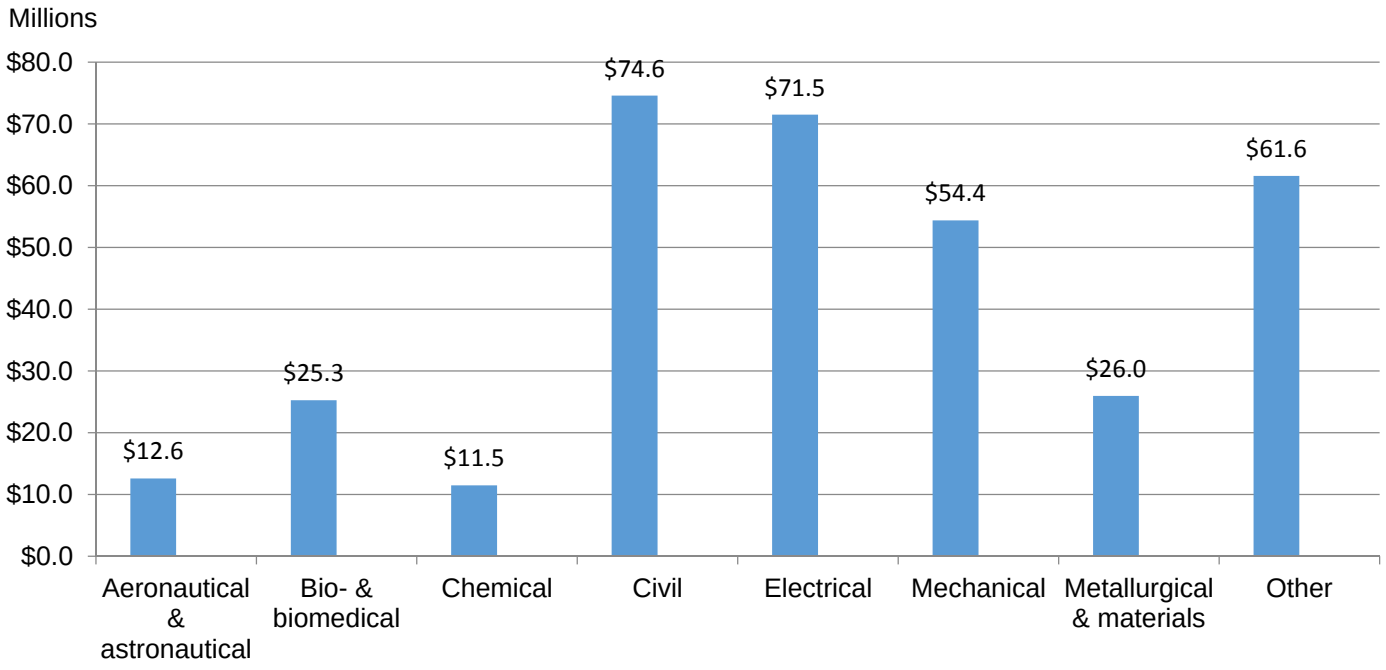


Figure 13: FY2015 Expenditures in Environmental Sciences by Subfield

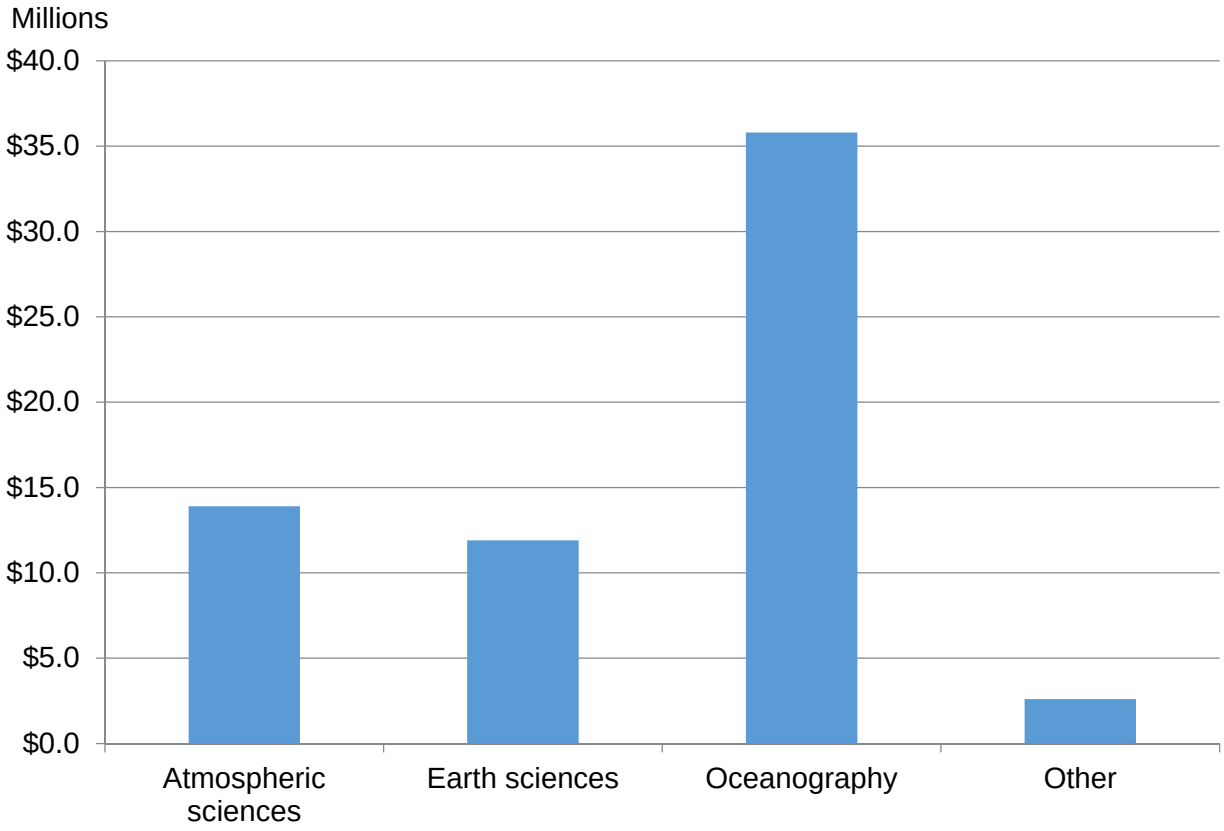


Figure 14: FY2015 Expenditures in Physical Sciences by Subfield

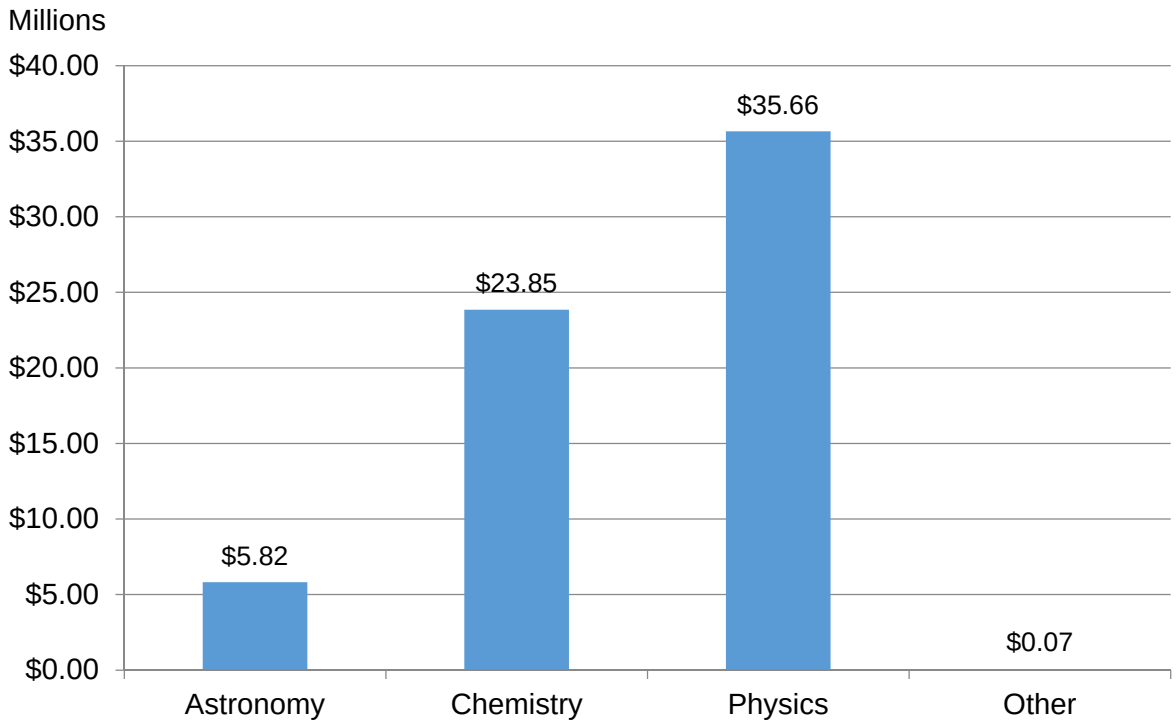
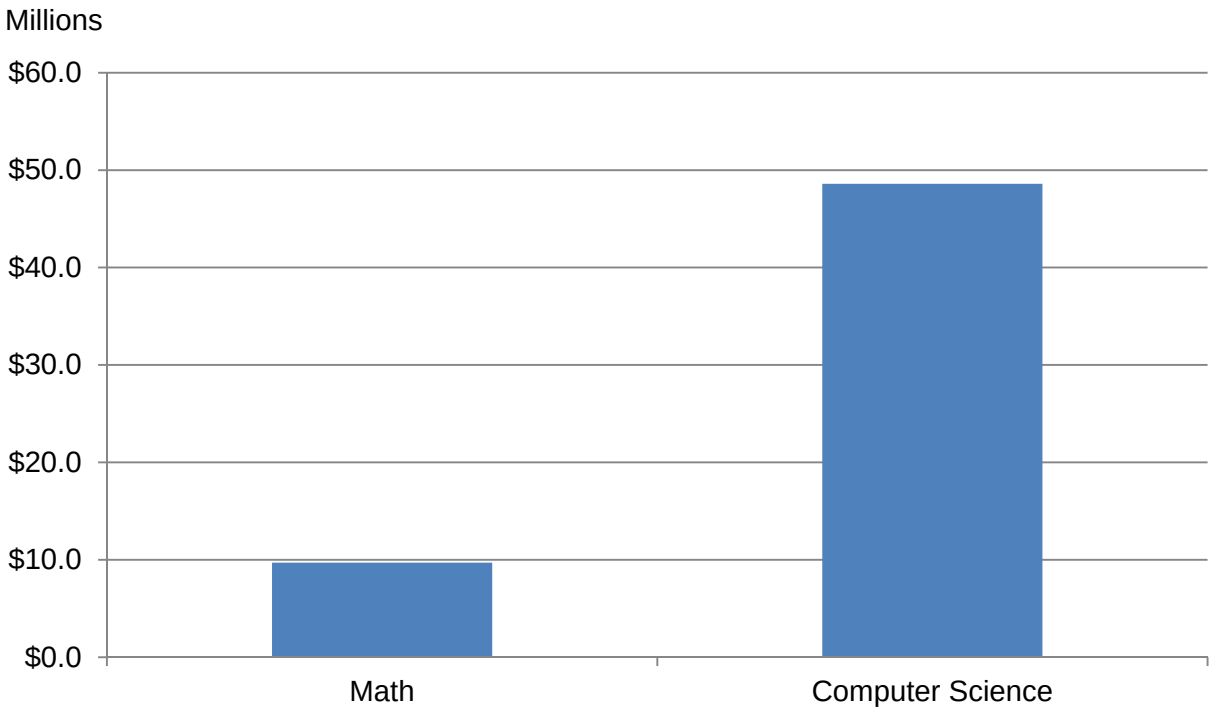


Figure 15: FY2015 Expenditures in Math and Computer Science by Subfield



Opportunities for Collaboration and Correlation to R&T Roadmap

There are many ways for VRIF stakeholders to interpret the data provided by the graphs in this report and then use that information to make decisions. One avenue is to examine the intersection between academic expertise, commercial potential, and the private sector.

The graphic on page 2 reveals both expertise and potential for commercialization in the following areas of research:

- Life sciences
- Chemistry
- Physics
- Electrical engineering

Drilling down into the subfields of these categories sheds additional light.

For example, the “physical sciences” category of R&D expenditures includes both physics and chemistry. The engineering category includes electrical engineering and correlates to the “electricity” patent category. There is a strong correlation, and therefore opportunities for collaboration, between the comprehensive institutions’ R&D expenditures and the private sector patent production in all of those areas of research.

In contrast, note that the “life sciences” category of R&D expenditures at the research universities accounts for almost half of all expenditures. Academic patent production in that category is also high at 38%, indicating strong potential for commercialization. However, patent production in that category in the private sector is quite low at 11%. Perhaps this indicates a greater likelihood that the research institutions will spin off their own companies to develop their patents rather than attempt to partner with the private sector in Virginia.

If the goal is to incentivize partnerships between research institutions and comprehensive institutions, then areas that are ripe for collaboration are physical sciences and engineering, along with life sciences.

In order to correlate patent production and R&D expenditures with the industries listed in the VRIF statutes and the R&T Roadmap, it is helpful to understand that most patents are assigned to more than one category. For example, many patents with a primary classification in health have additional classifications in chemistry. Many patents classified in the physics category also include desginations in electricity.

The connection between the research areas of data analytics and cybersecurity and patent production are less obvious. Encompassed within in the “physics” patent category is computing and calculating. The “electricity” patent category includes electronic communication. Therefore, strengths in these sectors indicate the expertise needed for cybersecurity and data analytics research.

In conclusion, staff suggest that, while the R&T Roadmap is under revision, the committee consider investing VRIF funds at the intersection of three vectors: university research strength and expertise; commercial potential; and the larger research ecosystem in Virginia.

Appendix A: Academic R&D Expenditures by Subfield and Institution

Figure 16: FY 2015 Expenditures in Life Sciences by Subfield and Institution

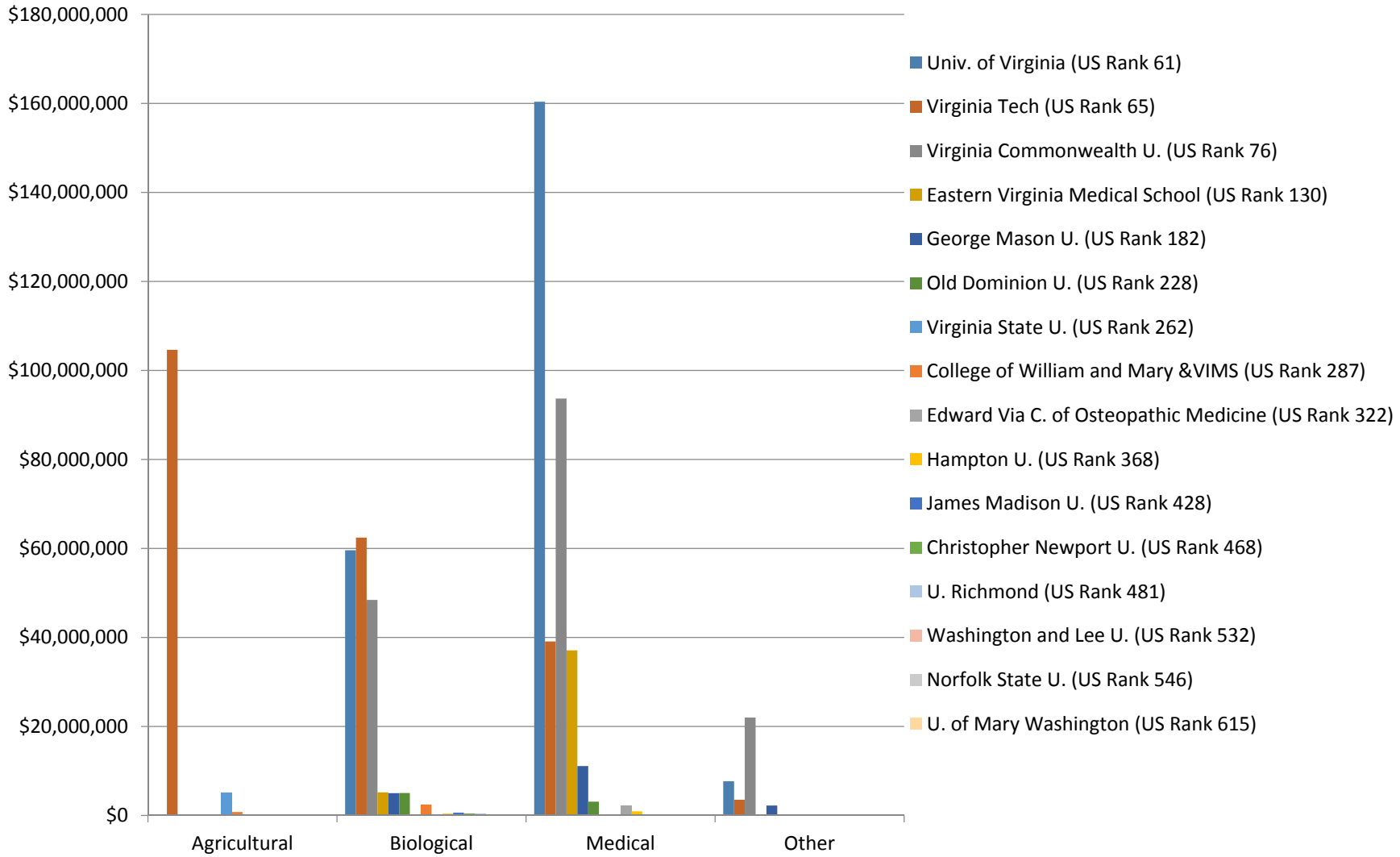


Figure 17: FY2015 Expenditures in Engineering by Subfield and Institution

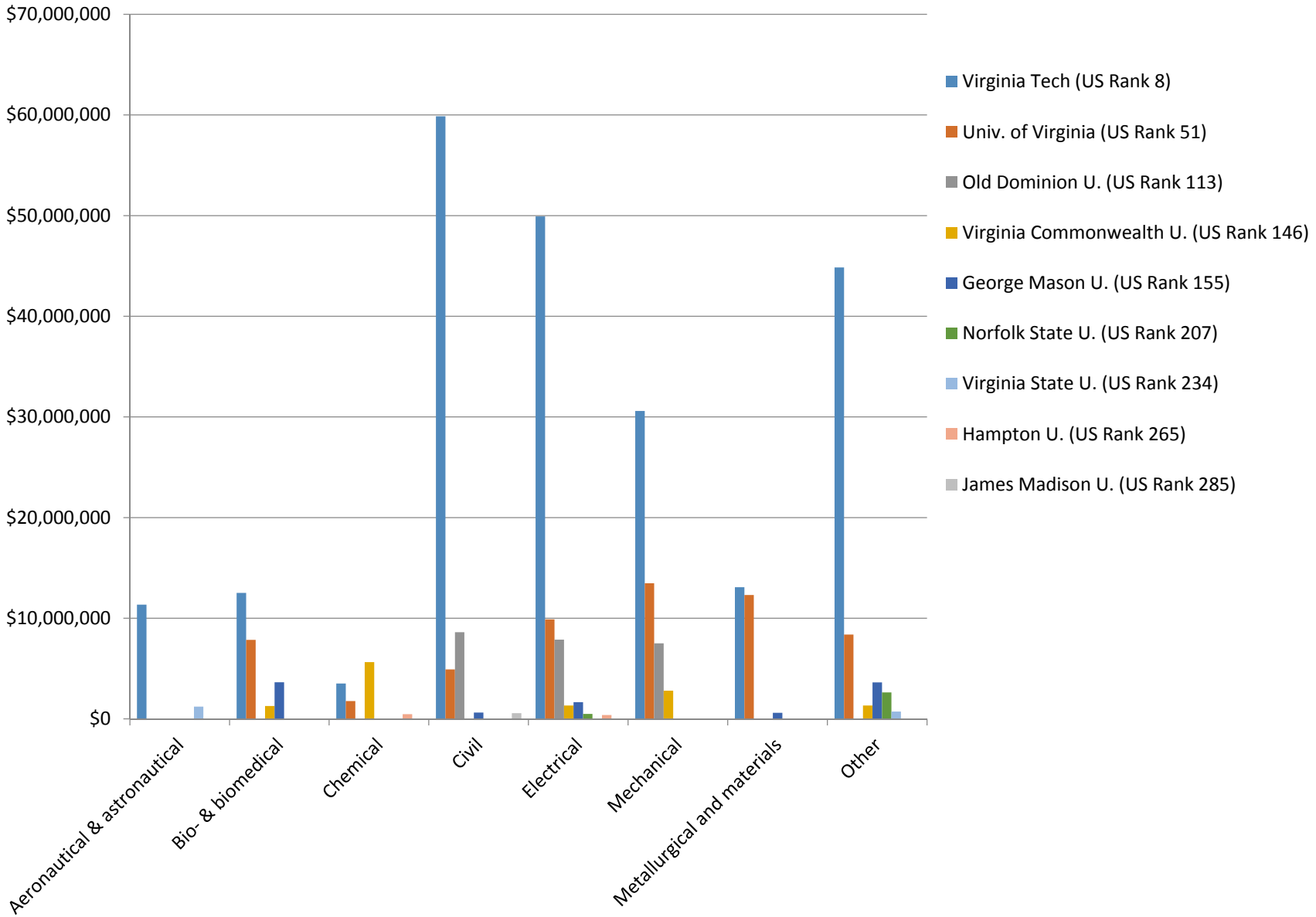


Figure 18: FY2015 Expenditures in Engineering by Subfield and Institution Minus VA Tech

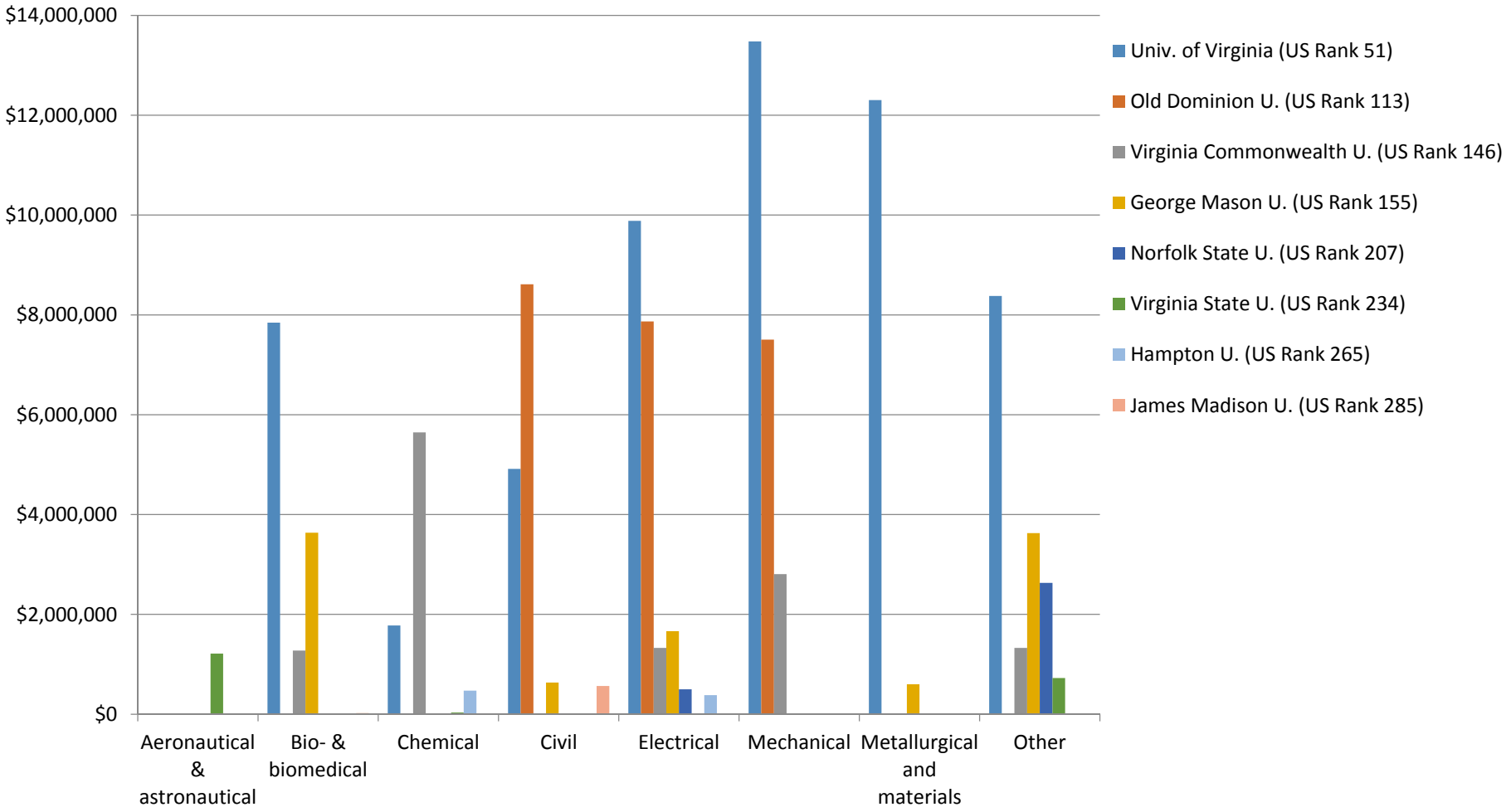


Figure 19: FY 2015 Expenditures in Environmental Sciences by Subfield and Institution

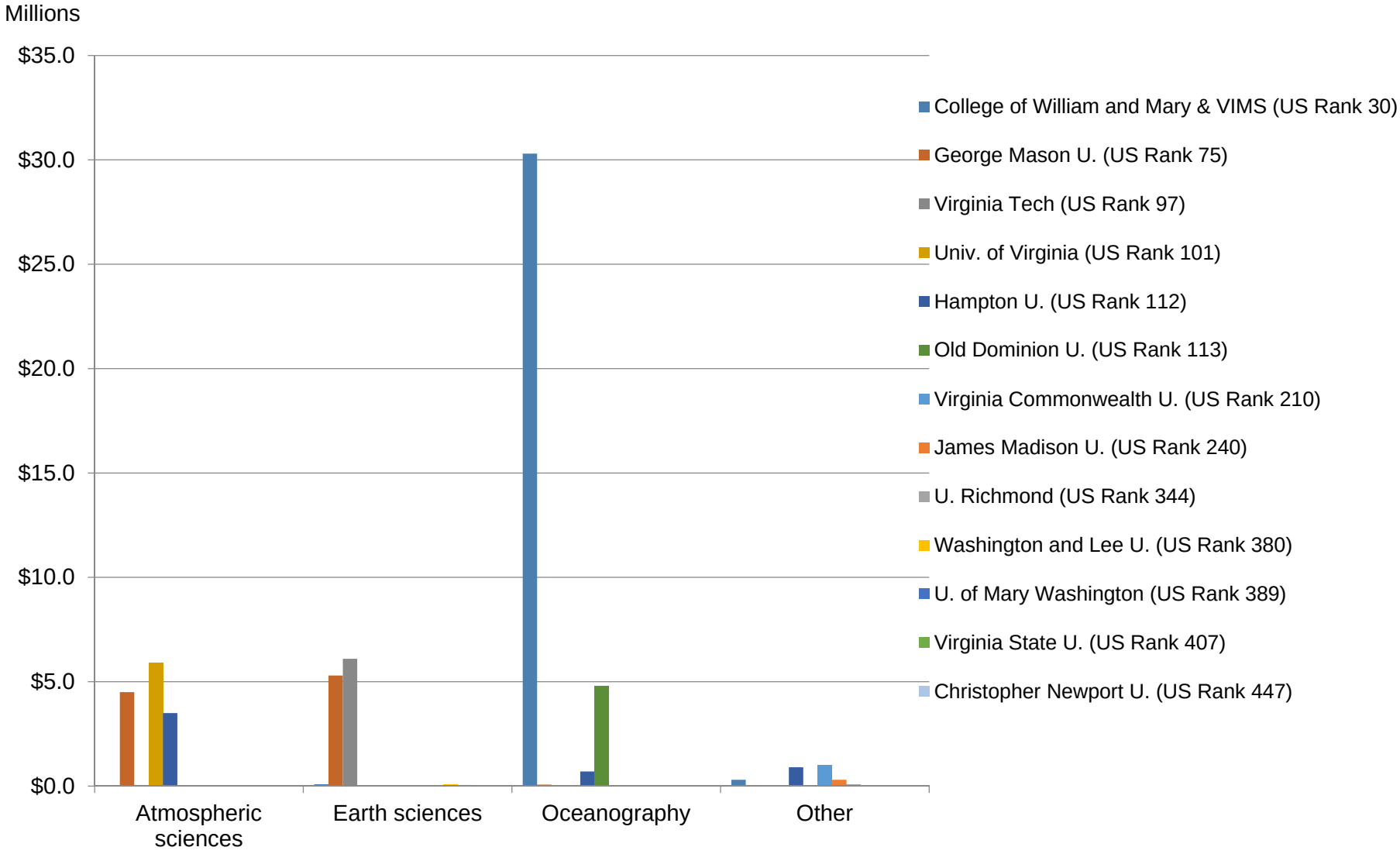


Figure 20: FY 2015 Expenditures in Physical Sciences by Subfield and Institution

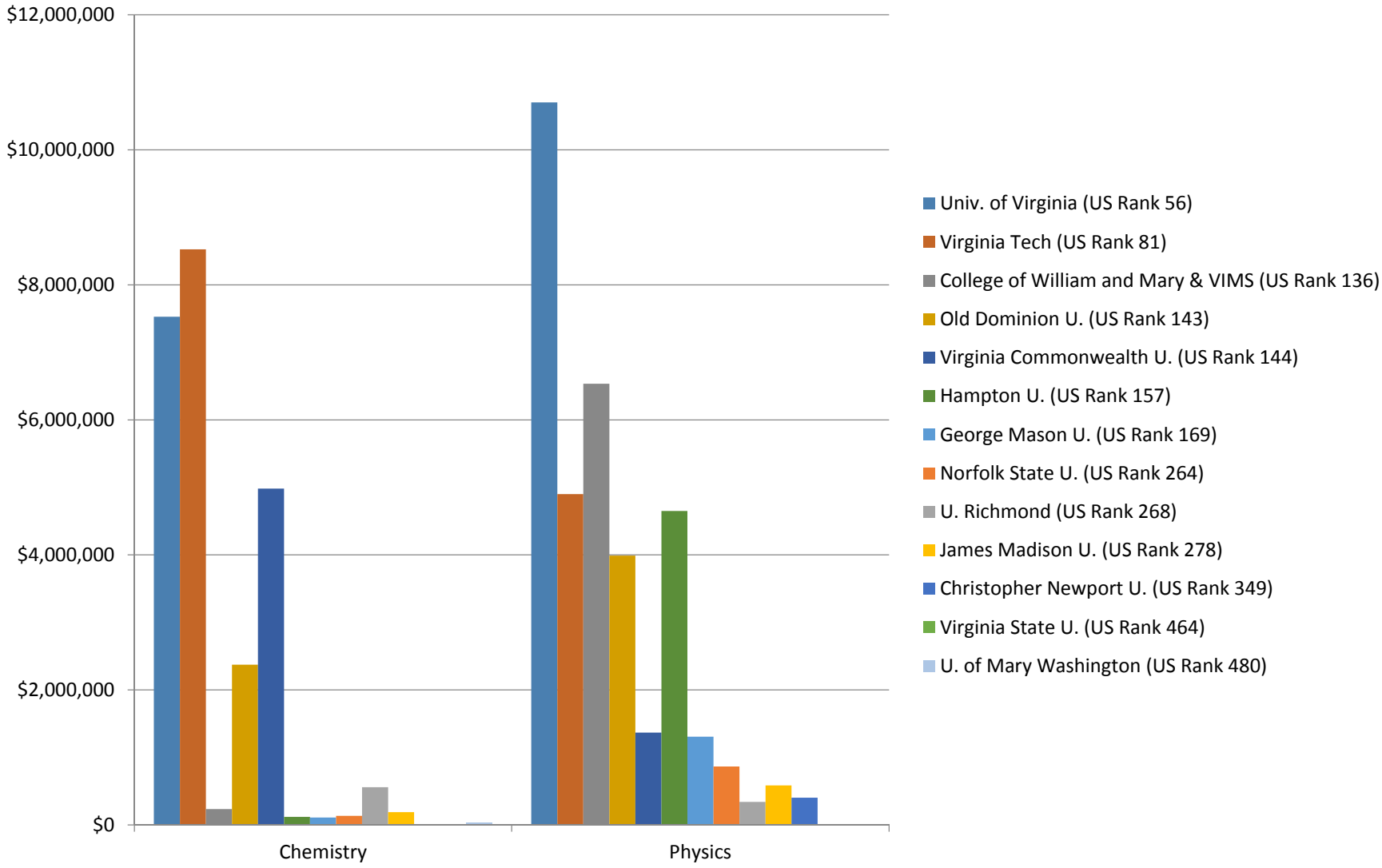
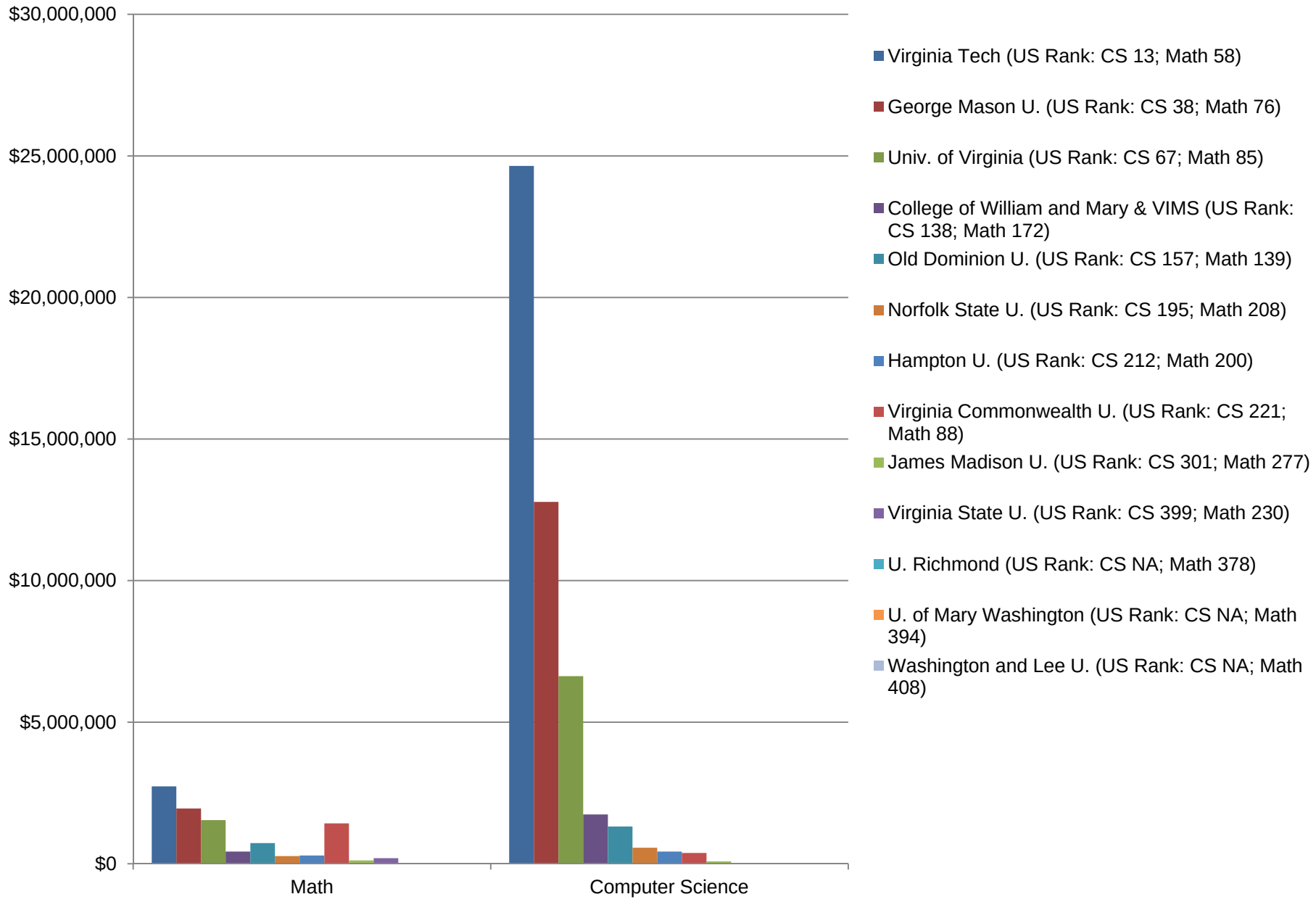


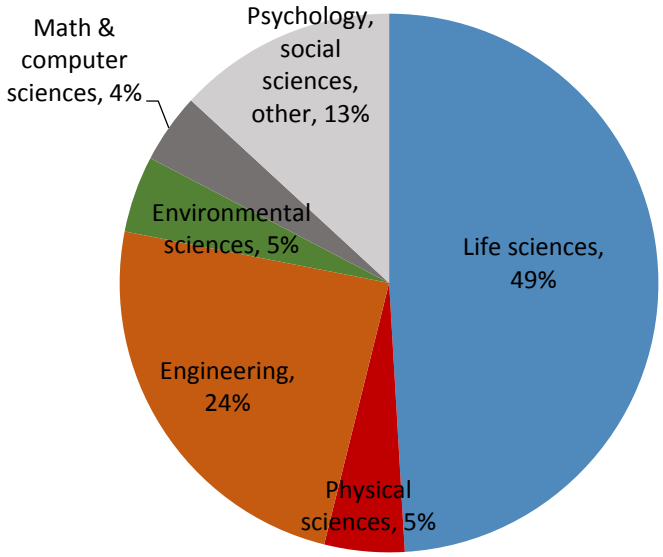
Figure 21: FY 2015 Expenditures in Math and Computer Science by Subfield and Institution

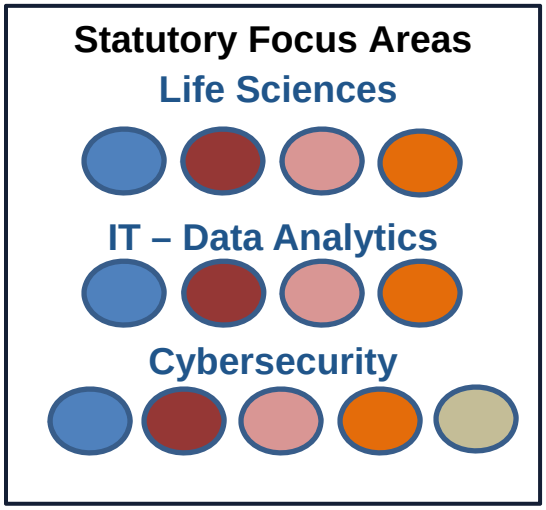


Appendix B: Intersection of Strengths and Commercial Potential (Color Graphic)

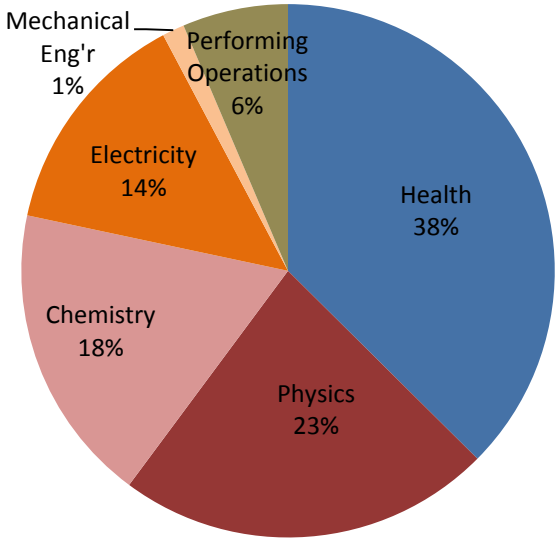
Intersection of Virginia's Research Strengths and Areas with Commercial Potential

R&D Expenditures at Virginia Institutions ($1.4 billion)





Academic Patents (2013-2016)



All Patents (2013-2016)