Economic Impacts and Qualitative Drivers of the Thomas Jefferson National Accelerator Facility

Fiscal Year 2018

Jefferson Lab
Thomas Jefferson National Accelerator Facility

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Executive Summary

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a U.S. Department of Energy Office of Science national laboratory managed by the Southeastern Universities Research Association (SURA), a consortium of 60 universities, which operates the laboratory through Jefferson Science Associates (JSA). The laboratory serves resident scientists and consortia of physicists from hundreds of universities and research organizations who use JLab's unique continuous electron beam accelerator and four research halls to explore subatomic particles and the forces binding them together inside of the protons and neutrons that define visible matter.

Jefferson Lab in Fiscal Year 2018 generated the following economic impacts:

For the **Hampton Roads Metropolitan Statistical Area**, JLab's Virginia home, its operations produced spending of **$269.1 million** for economic output, with **$149.2 million** in labor income earned by **2,015** area employees.

Within the **Commonwealth of Virginia**, JLab's economic output totaled **$308.7 million**, producing **$168.3 million** labor income for **2,240** job-holders.

JLab purchased output from across the nation and many of the goods bought by its Virginia suppliers and employees were made in other states, making the national economic impacts considerably larger than those in Virginia. For the nation, Jefferson Lab generated **$556.9 million** in economic output, providing **$250.7 million** in labor income earned by **3,448** workers.

The economic benefits to the region, state and nation created by JLab flow from three major sources:

- direct spending of **$181.4 million** by JLab and its contractors, and by its users and visitors,
- the extraordinary intellectual benefits derived by regional and national research institutions, colleges and universities, local schools and communities who obtain access to Jefferson Lab's capabilities and discoveries, and
- the commercialization of its technological innovations.

Other benefits to the region, state and nation accessible through JLab emanate from:

- locational advantages including skills and relationships that produce superior cost savings related to construction and operations,
- their storehouse of knowledge both unique and of general interest along with an educating culture to diffuse technology to all labs, and
- their inimitable military, educational, governmental, and commercial neighbors that assist in driving innovation, influence and inclusion.

The more than half a billion dollars of economic output is augmented with drivers that produce low costs, high-level capabilities and solid innovation with important partners.

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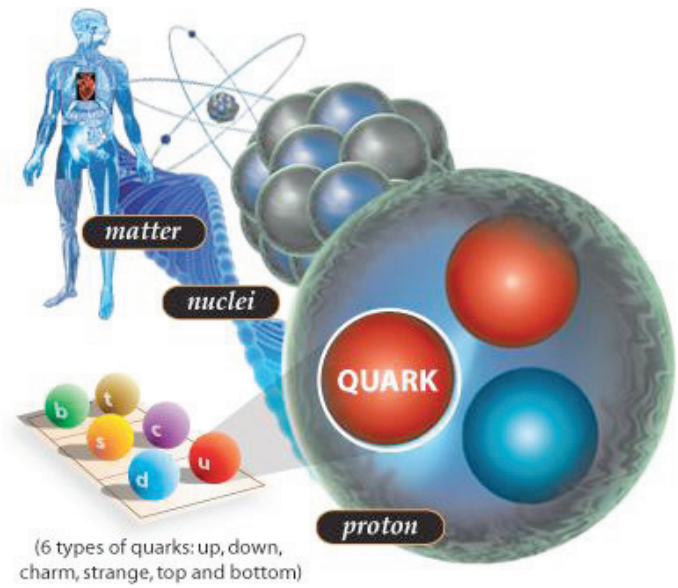


Introduction

This report describes the Fiscal Year 2018 (FY2018) economic impacts of the Thomas Jefferson National Accelerator Facility, also known as Jefferson Lab and less formally referred to here as JLab, on the economies of the United States, the Commonwealth of Virginia and the Hampton Roads Metropolitan Statistical Area (HRMSA). The report also describes some of the lab's more qualitative social-economic impacts. Jefferson Lab is a U.S. Department of Energy Office of Science national laboratory built and managed in the 1980s by the Southeastern Universities Research Association (SURA), a consortium of 60 universities, which today operates the laboratory through Jefferson Science Associates (JSA) – a SURA/Pacific Architects and Engineers (PAE) joint venture. The laboratory serves resident scientists and consortia of physicists from hundreds of universities and research organizations who use JLab's unique continuous electron beam accelerator and four research halls to explore the particles, such as quarks, and the forces binding them together inside of protons and neutrons that define visible matter.

A proton is an infinitesimally small object, but it is filled with a multitude of far smaller particles (the radius of a quark is smaller than 43 billion-billionths of a centimeter) interacting with each other in ways not fully understood. An electron with energy gained through acceleration to near the speed of light striking a proton acts as a giant microscope, making it possible to "see" particles inside. However, describing and understanding go well beyond seeing, and still are in the early stages.

JLab is one of two U.S. labs being considered to build the Electron-Ion Collider, or EIC, to reveal the role of gluons, the carriers of the strongest force in nature that holds quarks together, building protons, neutrons, and the nucleus itself to retain the U.S. global leadership in nuclear physics. This innovation investment is the "corn we're planting for the future… the most important thing we do is understand the nature of matter…because you don't know what will come out of it. We're developing new theoretical ideas and innovating technologies to measure which helps us advance that focus in a clearer way." Microscopic imaging within the atomic nucleus, its constituents and properties represents a change in paradigm and can produce knowledge that positively impacts society including scientific discovery, education, environmental cleanup, advanced materials, medicine, health, alternative energy, and security. Jefferson Lab implements these scientific objectives through great locational advantages along with effective cost management, essential capabilities development, and extensive community building.

The Economic Output Impacts

The economic impact of Jefferson Lab originates from its direct spending for personnel, its own labor force, and other contract labor at its site on Jefferson Avenue in northern Newport News, Virginia, and from its procurement of goods and services from other businesses and organizations. An additional direct economic impact comes from visitors to the HRMSA from around the world who consult, use and learn from JLab experiments and activities. Their expenditures while in the area and compensation for their time at JLab are directly attributable to Jefferson Laboratory.

FY2018 economic impacts are reported here by three measures: Output, the dollar value of goods and services used; Labor Income, the wages and salaries earned and benefits received by employees; and number of Jobs. For all three measures, the total economic impact is the sum of three types of impacts: the direct, indirect, and induced impacts.

The **direct impacts** give rise to the other two streams: the indirect and induced impacts. The Jefferson Laboratory direct U.S. output of $181.4 million in the first row of Table 1 is the flow of payments generated initially by its demand for goods and services.

Table 1 - Total JLAB FY2018 Economic Impacts, in Millions

Impact Type	Hampton Roads MSA Spending for Output	Virginia Spending for Output	United States Spending for Output
Direct Effect	$ 133.7	$ 153.2	$181.4
Indirect Effect	$ 54.4	$ 64.6	$ 140.9
Induced Effect	$ 81.0	$ 91.0	$ 234.6
Total Effect	$ 269.1	$ 308.7	$ 556.9

The **indirect** impacts are the business-to-business (B2B) flows created by direct purchases, labor income, and jobs. The $140.9 million shown in Table 1, Row 2 as U.S. indirect output is the B2B spending for inputs and supplies from other businesses – from providers of goods and suppliers of services ranging from electric power and other utilities to material inputs and cleaning, accounting, legal, and medical services. The output, labor income and jobs created by this B2B spending are indirect impacts, caused by and dependent upon the initial direct demand for goods and services. There also is a third impact stream created, labeled as **induced impact**. This is created as the income earned, by households and businesses in the process of meeting the direct and indirect demands, is spent – primarily for households' consumption. The U.S. induced output of $234.6 million in Row 3 of Table 1 is very real and predictable. Households do spend most of their income. For example, if a plant shuts down (a direct impact), not only do its suppliers lose sales and cut payroll and jobs (an indirect impact), but other businesses that sell to the households of the plant and suppliers' workers lose customers and cut back – an induced impact. The Jefferson Laboratory's $559.6 million total U.S. economic output in FY2018 is the sum of these direct, indirect, and induced impacts.

The direct economic impact starts at home in Newport News, part of the HRMSA, accounting for $133.7 million, nearly 75%, of the U.S. direct JLab spending. Purchases in the rest of Virginia bring the direct Virginia spending to $153.2 million, 84% of the U.S. total. However, the indirect and induced spending in the Hampton Roads MSA and Virginia include buying many goods produced with inputs outside of Virginia, holding the MSA's FY2018 Jefferson Lab economic output to$269.1 million, 48% of the U.S. total output; and the Virginia output, to $308.7 million, 55% of the U.S. total.

Labor Income and Job Impacts

Labor Income is the major cost in providing output, especially true for a non-profit service enterprise such as Jefferson Laboratory. The direct metropolitan area labor income in Table 2, $105.3 million, is 85% of JLab's directly generated U.S. labor income of $123.5 million. Local B2B purchases added $19.6 million to Hampton Roads MSA labor income, and employees spending their income generated another $24.3 million in area labor income, for a total labor income of $149.2 million, 60% of the JLab $250.7 million U.S. labor income created.

Table 2 - Total JLAB FY2018 Labor Income Impacts, in Millions

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 105.3	$ 112.4	$ 123.5
Indirect Effect	$ 19.6	$ 26.8	$ 52.0
Induced Effect	$ 24.3	$ 29.1	$ 75.2
Total Effect	$ 149.2	$ 168.3	$ 250.7

This $250.7 million U.S. labor income attributable to JLab FY2018 operations was paid to an estimated 3,448 employees nationwide, as shown in Table 3. Hampton Roads is home to 2,015 of these jobs, and Virginia to 2,440. These employment figures include part-time as well as full-time jobs, as in the U.S. Bureau of Labor Statistics and Virginia Employment Commission statistics. There is reliable information on FY2018 payroll and jobs by type of establishment, so our focus is on measures that can be estimated and verified with confidence.

In all three tables, the U.S. induced impacts are much larger than the Hampton Roads MSA and Virginia induced impacts because many of the household items bought by Virginians, as well as by residents of the rest of the nation, are made in the rest of the nation.

Table 3 - Total JLAB FY2018 Job Impacts

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	1,038	1,125	1,269
Indirect Effect	377	450	770
Induced Effect	599	665	1,409
Total Effect	2,015	2,240	3,448

The direct economic impacts of JLab-related activities were used as inputs into the IMPLAN PRO (IMpact analysis for PLANning) downloadable model Version 3.1.1001.12, to derive the indirect, induced, and total FY2018 economic impacts for Jefferson Laboratory. This a 536 sector IMPLAN model includes 2017 industry and trade flow data for the nation, Commonwealth of Virginia, and Virginia cities and counties, of which Gloucester County, Isle of Wight County, James City County, Mathews County, York County, and the cities of Chesapeake, Hampton, Newport News, Norfolk, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg comprise the Virginia portion of the Hampton Roads MSA. A strength of the IMPLAN PRO downloadable model is that it is an open model that allows the user to modify the coefficients to fine-tune the model. This flexibility is useful when modeling an enterprise such as Jefferson Lab which employs technicians and scientists with special skills using unique research equipment and facilities.

Direct Expenditures by Category

The $181.4 million in FY2018 Jefferson Laboratory U.S. direct purchases of current output in Table 1 were for a multitude of goods and services. This output spending is arranged in six major categories in Table 4, to illustrate the major sources of JLab's impact.

JLab is a huge research facility, with unique equipment and facilities which have been built, expanded, and upgraded over the last 30 years. The last upgrade, implemented at a cost of $338 million over the period 2008-2017, increased the accelerator energy from 6 billion electron volts (6 GeV) to 12 GeV, upgraded the three existing experimental halls and added an additional experimental hall. No major capital project currently is underway, so the FY2018 economic output is a normal operations example.

Table 4 - JLAB Direct FY2018 Expenditures By Category

In Millions of Dollars

Major Categories	Hampton Roads MSA	Virginia	United States
Total Onsite Personnel, Consultant, & Professional Services	$ 97.1	$ 99.5	$ 100.1
Information, Education, & Transportation	$ 4.9	$ 5.5	$ 8.2
Electric Power & Utilities	$ 2.3	$ 12.8	$ 12.8
Capital Improvements, Systems Maintenance & Repair	$ 8.5	$ 9.6	$ 10.3
Manufactured Supplies & Materials	$ 15.3	$ 19.7	$ 42.4
Visitor Time & Local Expenditures	$ 5.5	$ 6.0	$ 7.7
Total Direct JLAB Expenditures	$ 133.7	$ 153.2	$ 181.4
Percent of U.S. Total	*74%*	*84%*	

Jefferson Laboratory annual operations are quite labor intensive, as indicated by the categories in Table 4. FY2018 expenditures in Hampton Roads predominantly were the $97.1 million for onsite personnel services, consisting of $88 million in salaries and benefits for onsite employees, plus fees for consultants and other professional services. Another personnel services category is the income and local spending of visitors who come to the lab to conduct research and to learn. Note also the manufactured supplies and materials procured from other MSA companies was only $15.3 million, 11% of the $133.7 million in Hampton Roads output purchases; and for Virginia, $19.7 million or 13%. The U.S. $42.4 million direct JLab purchases of manufactured goods is more than double the included Virginia spending (due to purchases of very specialized inputs from companies outside of Virginia), but still only 23% of JLab's $181.4 million in U.S. expenditures. In sum, JLab annual operations are predominantly people-based, not materials based, especially in Hampton Roads and Virginia.

Locational Advantages and Effective Cost Management

The locational advantages of JLab are physical, educational, and communal. These advantages manifest themselves within three major categories: effective cost management, essential capabilities development, and extensive community building. Low costs are driven by access to inexpensive inputs but also supplier relationships, negotiation skills, and project management expertise that also produces innovation. JLab has acknowledged expertise in cryogenics innovation and is a leader in improving that technology across all accelerator laboratories. The community supports JLab's mission with

complementary skills supplied by a unique combination of military, commercial, and educational institutions including a consortium of historically black colleges and universities.

With the latest 12 GeV Upgrade Project, JLab utilized the locational advantages of Newport News. In both building and operating a new facility, JLab is extremely cost effective – below many DOE labs. Helium aka "liquid electricity" is available at great rates along with six cents per kilowatt-hour electricity. Deep-water ports and an excellent highway system keep transportation costs low and provide delivery ease of equipment, components, and raw materials. Labor costs and materials are ranked low with high quality of life (cost of living is double digits higher elsewhere) with good worker relationships and unionization not required. Travel related costs such as hotels, airlines, car rental, and per diems, all are ranked near the bottom. The costs to attract and retain top talent are attractive - this means low life cycle costs. In summary, the raw inputs to produce innovation are efficient in Newport News.

In close proximity, Tier 1 universities offer engineering and business degrees. The military, NASA, and Newport News Shipbuilding spin off well-trained, experienced personnel in critical areas not found elsewhere. Nearby universities house physics experimentalists and theorists of international renown – attracted because of the technology, cost of living, Virginia's quality public education, and relaxed style of the mid-Atlantic. JLab has room to grow in their footprint and even the geology favors them with an ease of excavation, movement of materials, and good options for excess soil. Besides the natural advantages of the location, there are some high level skills that play a key role in keeping costs low.

First, is an ability to work with suppliers and establish close relationships. This often includes problem solving assistance, technical training, and technology transfer. A point of pride is that numerous suppliers are small, agile, with many minority-owned. The DOE's target of 40% of contract value be given to small businesses is exceeded - the actual number is better than 50% - while 3% are in disadvantaged areas (meeting the requirements of HUBZone Act of 1997). Every year a "Supplier Fair" is held to actively recruit small business involvement in conjunction with city officials. The result is very tight relationships that produce trust, coordination, collaboration, and integration that drive lower costs and higher quality.

Second, is a high level of skill in negotiation, especially concerning international suppliers. JLab is gifted with retired military and contract officers with significant experience – again, proximity to the military and its suppliers play a key role. Military presence in the surrounding area is the strongest of the 50 largest metropolitan areas in the U.S. Every branch of the armed services is represented here: Langley Air Force Base (Hampton), Fort Eustis (Newport News), Naval Station Norfolk, Naval Air Station Oceana (Virginia Beach), Joint Expeditionary Base (Little Creek-Fort Story), Coast Guard Training Center (Yorktown), Yorktown Naval Weapons Station, Camp Peary (Williamsburg), Norfolk Naval Shipyard (Portsmouth), Naval Medical Center (Portsmouth), and Coast Guard, Atlantic Area (Portsmouth).

Third, is a critical ability to administer contracts and flourish in project management. There are common pieces of equipment that all the DOE laboratories need (including cryomodules and cryoplants). JLab is able to save 4% on these costs while meeting the quality requirements of 99% of their customers. They survey 100% of their users, track every part, personally talk to anyone with a negative experience, resolve every problem, and work with suppliers to eliminate problems in the future. There is a monthly report of the performance of each subcontractor including production and safety. Procurement personnel attend staff meetings of their customers every week. There is an ongoing commitment to "closing the loop" – continual improvement based on tracking results and using feedback to raise performance on all key measures. This ability to keep the voice of the customer intimately tied to the performance of the suppliers and offer solutions to both creates a value to customers and suppliers alike.

Because of its relationship with the community and local government, permits and inspections are easily obtained. They train safety personnel with local firefighters and other first responders. The city supplies resources and attention to the needs of JLab who uses their resources wisely.

Essential Capabilities Development

Jefferson Lab is especially proud of its expertise in cryo technology. While cryogenics and superconductivity magnets are not universally recognized as core technology, Jefferson Lab's ability to share their expertise is universally acknowledged as critical to the operations of many other

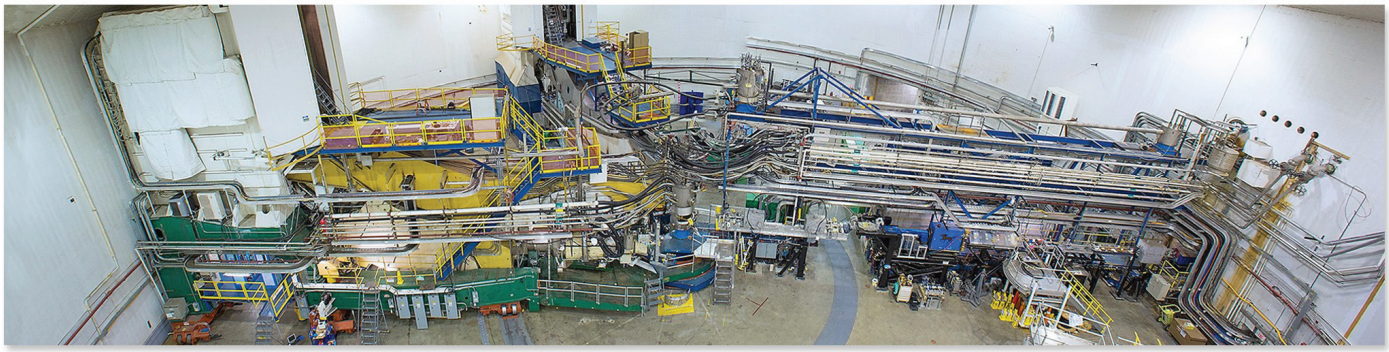
labs. It is underappreciated how "wicked" a problem is caused by a dynamic load, ongoing refrigerant loss, and an unstable phenomenon. Once solved, their solution produces unattended operations and motors that operate reliably for 70,000+ hours at 2 degrees Kelvin in an environment of superconductivity: the system holds stable, dissipates heat, power in, and data out.

A past professional in fabrication at the Michigan State University cyclotron confirmed this impression, "Jefferson Lab was capable and had extremely intelligent people. They were praiseworthy…They were the most effective place to go for cryomodule assemblies. They were in the same national lab circuit and so it was easy to go down to their lab, no dramatic elements, and it was worth benchmarking their operations."

While some studies may suggest JLab is isolated from other national labs based on contracts, they are generous in their consulting for other labs, trouble-shooting, benchmarking, training, and collaborating on ideas for future upgrades. This all points to Jefferson Lab as not only a repository of great knowledge but also exhibiting the critical culture to diffuse its technology and knowledge to other laboratories.

This ability to work well with others not only supports other labs but other local entities. For example, NASA supplies great machinists who do modeling work and Jefferson Lab has set up a five-stage compression plant for them. JLab pursued the University of Virginia Medical School and partnered with William & Mary business professor Dick Ash to commercialize applications and spinoff Dillon, a company who continues to diffuse JLab technological innovation into the medical field. Where needed, "entrepreneurial leave" from JLab is possible. Virginia Tech has a technology center that is adjacent. Jerry Gilfoyle from the University of Richmond is the chair of an international nuclear physics collaboration (known as the CLAS Collaboration) at JLab that consists of about 220 physicists from 39 institutions located in twelve countries. Each of the four JLab halls has a physics collaboration group researching that hall's experiments. For example, the new Hall D has an international group of more than 125 researchers from 28 institutions and 10 countries called the GlueX collaboration whose goal is to confirm a new property of the strong force. These collaborations demonstrate Jefferson Lab's leadership in sharing knowledge.

JLab has hired former employees of Newport News Shipbuilding and the Department of Defense that offer superb training grounds. This ability to attract and retain world-class talent in critical but obscure fields from local partners is distinctive. Unique abilities, a fast moving structure, cross-trained engineers, and low bureaucracy allow JLab to spin up to tackle challenges – both with their partners and on their own. This "flexibility" and "ease to work with" culture pays dividends not only at scientific institutions but also with the community.



Economic Impacts by Category

Table 4 shows only the Jefferson Lab direct output impacts by major category. For completeness, below is Table 5 with the total impacts by category, in which the indirect and induced impacts have been added to the direct impacts. This view gives a summary of the total output impacts by type of JLab activity and purchase. The remaining six tables give more detailed information by category, with the FY2018 direct, indirect, induced, and total JLab impacts on output, labor income, and employment in the Hampton Roads MSA, Virginia, and the United States.

Table 5 - JLAB Total FY2018 Economic Output Impacts

Major Categories	Hampton Roads MSA	Virginia	United States
Total Onsite Personnel, Consultant & Professional Services	$ 211.2	$ 221.0	$ 333.1
Percent Area Total	78%	72%	60%
Information, Education, & Transportation	$ 9.0	$ 10.5	$ 24.2
Electric Power & Utilities	$ 3.7	$ 19.6	$ 30.9
Capital Improvements, Systems Maintenance & Repair	$ 13.9	$ 16.4	$ 29.2
Manufactured Supplies & Materials	$ 23.9	$ 33.0	$ 125.3
Visitor Time & Local Expenditures	$ 7.4	$ 8.3	$ 14.3
Total Direct JLAB Economic Output	$ 269.1	$ 308.7	$ 556.9
Percent of U.S. Total	*48%*	*55 %*	

Table 6 reports the JLab Onsite Personnel, Consultant, & Professional Services direct impacts on output, labor income (including benefits), and employment, nearly all of which are in Hampton Roads. For example, the estimated 766 direct jobs in Hampton Roads are predominantly the 714 Jefferson Science Associates employees at Jefferson Lab. Furthermore, labor income was 95% of the $97.1 million direct spending for output of goods and services in the MSA. The induced MSA ripple effects of $70.5 million in the output section of the table are produced by household spending of their income, well more than the $43.6 million indirect output generated by B2B purchases of goods and services. This category of JLab impacts illustrates how spending for labor services creates more induced demand for consumer-oriented businesses than for businesses indirectly supplying goods used by the enterprise.

Table 6 - JLAB Onsite Personnel, Consultant, & Professional Service Impacts

(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 97.1	$ 99.5	$ 100.1
Indirect Effect	43.6	47.8	75.0
Induced Effect	70.5	73.6	158.1
Total Effect	$ 211.2	$ 221.0	$ 333.1

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 92.2	$ 93.5	$ 94.3
Indirect Effect	15.8	20.3	30.4
Induced Effect	21.1	23.5	50.6
Total Effect	$ 129.1	$ 137.3	$ 175.3

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	766	787	799
Indirect Effect	304	332	456
Induced Effect	521	546	949
Total Effect	1,590	1,665	2,204

Information, Education and Transportation Impacts

Table 7 shows the output, labor income, and employment impacts of JLab information, education, and transportation expenditures. Over 70% of the direct expenditures were for data processing and storage of the petabytes (quadrillion bytes) of data generated by the particle collisions in the collider experiments, not a labor-intensive operation. As a consequence, the indirect impacts in Hampton Roads and Virginia on business suppliers are larger than the induced labor-related impacts on output, labor income, and employment. The rest of the direct expenditures include travel expenses and training and development of JLab staff.

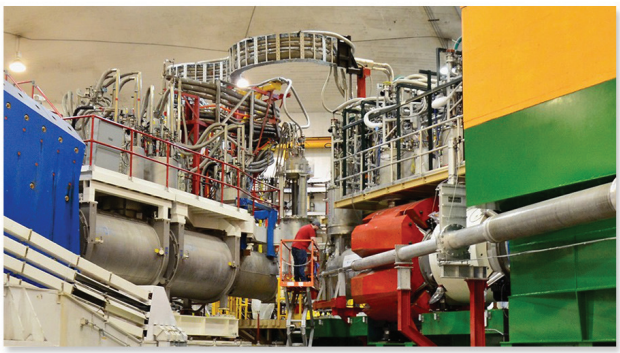
Table 7 - JLAB Information, Education, & Transportation Impacts

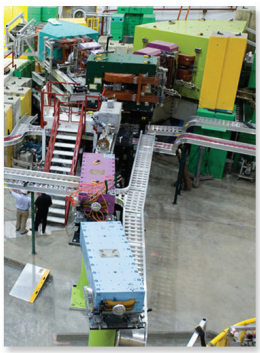
(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 4.9	$ 5.5	$ 8.2
Indirect Effect	2.4	2.6	7.2
Induced Effect	1.7	2.4	8.8
Total Effect	$ 9.0	$ 10.5	$ 24.2

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 1.3	$ 2.1	$ 3.0
Indirect Effect	0.9	1.0	2.6
Induced Effect	0.5	0.8	2.8
Total Effect	$ 2.7	$ 3.9	$ 5.4

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	21	39	49
Indirect Effect	18	36	55
Induced Effect	12	17	53
Total Effect	51	92	121





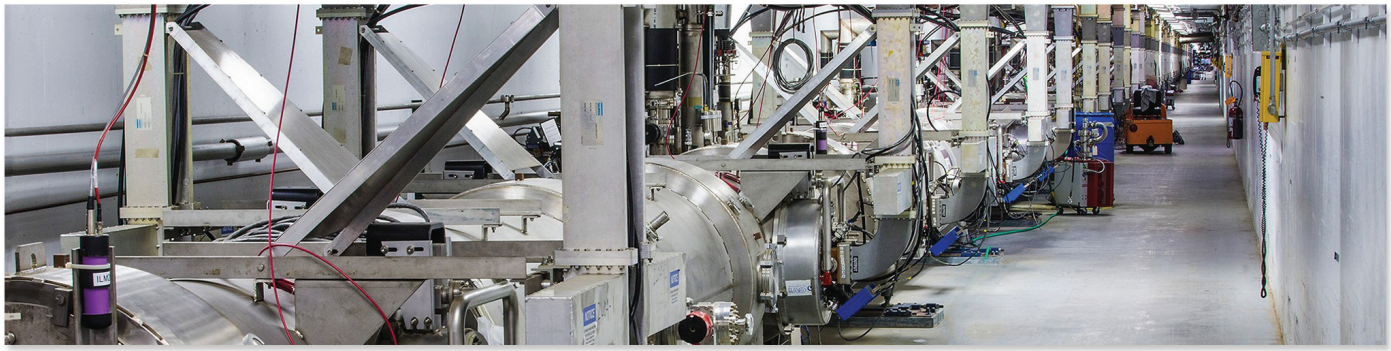
Electric Power and Utilities Impacts

An explanation for the Table 8 numbers for the Electric Power & Utilities category is in order. Electric power for the electron beam accelerator was nearly all the $12.8 million in JLab expenditures shown for Virginia. The electricity was delivered and used in Newport News in the MSA, but it was produced elsewhere, hence the MSA output reported in the impact model is only $2.3 million.

Table 8 - JLAB Electric Power & Utilities Impacts

(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 2.3	$ 12.8	$12.8
Indirect Effect	0.6	3.7	8.9
Induced Effect	0.8	3.1	9.1
Total Effect	$ 3.7	$ 19.6	$ 30.9
Impact Type	**Hampton Roads MSA Labor Income**	**Virginia Labor Income**	**United States Labor Income**
Direct Effect	$ 0.9	$ 2.6	$ 3.0
Indirect Effect	0.2	1.4	2.9
Induced Effect	0.2	1.0	2.9
Total Effect	$ 1.3	$ 5.1	$ 8.8
Impact Type	**Hampton Roads MSA Jobs**	**Virginia Jobs**	**United States Jobs**
Direct Effect	9	24	35
Indirect Effect	4	22	39
Induced Effect	6	21	55
Total Effect	19	68	113



Capital Improvements, Systems Maintenance and Repair Impacts

As previously noted, no major capital project currently is underway at Jefferson Lab. The FY2018 capital procurement was less than 10% of the Jefferson Lab direct expenditures in Table 9, with the bulk of the spending going for normal maintenance and repair of systems, equipment, and structures. As indicated in the table, the JLab spending and labor income is predominantly local and nearly all in Virginia.

Table 9 - JLAB Capital Improvements, Systems Maintenance & Repair Impacts

(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 8.5	$ 9.6	$ 10.3
Indirect Effect	2.2	2.7	7.8
Induced Effect	3.1	4.1	11.1
Total Effect	$ 13.9	$ 16.4	$ 29.2

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 3.4	$ 4.3	$ 4.5
Indirect Effect	0.8	1.0	2.5
Induced Effect	0.9	1.3	3.5
Total Effect	$ 5.1	$ 6.6	$ 10.6

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	97	102	120
Indirect Effect	16	17	37
Induced Effect	23	28	67
Total Effect	156	147	224

Manufactured Supplies and Materials Impacts

The category summarized in Table 10, JLab Manufactured Supplies and Materials, is a very wide-ranging group of purchases, in over 150 North American Industrial Classification System (NAICS) six-digit industry codes. Over half of these purchases were from businesses in other states, most directly from manufacturers of the specialized equipment and materials used in JLab operations.

Table 10 - JLAB Manufactured Supplies & Materials Impacts

(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 15.3	$ 19.7	$ 42.4
Indirect Effect	4.6	6.7	39.1
Induced Effect	4.1	6.6	43.8
Total Effect	$ 23.9	$ 33.0	$ 125.3

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 3.7	$ 5.8	$ 14.2
Indirect Effect	1.7	2.7	12.7
Induced Effect	1.2	2.1	14.0
Total Effect	$ 6.6	$ 10.6	$ 41.9

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	88	107	209
Indirect Effect	29	37	169
Induced Effect	30	45	263
Total Effect	148	189	642

A few of the contracts were for services, but 87% of the expenditures were for manufactured goods. The top seven out-of-state NAICS industry codes of suppliers were All Other Miscellaneous Fabricated Metal Product Manufacturing, All Other Miscellaneous General-Purpose Machinery Manufacturing, Air and Gas Compressor Manufacturing, Industrial Gas Manufacturing, Other Electronic Component Manufacturing, Electronic Computer Manufacturing, and Computer Storage Device Manufacturing.

Table 11 - JLAB Visitors Time & Local Expenditures Impacts

(All Dollar Amounts are in Millions)

Impact Type	Hampton Roads MSA Output	Virginia Output	United States Output
Direct Effect	$ 5.5	$ 6.0	$ 7.7
Indirect Effect	0.9	1.1	2.9
Induced Effect	0.9	1.1	3.8
Total Effect	$ 7.4	$ 8.3	$ 14.3

Impact Type	Hampton Roads MSA Labor Income	Virginia Labor Income	United States Labor Income
Direct Effect	$ 3.8	$ 4.0	$ 4.5
Indirect Effect	0.3	0.4	0.9
Induced Effect	0.3	0.4	1.2
Total Effect	$ 4.4	$ 4.7	$ 6.6

Impact Type	Hampton Roads MSA Jobs	Virginia Jobs	United States Jobs
Direct Effect	58	66	77
Indirect Effect	6	6	14
Induced Effect	7	8	23
Total Effect	70	80	113

Visitors' Time and Local Expenditures Impacts

Table 11 contains estimates of the economic contributions of JLab visitors. Jefferson Lab had several thousand visitors in FY2018, who fall into two groups: Working Visitors, here to conduct experiments in the lab halls or attend conferences of the scientists collaborating on the different experiments; and Touring Groups, here to see and learn about JLab exploration of the subatomic world. There were hundreds of Tour Groups, including students, government officials, visiting scientists, reporters, and the general public.

The Working Visitors were at Jefferson Laboratory for over 40,200 hours, doing valuable research and analysis, valuable output not being paid for by JLab. However, this output is directly attributable to JLab and its facility. The Working Visitor hours were being compensated by their employers, so their estimated hourly labor income offers a reasonable, if probably low, proxy for the value of their JLab activity, entered as visitor time output in Table 11. These working visitors were from around the world: 20% of the JLab hours were by scientists from outside the United States, 50% were from other U.S. states, and 30% were hours of Virginia researchers. Their travel expenditures to get to Newport News, by air or ground, and meals, sundries, and accommodations in Hampton Roads while here, also are direct expenditures attributable to JLab and its operations.

Extensive Community Building

Among the crowd of attendees were 115 5th graders from Mt. Vernon Elementary School for one of 16 "Physics Fest" events. Sitting and facing the three tables full of equipment, you can hear the excited buzz of the students. A free-for-

all quiz is administered with students yelling the answers, "Periodic table!" "Elements!" "Two hydrogen and one oxygen!" Liquid nitrogen and a Van de Graaff generator are the major tools used along with plenty of jokes and physical pranks to lead a wide-ranging two-hour discussion of atomic science. Questions ensue: some tangential, "What would happen if you stuck your hair into an outlet?" and some insightful, "If opposites attract, why don't electrons stick to the protons in the nucleus of an atom?" All are entertainingly answered (although the second one is praised as an important scientific question).

Roughly 13,000 students and 300 teachers attend these types of programs every year. JLab also supports high school mentorships and internships, undergraduate experiences, graduate programs, and post docs. The newest program is geared to first generation college students, to those who qualified for reduced lunches, and to Pell grant recipients – it makes college more affordable ($4,000 per year) and inspires with mentorships and access to a college statistics course their senior year of high school.

Regional Influence

In the 1990s, Hampton University graduated three African-American physics Ph.D.s including one woman. Dr. Warren Buck, instrumental in that success, earned his Ph.D. (1976) in theoretical physics from William & Mary and is a current professor and chancellor emeritus of the University of Washington, Bothell (UWB). Prior to joining UWB, Dr. Buck was a prominent member of a team that established the scientific program at the Department of Energy's Thomas Jefferson National Accelerator Facility and was the founding director of the Nuclear/High Energy Physics Research Center of Excellence and a professor of physics at Hampton University. Dr. Buck describes that path to success, "The excitement of the new accelerator at that time got a lot of people interested. We had great undergraduates interested in physics and proximity was key…along with having mentors who the students could imagine themselves becoming."

The universities and schools benefit mightily from a close connection with the Jefferson Lab facility. The nuclear physics program at W&M owes much to interaction with Jefferson Lab. This nuclear physics program is "out of scale" for such a small school; it has granted 63 PhDs to date based directly on JLab research (both theory and experimental work). Currently, there are 14 students in W&M's program working towards a JLab-based Ph.D. Old Dominion University (where Stuart Henderson, director of JLab is a professor) has also been positively affected, as has Hampton University. In fact, the historically black university may have produced more African-American physics Ph.Ds. than anywhere else in the world. With only one practicing black experimental nuclear physicist, Paul Gueye, in all the Historically Black Colleges & Universities (HBCUs) in 2017 (https://www.aps.org/units/fps/newsletters/201710/senegal.cfm), continued nurturing is needed to drive these accomplishments forward.

Hampton University has established itself as #1 across all HBCUs Physics Departments including nuclear physics, accelerator physics, medical physics, and optical and material sciences. They lead major projects at Jefferson Lab, house the only HBCU graduate program in nuclear physics, and collaborate with the #1 Physics Department in nuclear physics in the U.S.: Michigan State University. Their Center for the Origin and Structure of Matter (COSM) is a National Science Foundation Physics Frontier Center in particle and nuclear physics - a partnership among three HBCUs: Hampton University, Norfolk State University, and NC A&T State University.

The JLab impact also extends downstream of higher education on teachers and the way science is taught in local school systems. JLab improves the quality and time spent on planning for science; they offer critical supplies; they support a network across schools; and they provide professional development; they engender excitement. "Nerd shirts" are clearly a point of pride at these events by students and JLab leaders alike. One teacher commented, "It always excites the kids about science – and they remember it." Another gushed, "Fun and physics makes my job easier. They have a lot of great resources that really help." Each program includes an array of demonstrations designed to help students better understand scientific methodology and nuclear principles.

Additionally, they produce a YouTube channel called "Frostbite Theater" with nearly 100 science experiments and informational videos. Finally, they offer Virginia's Standard of Learning (SOL) tests online for math, science, and technology – these are often called "JLabs" as a synonym for "studying science"…as in "Have you completed your JLabs for the SOL?" For STEM, JLab was "Best in DOE" as

measured by the variety of programs offered along with the number of students and teachers stimulated.

There is organic support from the local community who see JLab as a great opportunity for education, jobs, and other economic development. The community is positive to expansion; it is not necessary to change negative perceptions. JLab supports this positive and open perception with "open houses," community and student educational opportunities, along with military support.

The Chambers of Commerce for Hampton Roads, the Virginia Peninsula, and Richmond are all eager partners. Bob McKenna, President of the Virginia Peninsula Chamber of Commerce says,

> "Getting more involved with Greater Peninsula Now and the Hampton Roads-Richmond collaborative could help in ongoing efforts to attract, among other things, an electron-ion collider to Jefferson Lab…The chamber is planning to set up a science and technology subcommittee focused on helping efforts related to Jefferson Lab and NASA Langley Research Center…To better market the Peninsula's major economic assets, the Peninsula chamber started an event series called Spotlight on the Peninsula — starting with Jefferson Lab and NASA Langley."

The area boasts a large technical base with people exhibiting the relevant experience with similar technology, eager supplier base, and supportive population including a large well-integrated military presence (both active and retired) along with technology suppliers with nuclear capability.

The JLab couples with technology innovators, e.g., Meijers Tool, Ability Engineering, Everson, Branscome, and AES, who help them "build weird stuff" that allows them to, like Lewis Carol states in the character of the Queen, "… believe as many as six impossible things before breakfast"… but also solve some of those "impossible" problems. There are literally hundreds of incremental innovations (e.g., "Felda" welds, high density borated concrete, skid redesigns, a process that atomizes and then removes oil out of helium) - these add up to significant advantages for technology such as those now resident in the cryogenic components.

The "Supplier Fair," as an outreach to small businesses, is also a partnership with local city governments, e.g., Newport News, Hampton, and Virginia Beach. These informal matchmaker events increase available capabilities to JLab's internal customers and expand the range of suppliers helping with the required innovation efforts. This helps build the economies of these locales. Not all suppliers are high tech: guards, janitorial staff, grounds keepers and pest control offer additional jobs in the community of suppliers. The city of Newport News reciprocates with free police, fire and emergency services. JLab also benefits from their supplying free land to SURA and reduced lease costs for staff and lab space.

State/Richmond Influence

Before 9/11 the ports were secure but subsequently the state and federal government realized the importance of higher vigilance. Given concerns, the natural partner to solve this important problem was the JLab. Previously, trucks were randomly inspected while after the solution, the ports could detect any problem with every truck, container, and refrigerated shipment moving through the ports. Besides solving security concerns, JLab has provided jobs, serves as an economic multiplier of investment and incomes, and produced tax revenues. Finally, it is a prestige institution that burnishes the reputation of the state as a technology leader. JLab serves as proof of Virginia's commitment to growing its technology footprint and influence. Many state and private universities across Virginia support this mission.

National/International Influence

Currently, JLab has over 3,000 users with 1,600 visiting the facilities each year They work with over 125 universities and fund joint appointments between the researchers' home university and JLab. There are an additional 700 scientists who have already communicated interest in using the new facility when it is completed. Nationally, this location is the third largest producer of new Ph.D.s in nuclear physics.

One of the founding events in their scientific community started at the Stanford Linear Accelerator Facility (SLAC) where people across the labs were pulled together to solve problems related to beam lines and three dimensional geocity on the linear accelerator. This led to engineering workshops put together by JLab on topics such as accelerator alignment, cryogenics, and reliability issues. This leadership and collaborate approach leverages the investment in one location across many national labs. If you care for the future, then how much better are the students of today prepared and excited to contribute to the required technology of forthcoming challenges.

APPENDIX: BIOGRAPHICAL SKETCHES

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A Raymond A. Mason School of Business faculty member since 1971, Roy Pearson was named the Chancellor Professor of Business in 1987 and retired to Emeritus status in 2005. He served as Director of the College's Bureau of Business Research from 1984 to 1998, doing research projects for government agencies and businesses and publishing the **Virginia Outlook**, providing forecasts three times annually for Virginia and its six largest metropolitan areas.

Economic impact modeling is another specialty. For public and private reports, Roy has used all three of the major impact models, IMPLAN, REMI, and RIMS II. Some economic impact studies he prepared while in the Bureau of Business Research were: ***The Government Returns and Economic Impacts Generated by Current Richmond International Airport Expansion Initiatives; The Virginia Economic Impacts of Philip Morris U.S.A.; The Estimated Economic Impact of Disney's America on Prince William County, the Northern Virginia MSA, and the Commonwealth of Virginia; The Estimated Economic Impact of the Lego Family Park USA on Prince William County, the Northern Virginia MSA, and the Commonwealth of Virginia; and Economic Impacts of Alternative Regulation Environments for Virginia Telephone Companies***. He and Scott Swan completed ***The Fiscal Year 2013 Virginia Economic Impacts of the Port of Virginia*** in December 2014, and ***The Fiscal Year 2013 Economic Impacts of Virginia Maritime Industry International and Domestic Commerce*** in February 2016. Roy and Scott did a series of four economic impacts studies for the Norfolk Redevelopment and Housing Authority during the period 2012-2014. They also produced three 2030 scenarios of ***The Future of Housing in Virginia, in Addressing the Impact of Housing for Virginia's Economy, A report for Virginia's Housing Policy Advisory Council***, November 2017, online at https://www.vchr.vt.edu/wp-content/uploads/2017/11/HPACReport_AddressingtheImpactofHousingforVirginiasEconomy.pdf.

Roy has served on the Governor's Joint Advisory Board of Economists at the pleasure of eight Virginia governors, Robb, Baliles, Wilder, Allen, Warner, Kaine, McAuliffe and Northam. President of the Virginia Association of Economists in 1990-91, he was named a Distinguished Fellow of the Association in 1998. In 1994-95, he was President of the Association for University Business and Economic Research, and in 1999 he was elected to honorary membership. He has served on the Board of Directors of the International Institute of Forecasters (IIF), and as the Associate Editor of the IIF's Foresight: The International Journal of Applied Forecasting. His other professional memberships include the National Association for Business Economics. He received a B.S. in Commerce and Ph.D. in Economics from the University of Virginia.

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K. Scott Swan, Ph.D. is a Professor of International Business, Innovation, and Marketing at The College of William & Mary, Raymond A. Mason School of Business. He serves as Head of Marketing and on the board of the Alan B. Miller Entrepreneurship Center. He teaches classes related to export management, international marketing, entrepreneurship, design thinking, and innovation strategy. Prof. Swan was instrumental in the start of the Innovation and Design Studio that helped lift the Marketing Area to a #1 rating for undergraduate programs in BusinessWeek's 2013 ranking of U.S. universities. He has co-developed an Innovation & Entrepreneurship minor to serve students in the new Engineering and Design Area across the W&M campus and currently innovating an online Masters of Marketing built upon creative problem-solving. He was awarded a Senior Fulbright Chair: the 2015-2016 Hall Chair for Entrepreneurship in Central Europe at WU (Vienna, Austria) and The University of Bratislava, Slovakia - one of two in business worldwide.

Prof. Swan has published widely and serves on the board of two journals related to product de velopment, innovation management, and design: The Design Journal and the Journal of Product Innovation Management along with authoring of three books on these subjects. One book, Innovation and Product Management: A Holistic and Practical Approach to Uncertainty Reduction (with Kurt Gaubinger, Michael Rabi, and Thomas Werani - Springer Science & Business Media 2015), has experienced approximately 45,000 chapter downloads.

http://www.springer.com/business+%26+management/technology+management/book/978-3-642-54375-3

Professor Swan has worked in project management for Flour-Daniel, marketing management for Foremost Corporation of America, as well as founding several small businesses related to design. He has completed two economic impact studies for the Virginia Port Authority and four for Norfolk Redevelopment and Housing Authority, along with others including Union Mission, Virginia Maritime Association, and Governor's Report for Virginia's Housing Policy Advisory Board – all with Prof. Roy Pearson. These studies have often required innovative tools and solutions to complex problems that have not been tackled previously. The approaches have been presented at national conferences. The approaches have been presented at national conferences and received positive press coverage. The analysis, recommendations, and insights have been used for annual reports, adopted for implementation, and benefited clients with strategic outcomes.

Dr. Swan has presented at conferences across most of Europe, Asia, and South America. He has lectured internationally at University of Applied Science Upper Austria (Wels), Corvinus University in Budapest, MCI in Innsbruck, Tsinghua University in Beijing, Aoyama Gakuin University in Tokyo, WHU in Koblenz, Germany, The University of Bratislava in Slovakia, and the Vienna Business School (WU) in Austria.

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