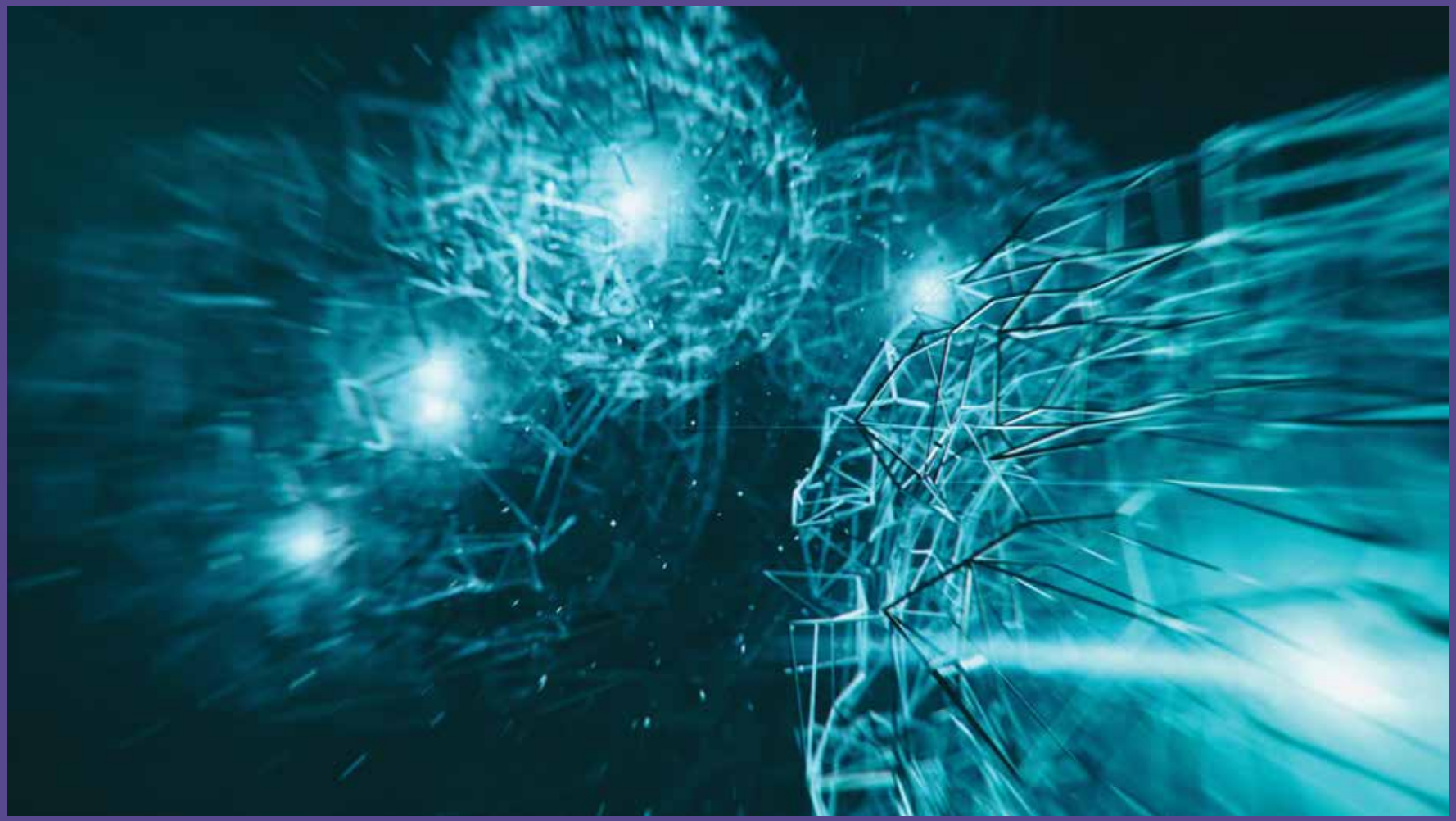
Jefferson Lab Ponders Its Future



JEFFERSON LAB PONDERS ITS FUTURE

What if Hampton Roads were selected as the site of a new federal laboratory whose research could be applied to battle cancers, improve surgeries and sterilization procedures, remediate water and sludge, develop super magnets, produce super-cooled materials that lose resistance to electricity, improve the scanning of cargoes at the Port of Virginia and even help defend the United States? This would set off a tremendous celebration and regional citizens would think they had just struck modern technological gold.

The amazing news (to some, anyway) is that this jewel of a high-technology federal laboratory already exists and is operating in our midst – it is the Thomas Jefferson National Accelerator Facility in Newport News (commonly referred to as Jefferson Lab). Jefferson Lab experiments simultaneously improve our understanding of the physical nature of the universe (why physical things behave the way they do) and open doors to an intriguing set of applications. It is high time that the lab's impact and potential become better known.

Formally a laboratory of the U.S. Department of Energy's Office of Science, Jefferson Lab engages in world-class physics research that focuses both on the very nature of matter – how the universe is put together – and applications of that knowledge. Scientists and researchers from around the world join approximately 700 Jefferson Lab scientists and support personnel in utilizing the facility's continuous electron beam accelerator and four associated research halls. Most come to the Newport News facility, but some do so virtually. They use the facility to probe the nucleus, the building block of the universe. The science behind the accelerator is highly complex, yet disarmingly simple in concept. Electrons are accelerated to approach the speed of light (approximately 186,000 miles per second) and directed at stationary targets (such as hydrogen, helium or carbon) to study the nuclei of atoms. Detecting what happens when the collisions occur is the focal point of Jefferson Lab research.

Jefferson Science Associates formally manages the facility for its owner, the U.S. Department of Energy's Office of Science. Jefferson Science Associates is a partnership between about 60 southeastern research universities and PAE, a large international technology management organization headquartered in Falls Church, Virginia.

The academia connection is an important one because 1,700 researchers in the United States and around the world utilize Jefferson Lab for their research. A majority of the researchers are university faculty members. Regionally, William & Mary and Old Dominion University each boast significant stables of faculty who utilize the laboratory in their research, while smaller contingents exist at Hampton University and Norfolk State University. For example, more than a dozen ODU faculty members run experiments at Jefferson Lab. Seven of these faculty are jointly appointed by Jefferson Lab and ODU, with the institutions sharing their salaries. The laboratory also supports "bridge" faculty members whose salaries are shared by Jefferson Lab and institutions around the country for a period of five years.

To the casual observer, the most visible connection of Jefferson Lab to the region may be Hampton University's Proton Therapy Institute, especially well known for its work in fighting prostate and head and neck cancers. The institute, which opened in 2010, directs precisely focused beams of protons at cancers and tumors to reduce their size or eliminate them entirely. Fortuitously, this can be accomplished in a nonsurgical context. Jefferson Lab's Cynthia Keppel was a founding member of the institute and is jointly appointed at HU. She now leads experiments in the laboratory's Halls A and C and holds nine patents in medical technology.

Jefferson Lab has established a radiation detector and imaging group that applies nuclear physics detector techniques to medical imaging and

diagnostics. This genre of work has led to additional patents on devices used to treat breast cancers and other maladies.

Even if Jefferson Lab were not engaged in world-class research, it would be vitally important to Hampton Roads because of its economic impact. A January 2019 study conducted by W&M professors Roy L. Pearson and K. Scott Swan estimated that the laboratory's 2018 fiscal year regional economic impact was $269.2 million in economic output, resulting in $149.2 million in labor income and 2,015 jobs. This places Jefferson Lab roughly among the 50 largest regional institutions in terms of its economic profile.[1]

Atoms are the basic building blocks of matter and consist of a nucleus composed of protons and neutrons and orbited by electrons. Streams of electrons (beams) can be used to bombard specific targets, for example, a cancer. When the beam collides with its target, energy is deposited in the tissue cells. This may control or eliminate the cancer. The beams also can kill healthy cells, so electron therapy is best suited for surface cancers. Proton beams, on the other hand, can penetrate to deep-seated tumors.

Jefferson Lab's imprint on the region extends well beyond its scientific research and economic impact. The laboratory has developed strong contacts with area K-12 schools and has become an energetic contributor to science education. Jefferson Lab maintains its own Science Education Team and its personnel frequently make presentations in regional schools. The laboratory also provides a website for K-12 students to prepare for Virginia's Standards of Learning exams. These practice tests, which focus on topics in the fields of science,

1 Roy L. Pearson and K. Scott Swan, "Economic Impacts and Qualitative Drivers of the Thomas Jefferson National Accelerator Laboratory: Fiscal Year 2018" (January 2019), www6.sura.org/wp-content/uploads/2019/01/FY18JLabImpactRpt.pdf. The duo estimated that the Virginia economic impact of the JLAB was $308.7 million in economic output, $168.3 million in labor income and 2,240 jobs. The national economic impact numbers were $556.9 million in economic output, $250.7 million in labor income, and 3,448 jobs.

technology, engineering and mathematics (STEM), align with Jefferson Lab's ongoing research program.

More so than some federal laboratories, Jefferson Lab has attempted to be a good citizen and participates in and contributes to a wide variety of educational and social programs in Hampton Roads. As a city council member from the Peninsula observed, "They go out of their way to get involved."

Financial And Programmatic History

The U.S. Department of Energy provided initial funding for Jefferson Lab in 1984 and Congress appropriated construction funds for what would be known as the Continuous Electron Beam Accelerator Facility (CEBAF) in 1986. It was not until 1993, however, that all pertinent aspects of CEBAF were fully in place. CEBAF first used highly focused beams of electrons to explore the state of matter in 1994.

In 1996, CEBAF became the Thomas Jefferson National Accelerator Facility. The first licensing of Jefferson Lab scientific work occurred soon after when Dilon Technologies began to use the lab's technology for detecting breast cancers. The Dilon Navigator Gamma Probe continues to be used to detect cancers and perform surgeries.

In 2009, Jefferson Lab began a major upgrade of CEBAF, a $338 million project (the 12 GeV upgrade)[2] that doubled CEBAF's beam energy and was completed in 2017. Graph 1 reports Jefferson Lab's funding for operations and construction between fiscal years 2009 and 2019. The upward bump in funding in the early part of the 2010-2020 decade reflects the impact of the 12 GeV upgrade.

The flow of personnel at Jefferson Lab similarly reflects the impact of the 12 GeV upgrade construction (Graph 2). Personnel exclusive to the lab topped out at 763 in the 2011 fiscal year. In the 2018 fiscal year, there were 721 positions (693 individuals exclusive to Jefferson Lab plus 28 joint/bridge faculty who were shared with universities). In terms of compensation, the lab is an attractive place to work because it pays its workers considerably more than regional averages. **The average employee in the Hampton Roads metropolitan region earned $23.86 per hour in May 2018.[3] This translated to $49,620 annually. Three-quarters or more of all Jefferson Lab positions pay more than this – many, considerably more. The average salary of a Jefferson Lab worker was $82,000 in 2019, according to payscale.com.[4]**

Figure 1 shows the locations of the major Department of Energy laboratories in the United States. The labs whose research agendas may overlap with those of Jefferson Lab are Brookhaven National Laboratory on Long Island; Lawrence Berkeley National Laboratory and the Stanford Linear Accelerator Center (SLAC), both of which are located in the Bay Area of California; and the Argonne National Laboratory and Fermi National Accelerator Laboratory, which are both located in suburban Chicago. None of these other laboratories, however, is as much a single-purpose laboratory as is Jefferson Lab.

One of Jefferson Lab's presumed advantages over the sometimes complementary, sometimes competitive, federal laboratories in New York, Illinois and California has been its lower costs of operation. Graph 3 demonstrates that price levels in general in Hampton Roads are below mid-Atlantic and national average price levels and dramatically lower than prices in the New York City region (where the Brookhaven lab is located) and the San Francisco metropolitan area (site of SLAC and the Lawrence Livermore Berkeley National Laboratory). Prices in Hampton Roads are roughly comparable to those in Chicago, the site of the Argonne laboratory and Fermilab.

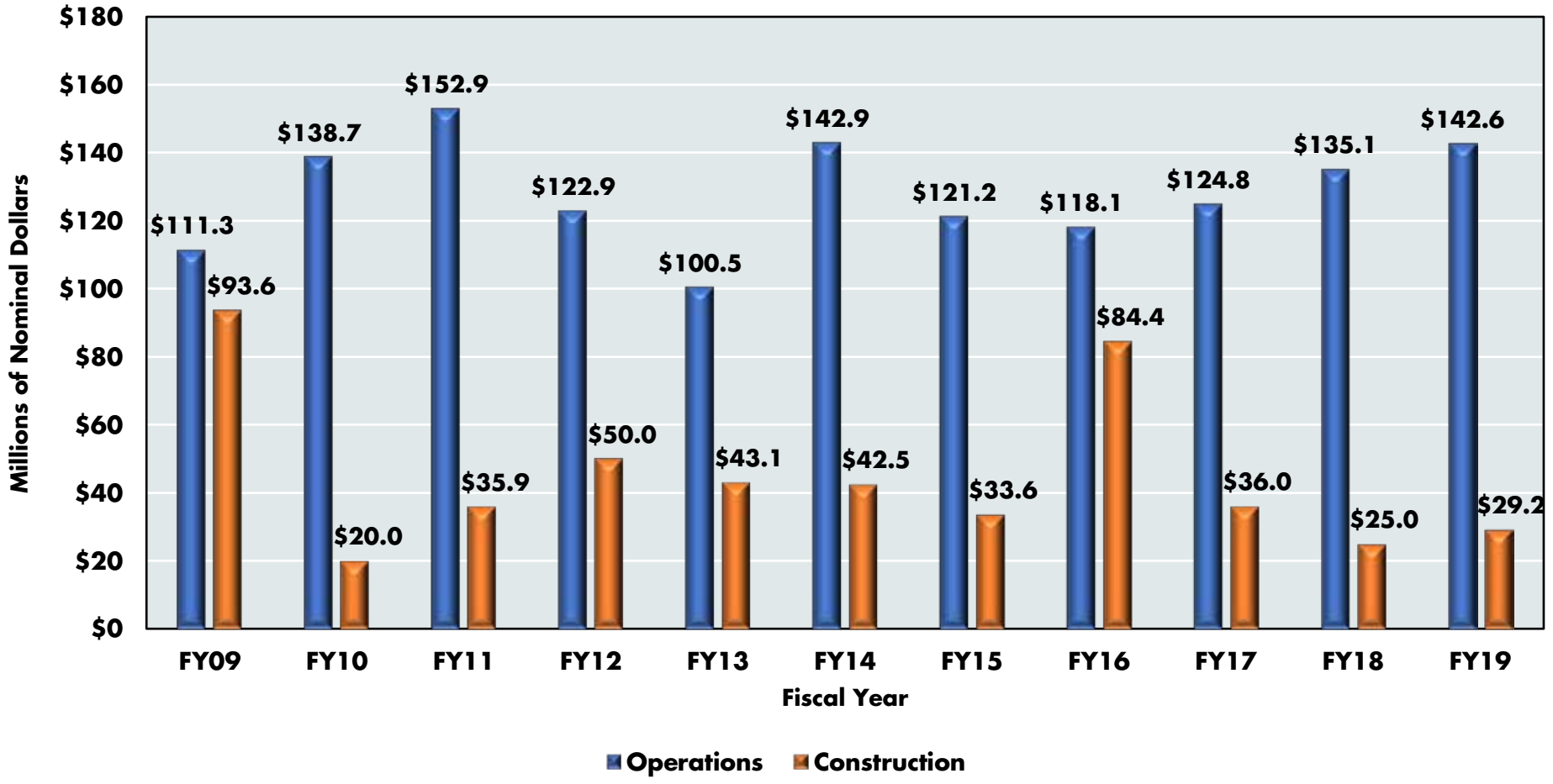
Salary.com, an interesting though less rigorous source of cost-of-living information, reports much larger differentials – prices in the New York City metropolitan region are 83% higher than in Hampton Roads, while prices in the San Francisco and Chicago regions are 62.5% and 16.7% higher, respectively. Salary.com also indicates that prices in Newport News specifically are .44% above the national average.[5]

The moral to the story, however, is that dollars go further at Jefferson Lab than they do at any of its major competitors. It is less expensive to accomplish the same task at Jefferson Lab than it would be at Brookhaven, Livermore or Argonne.

2 A GeV is a giga electron volt of kinetic energy, where giga stands for 1 billion.
3 Bureau of Labor Statistics, "Occupational Employment and Wages in Virginia Beach-Norfolk-Newport News: May 2019," www.bls.gov/oes/current/oes_47260.htm#00-0000.
4 "Average Jefferson Lab Salary," Payscale, www.bls.gov/oes/current/oes_47260.htm#00-0000.
5 "Cost of Living Calculator," www.salary.com/research/cost-of-living/virginia-beach-va.

GRAPH 1

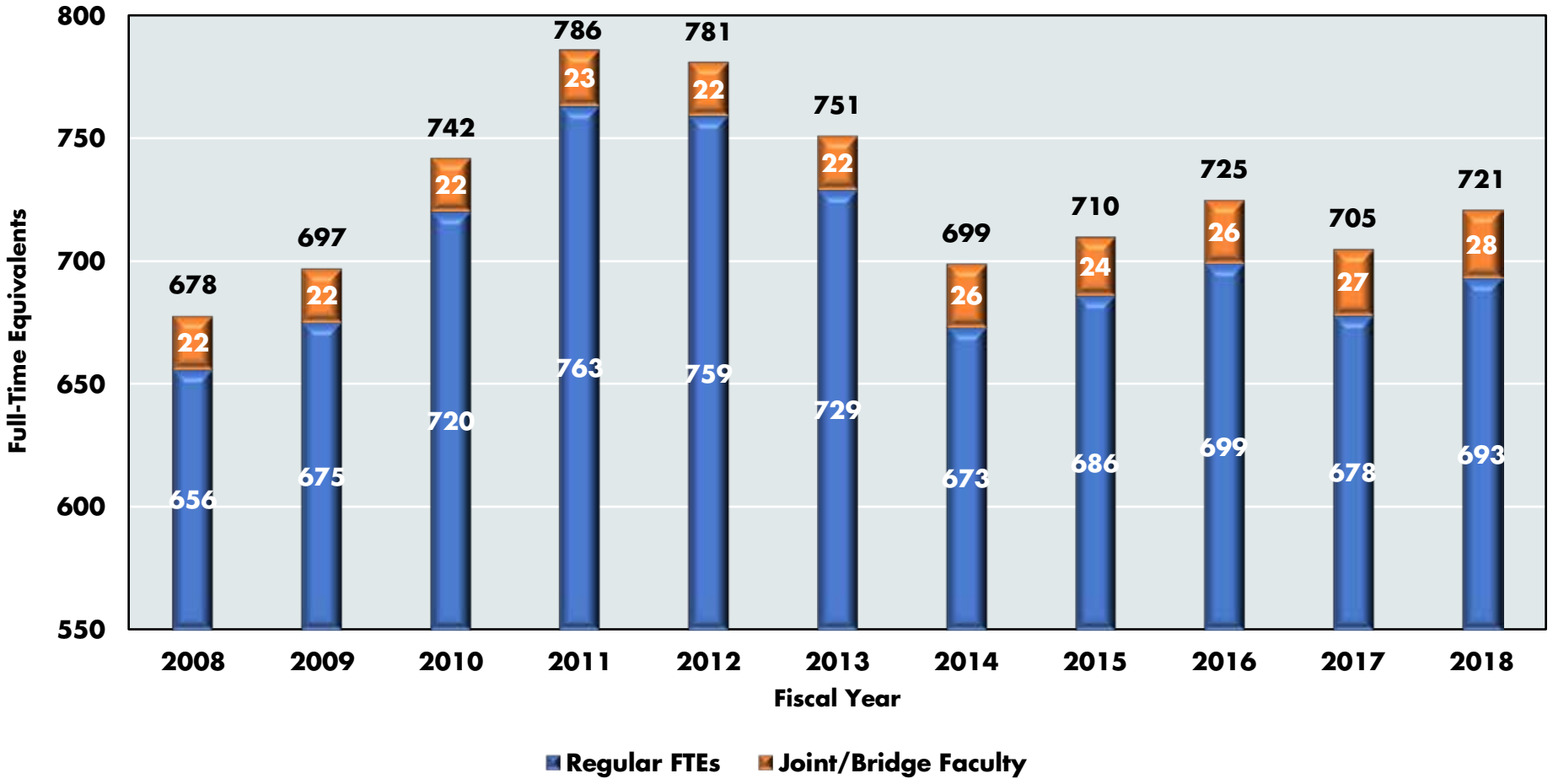
JEFFERSON LAB EXPENDITURES FOR OPERATIONS AND CONSTRUCTION, FY 2009 THROUGH FY 2019 (IN MILLIONS OF DOLLARS)



Source: Jefferson Lab

GRAPH 2

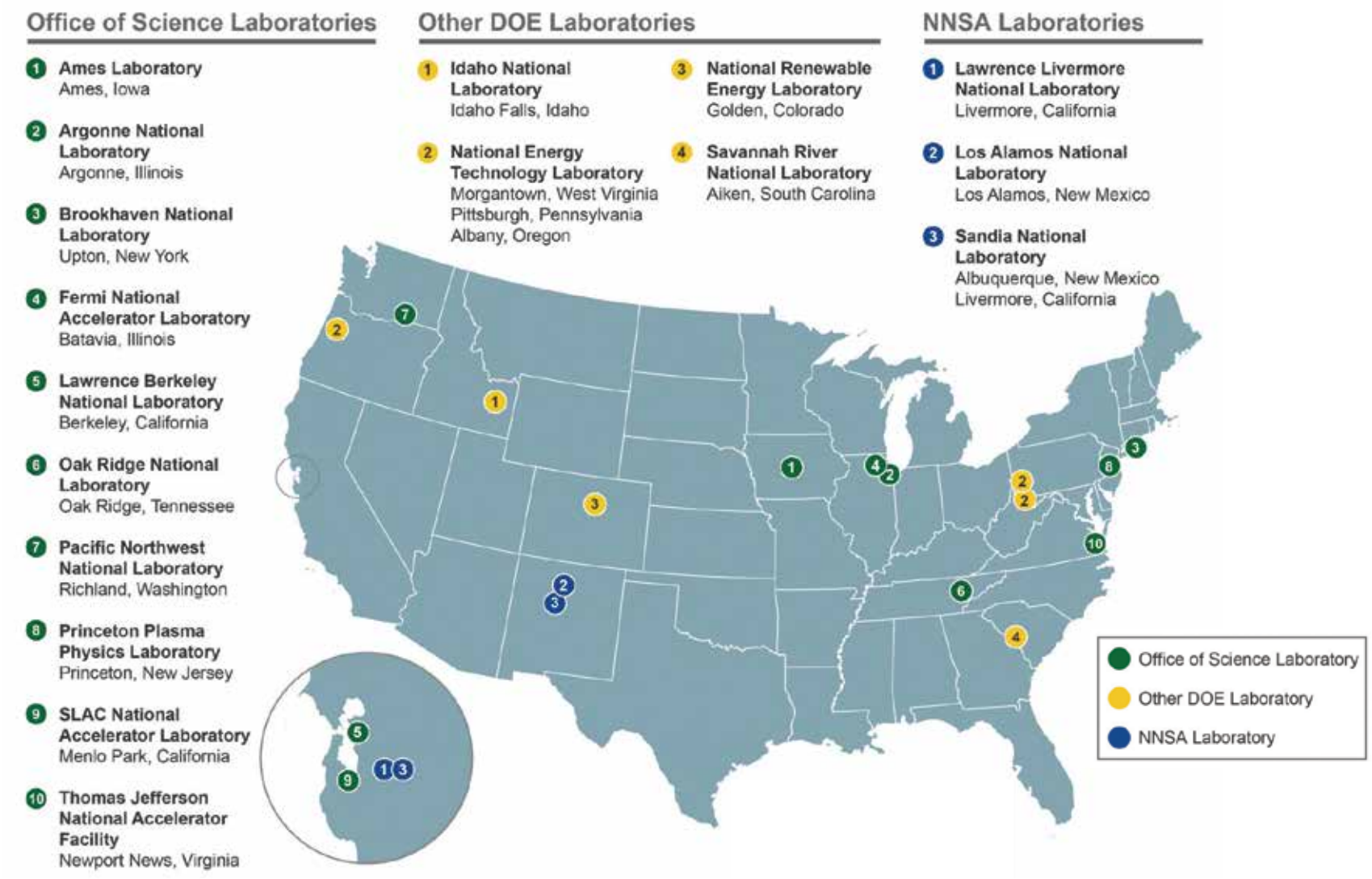
JEFFERSON LAB FULL-TIME EQUIVALENT EMPLOYEE POSITIONS, FY 2008-FY 2018



Source: Jefferson Lab

FIGURE 1

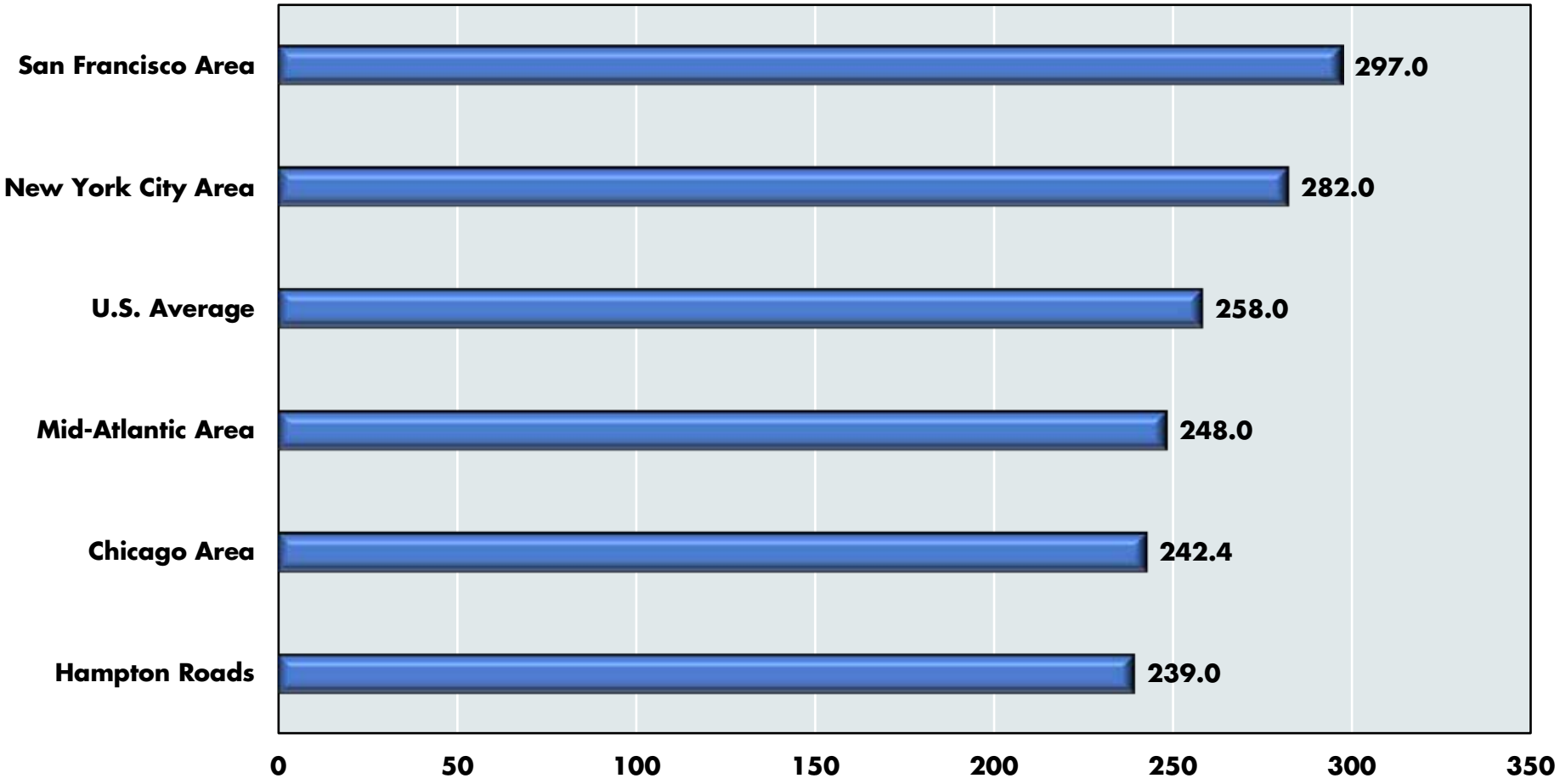
LOCATION OF U.S. DEPARTMENT OF ENERGY LABORATORIES IN THE UNITED STATES



Source: https://www.energy.gov/science/science-innovation/office-science-national-laboratories

GRAPH 3

CONSUMER PRICE INDEX FOR ALL URBAN CONSUMERS, JANUARY 2020



Source: Bureau of Labor Statistics, www.bls.gov/regions

The Electron-Ion Collider Decision

On Jan. 9, 2020, the Department of Energy announced that its new Electron-Ion Collider (EIC) would be placed at the Brookhaven National Laboratory in Brookhaven, Long Island. The EIC represents a "new window" through which the very nature of matter can be studied.[6] It has been advertised as a "one of a kind" development that will enable scientists to peer inside protons and, among other things, take the equivalent of 3D pictures of the insides of atomic nuclei.[7]

Jefferson Lab easily could have been chosen as the site for the EIC, given its strong performance record and the cost advantages noted previously. However, when push came to shove, the lab was not selected, and this somewhat unexpected defeat depressed many connected to it. This is despite the fact that Jefferson Lab had just completed the 12 GeV upgrade, while Brookhaven was perceived to be winding down its current science program.

By any standard, the EIC will be a massive project whose total design and building costs could reach $2.6 billion.[8] The EIC would have constituted a massive, steady economic development injection into the Hampton Roads economy and would have helped diversify the region's economic portfolio beyond defense spending.

The Brookhaven National Laboratory was quick to assert that the "Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia, is expected to be a major partner in the project and make significant contributions,"[9] but this could not mask the major disappointment attached to the Department of Energy's decision.

Some observers hinted that the state of New York's offer of $165 million in economic development grants tipped the balance in Brookhaven's favor.[10] The precise value of Virginia's bid for the EIC is unknown, but all observers agree that the New York state offer massively exceeded that of Virginia. Plausibly, Virginia's recent success in winning the Amazon headquarters expansion contest – despite being substantially outbid in economic incentives by several other states including New York – led those involved in Virginia's bid to conclude that the size of economic development incentives being offered was not the key to success. At this time, we do not know.

New York's bid no doubt also benefitted from the existence of a more robust nearby university research connection than held true in Virginia. Graph 4 reports National Science Foundation research and development (R&D) expenditures for a variety of institutions in 2017. Stony Brook University (a unit of the State University of New York) recorded more than $238 million in R&D expenditures in 2017. All major Hampton Roads institutions combined weighed in at only $155.9 million in funded R&D. Put simply, there is more "big-time" funded research activity going on near the Brookhaven Laboratory than there is surrounding Jefferson Lab, and this may have been a persuasive factor.

In addition, it cannot be asserted that the Hampton Roads universities would be closer to an EIC located here than an EIC on Long Island would be in relation to Stony Brook. Stony Brook is 22 miles away from Brookhaven, while Old Dominion and William & Mary are almost exactly the same distances away from the Jefferson Lab. Further, Brookhaven is only 65 miles from Manhattan, where research giants Columbia University ($947.5 million in R&D expenditures in FY 2017) and New York University ($887.6 million in FY 2017) are located.[11]

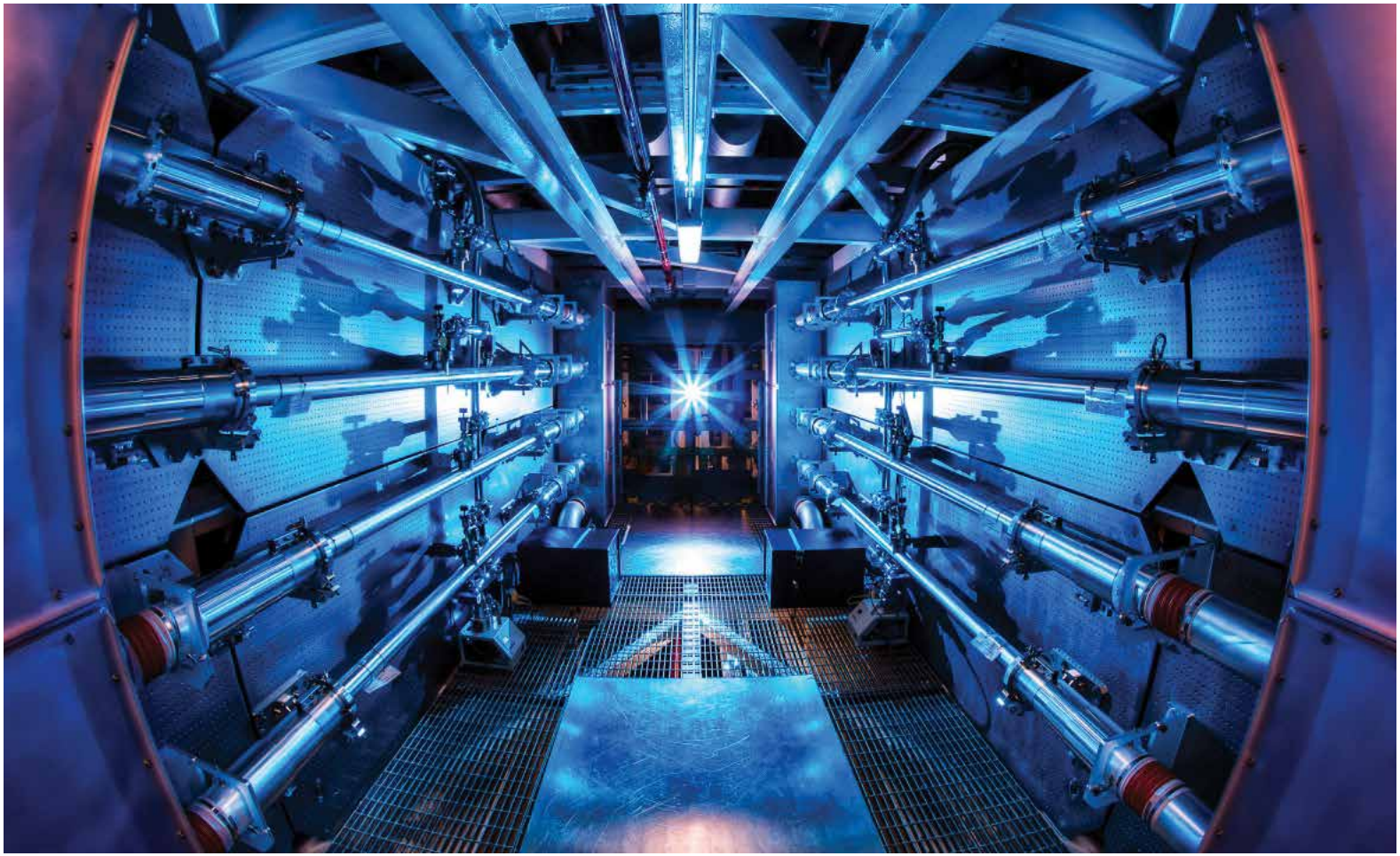
Air and rail connections from Hampton Roads likely did not help Jefferson Lab's proposal. It takes considerable time for anyone to travel from the lab to sites such as Washington, D.C., Brookhaven or Livermore (to name representative locations). Driving from Hampton Roads to Washington, D.C., one must count on a three-hour trip at minimum, with the understanding that the precise time of arrival can be rather unpredictable. Flights from Jefferson Lab to more remote locations initially require a trip to airports in Norfolk or Richmond and then at least one connecting flight. Rail transportation

6 The Electron-Ion Collider," Jefferson Lab, www.jlab.org/eic/home.
7 Brookhaven National Laboratory, "Department of Energy Selects Site for Electron-Ion Collider (Jan. 10, 2020), www.bnl.gov/newsroom/news.php?a=116998.
8 "The Electron-Ion Collider," https://www.sciencemag.org/news/2020/01/department-energy-picks-new-york-over-virginia-site-new-particle-collider.
9 Brookhaven National Laboratory.
10 "Editorial: Learn from Jefferson Lab's Strikeout," *The Virginian-Pilot* and the *Daily Press* (Jan. 14, 2020), www.pilotonline.com/opinion/vp-ed-editorial-jefferson-lab-collider-0114-20200114-eeewdisdovf55bs4euxmmw4ezi-story.html.
11 National Science Foundation, "Rankings by Total R&D Expenditures," https://ncsesdata.nsf.gov/profiles/site?method=rankingBySource&ds=herd.

is promising, but not yet developed. By contrast, LaGuardia Airport, with connections to anywhere in the world, is about 70 minutes distant from Brookhaven.

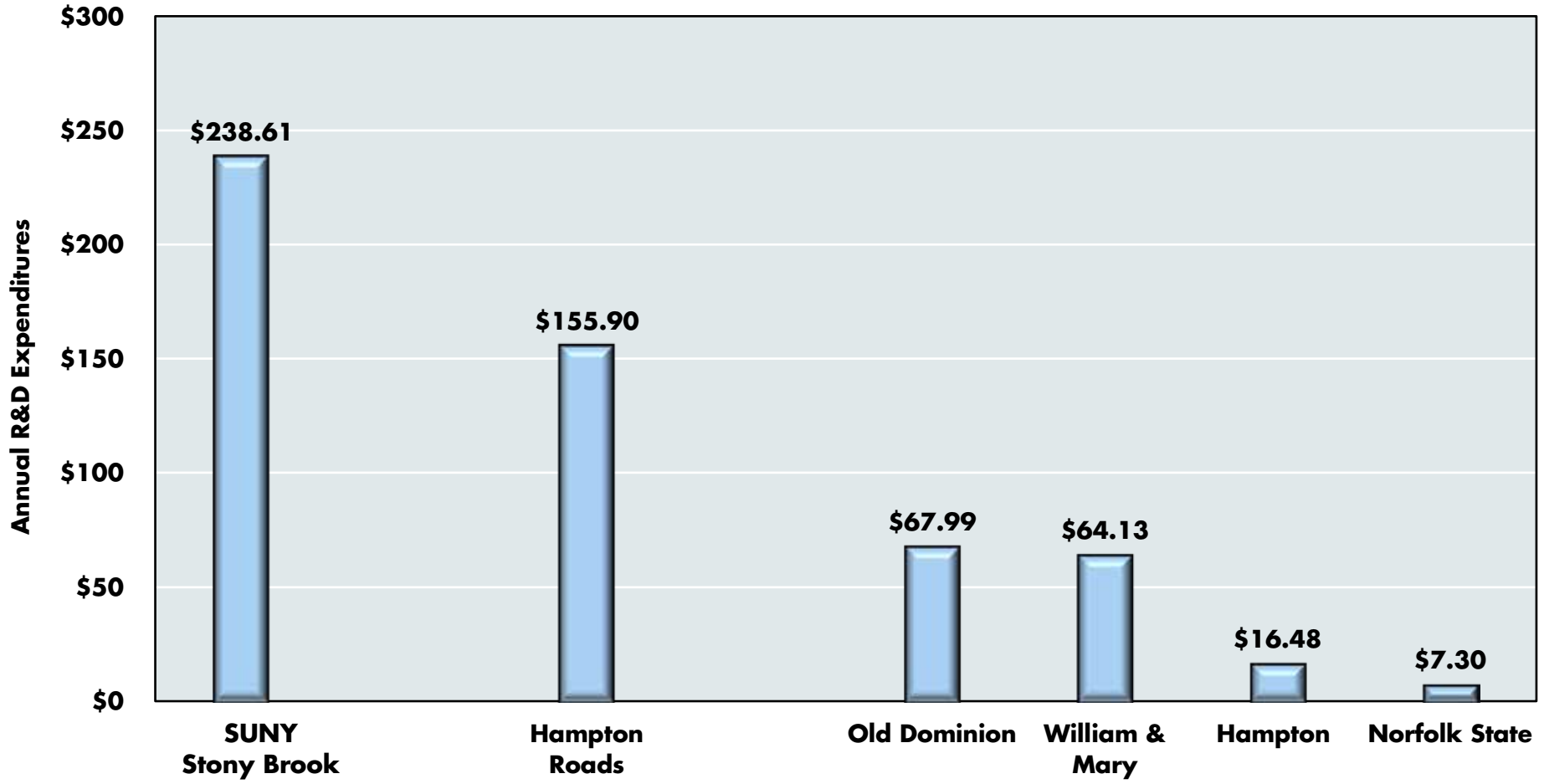
It also is possible that Jefferson Lab's single-purpose nature worked against it in this high-level competition. The lab is very good at what it does but its work has been more narrowly focused. The Brookhaven, Argonne and Livermore laboratories support multipurpose science programs. "Everything is related to everything else in science," commented an experienced JLAB researcher, because broader modes of scientific inquiry often generate superior (sometimes serendipitous) results. Further, some of the same equipment and techniques (such as high-speed computing) that are used in energy research also can be used in other contexts (and vice versa). We address these possibilities in the next section.

Finally, one should not discount the impact of classic political factors on the EIC location decision. Such decisions seldom are made in a political vacuum.



GRAPH 4

TOTAL RESEARCH AND DEVELOPMENT EXPENDITURES FOR SELECTED INSTITUTIONS, 2017 (IN MILLIONS OF DOLLARS)



Source: National Science Foundation, "Rankings by Total R&D Expenditures," https://ncsesdata.nsf.gov/profiles/site?method=rankingBySource&ds=herd

Broadening The Scope Of Jefferson Lab And Increasing The Focus On Applications

A consensus has arisen in and around Jefferson Lab that it should pursue opportunities to broaden its scientific focus. The lab's traditional focus has been nuclear physics but Robert McKeown, its deputy director for science, notes that this is but one of six major program areas in the Department of Energy's Office of Science. Nuclear physics accounts for only 3% of this cabinet department's budget expenditures.

Consider the mission statement of the Argonne National Laboratory: *Argonne is a multidisciplinary science and engineering research center, where talented scientists and engineers work together to answer the biggest questions facing humanity, from how to obtain affordable clean energy to protecting ourselves and our environment. Ever since we were born out of the University of Chicago's work on the Manhattan Project in the 1940s, our goal has been to make an impact – from the atomic to the human to the global scale.*[12]

Were Jefferson Lab to adopt a broader scientific mission similar to that of the Argonne National Laboratory, it would open a broad vista of exciting new opportunities for the lab to deploy its considerable expertise. For example, Jefferson Lab believes that it has the ability to do quality work in the areas of high-performance computing, big-data manipulation and cryogenics. Fortuitously, expenditures by the DOE's Office of Science on high-performance computing are one-third larger than those on nuclear physics. An increased emphasis on high-performance computing would be consistent with trends at other major federal energy laboratories. Two of the 10 most powerful supercomputers in the world reside at the Livermore and Argonne labs. "Exascale computing" (systems capable of executing a quintillion calculations per second) has been assigned a high national priority by the United States, not the least because China has entered this arena with great energy. To the extent that Jefferson Lab can contribute here, its work will be highly valued.

12 Argonne National Laboratory, "About Argonne," www.anl.gov/argonne-national-laboratory.

The Office of the Under Secretary for Science in the U.S. Department of Energy has identified six priority multidisciplinary initiatives: (1) advanced and sustainable energy; (2) artificial intelligence and machine learning; (3) genomics; (4) high-performance computing; (5) large-scale scientific instrumentation; and (6) quantum information science.

Big data is the terminology used almost casually today to refer to the use of predictive analytics to extract value from very large bodies of information. Most people understand that firms such as Google analyze and extract valuable information from the huge amounts of data it accumulates from our Google search and Gmail patterns. Jefferson Lab similarly acquires mountains of information from its experiments, and one of its challenges is to extract meaningful scientific information and patterns from these data. The high-performance computing methods it uses to do so potentially have many governmental and commercial applications.

Cryogenics relates to the production and use of materials that are created or exist at extremely low temperatures. Jefferson Lab currently utilizes very low cryogenic temperatures to accelerate electrons in its beams, operate high-power magnets and produce high-density targets. Laboratory engineers have made critical advances in the field. In general, cryogenic conditions result in materials that sometimes exhibit rare and very useful characteristics – a prime example being superconductivity, when electrical resistance vanishes. In theory, an electrical current facing zero resistance (superconductivity) could persist indefinitely without any additional source of power. If this situation were made commercially feasible, for example, in power transmission, it would have a profound effect on energy use.

Superconducting materials would likely have a wide range of uses in defense, including improvements in the electrical efficiency of naval and jet engines, radar systems and surveillance capabilities. If superconducting materials became commercially feasible, it would have a revolutionary impact on power transmission, computing and many other fields.

Cryogenics is not fantasy science; today's cryogenic techniques are used to freeze foods and vaccines and also to maintain fuels in a liquid state. Previously, we noted the applications of cryogenics to medicine and in particular to surgery. Jefferson Lab has developed promising research avenues in this area.

Another promising research area for the lab is medical imaging. The essence of medical imaging is the creation of a visual representation of the interior of human bodies. Imaging enables physicians and medical personnel to "see" inside a human body without having to cut into it, allowing them to see bones and density of tissue, for example. Jefferson Lab is working to improve the imaging of tumors through the use of nuclear medicine technology. It is not precisely clear where this research will lead but it is fair to say that the imaging cost, accuracy and quality are very important considerations in medicine. The United States currently is spending almost $4 trillion annually on medical care, and any technique that reduces or controls these costs should receive warm commercial acceptance.

Accelerator science is the name attached to the study of devices that accelerate particles. Potentially fruitful applications of accelerator science include superconductivity, free-electron lasers, high-performance computing, big data, cryogenics and medical imaging. The Center for Accelerator Science at Old Dominion University focuses on such applications and prepares students to take jobs at institutions pursuing the applications.

Related to Jefferson Lab's efforts in medical imaging is Virginia Tech's new Tech Center, recently opened nearby at the corner of Oyster Point Road and Jefferson Avenue. The center is adjacent to the 16-acre parcel and building that the city of Newport News has given the Jefferson Lab, and hence the long-run synergistic potential of these sites is considerable. Nevertheless, given Virginia Tech's significant programmatic and financial obligations connected to the Amazon headquarters development in Northern Virginia, it is not clear how large its scientific commitment to this development will be. The larger, the better. The first building of an anticipated 10-building technology park represents only a desirable first step.

Given its substantial sponsors and experienced investors, in addition to its prime location, it seems likely that the Tech Center will be a commercial success; however, the probability is lower that it will be of direct and immediate assistance to Jefferson Lab as it moves to broaden its research agenda.

Regional Policy Implications

Jefferson Lab is a world-class nuclear physics research facility. It can become much more. The first step is for the lab to broaden its mission. Regional citizens should give strong support to this transition because Jefferson Lab's potential to generate commercially significant inventions and innovation is huge. Possible applications span medicine, computer science, big data, the environment and national defense.

Our region can hasten and strengthen Jefferson Lab's transition in several ways. First, it can ensure that our congressional delegation and state representatives are fully aware of and support the huge potential of the lab to do high-quality science that lies outside the conventional boundaries of nuclear physics. Second, it should ensure that Jefferson Lab is fully aware of already existing scientific and commercial activities in Hampton Roads that are related to the lab's new directions. Sponsored conversations and visits involving Jefferson Lab and carefully selected university and business personnel have the potential to enrich and expand the lab's endeavors while also capitalizing on its existing technology for commercial applications. Third, the region should back specific federal funding legislation and state budget amendments that will allocate funds to support these efforts. The lab's medical imaging, environmental cleanup and big-data thrust appear to be particularly well matched to the needs and current academic strengths of our region. We should not expect such developments to occur rapidly, however, without resources being devoted to these tasks. "We need to shake the trees in Richmond and

Washington," commented an elected official. This is sound advice, but will require consultation, cooperation and persistence over several biennia to succeed.

Final Observations

The Thomas Jefferson National Accelerator Facility neither lacks for challenges nor opportunities. Not being designated as the site of the new electron-ion collider was a blow to the lab, but in the long term might turn out to be beneficial. It has forced Jefferson Lab to ask existential questions: Who are we and what should we aspire to become?

Jefferson Lab's life as a single-purpose laboratory has served it and the region well for nearly three decades. Continuing as a single-purpose laboratory may be possible, but not as rewarding as one that broadens its research mission. Such a step would benefit the laboratory and the region. This is both appropriate and in some ways inevitable. Knowledge typically knows no boundaries, and productive commercial applications frequently draw from multiple academic disciplines. The notion of nuclear physicists working side by side with computer scientists, biologists, physicians and even a stray social scientist from time to time not only is more interesting, but also potentially more productive.

Jefferson Lab's task now is to select – with great care and working with the DOE – several promising research themes outside the conventional lines of nuclear physics and to give additional attention to commercialization. While much already has been accomplished in this regard, this movement needs to be accelerated. This could mean amending Jefferson Lab's raison d'être, strategic plan and resource allocation. The consensus is that the lab should not shrink from the task. Nuclear physics will remain the keystone of Jefferson Lab's activities, but this does not imply that it should be the only activity.

Success will more likely be achieved if the lab has the participation of faculty from area universities who work in this new, broader array of specialties. Of course, this is much more likely to occur if funding is available. Given the substantial commercial potential of a broader mission, the region's legislators should be supportive of plans, programs and allocations that would cement partnerships among Jefferson Lab, regional academic institutions and the private sector. Matching-fund initiatives that pair the lab with area university faculty make sense and may have the greatest appeal in the Virginia General Assembly.

These are exciting times at Jefferson Lab, as opportunities abound and the laboratory's willingness to pursue them points to the promise of what is to come. Like Robert Frost's oft-cited traveler, it has approached a fork in the road. Which direction the lab decides to take will have a profound effect on its future – and that of Hampton Roads.