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The NASA Glenn Research Center: An Economic Impact Study Fiscal Year 2019

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Prepared for:
NASA GLENN RESEARCH CENTER

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EXECUTIVE SUMMARY

- Located at Lewis Field (next to Cleveland Hopkins International Airport) and Plum Brook Station (Sandusky, Ohio), the NASA Glenn Research Center performs research, engineering development, and testing to advance aviation, enable exploration of the universe, and improve life on Earth. Its scientists and engineers deliver advanced technology and flight systems for spacecraft and improve efficiency in aircraft, often in partnership with U.S. companies, universities, and other government institutions. The center's core capabilities concentrate on air-breathing and in-space propulsion, power systems, aerospace communications, materials for extreme environments, biomedical technologies and high-value space experiments in the physical sciences - all focused on solving important, practical aerospace problems and opening new frontiers (scientific, technological, and economical) for our nation.[1]

- NASA Glenn's campuses include more than 198 buildings that contain a unique collection of world-class laboratories and test facilities. Since the groundbreaking for the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics (forerunner to NASA) on January 23, 1941, more than $930 million has been invested in the construction of NASA Glenn's campuses. The estimated current replacement value of Lewis Field and Plum Brook Station is approximately $4 billion. The Lewis Field Campus and Plum Brook Station each host large-scale facilities that are uniquely and specifically designed to test aviation and spaceflight hardware. Both locations enable NASA, other governmental agencies, and academic and industry partners from across the country to perform specialized research and testing to support the Agency's Aeronautics, Space and Science Missions, as well as the country's interests in these areas.

- During the period covered in this report, NASA Glenn has had several leadership roles that are critical to programs and projects in all of NASA's missions: Deep Space Exploration Systems, Low Earth Orbit, and Spaceflight Operations, Science, Exploration Technology, and Aeronautics Research. Within the Deep Space Exploration Systems, it captures Exploration Systems Development and Exploration Research and Development of the systems and capabilities needed for human exploration of the Moon and Mars. Low Earth Orbit and Space Flight Operations includes utilization and operations of the International Space Station and associated Space and Flight Support communications and navigation services. The role in Science is focusing on applying research capabilities and technology development for planetary and earth science missions. Exploration Technology is centering on advancing the creation of novel technology investments to go, land, live, and explore the Moon, Mars, and beyond.

- In addition, NASA Glenn is leading the aeronautic research that includes managing the Advanced Air Transport Technology Project, defining the most compelling technical challenges facing the air transport industry as envisioned for the 2030-2040-time horizon. The research explores and advances knowledge, technologies, and concepts to enable giant steps in energy efficiency and environmental compatibility, resulting in less fuel burn and less direct impact with the atmosphere.

[1] For further information, use the following link: http://www.nasa.gov/centers/glenn/home/index.html#.U7R0kpRdUwA

- This report is structured with the following sections: Sections A and B consist of the report's introduction and background describing NASA Glenn's campuses, their location, and the mission of the Center. Section C provides an economic overview of NASA Glenn, including information about its employment and occupations, employee residences, payroll, expenditures, awards to academia and other institutions, revenues, and taxes paid by NASA Glenn employees. Section D describes the economic impact created by NASA Glenn Research Center on two regions, an 8-county Northeast Ohio region and the State of Ohio during FY 2019. This report is an update of several earlier studies that described NASA Glenn and measured its economic impact on Northeast Ohio and Ohio.

ECONOMIC IMPACT GENERATED BY NASA GLENN RESEARCH CENTER SPENDING

The NASA Glenn Research Center creates the benefits within the regional economy by engaging contractors from Northeast Ohio and Ohio, paying high wages to their employees who spent most of their income locally, and collaborating with local higher education institutions providing them with research grants and contracts. This study uses a multi-regional input-output (I-O) model to estimate the effect of NASA Glenn Research Center's spending on the economies of Northeast Ohio (NEO) and Ohio. This model measures economic impact in terms of growth in output (sales), value added (output less intermediary goods), number of new and supported jobs, labor income, and tax revenues. This year's study uses an improved methodology to measure NASA Glenn's impact on the economies of Northeast Ohio and Ohio, and to account for the inter-relationships of two connected regions. This methodology is comparable with the one used in previous studies. The Multi-Regional Input-Output analysis better accounts for the Ohio regional supply chain, calculating the impact for the larger region as the economic impact of NASA Glenn on Northeast Ohio and on the remainder of Ohio. This report accounts for diverse economic sectors and illustrates the impact they make on the regional economies of Northeast Ohio and the State of Ohio. The table below summarizes NASA Glenn's economic impact on Northeast Ohio and the State of Ohio during FY 2019.

Economic Impact	Northeast Ohio	State of Ohio
Output	$1,618.4 million	$1,733.2 million
Value Added	$866.4 million	$914.9 million
Employment	6,989 jobs	7,651 jobs
Labor Income	$505.1 million	$549.8 million
Taxes	$117.9 million	$129.3 million

Note: Direct value added impact was assessed as a percentage of output, whereas in studies prior to FY 2013 it accounted only for labor income as a direct value added impact.

- NASA Glenn's $928.3 million worth of direct spending originating primarily from outside of the region resulted in an output (Sales) change of $1,618 million across all industry sectors in Northeast Ohio. The value added increased by $866.4 million as a result of NASA Glenn's activities. In addition, 6,989 jobs were created and supported in the region, and labor income in Northeast Ohio increased by $505.1 million. NASA Glenn's activities in Northeast Ohio also generated $117.9 million in local, state, and federal taxes.
- NASA Glenn's activities in Ohio in FY 2019, stimulated by $928.3 million in direct spending originating primarily from outside of the state, generated an increased demand in output (sales) for products and services produced across the state valued at $1,733 million.
- Ohio value added increased by $914.9 million as a result of NASA Glenn's activities in the state. In addition, 7,651 jobs were created and supported in Ohio, and labor income across the state increased by $549.8 million. NASA Glenn operations in Ohio also

generated $129.3 million in local, state, and federal taxes.

- Direct NASA Glenn spending had the greatest impact in the areas of scientific research and development services, administrative and waste management services, facilities support services, maintenance and repair construction of nonresidential structures, computer related services, educational services, investigation and security services, and architectural, engineering, and related services.
- Spending by NASA Glenn personnel and other workers was in line with typical consumer spending patterns. Industries that benefited the most from NASA Glenn spending included real estate and rental services, hospitals and healthcare offices, insurance carriers, food services, and nursing and community care facilities.

NASA GLENN RESEARCH CENTER: AN OVERVIEW

- In FY 2019, NASA Glenn had 1,578 civil service employees, including 347 administrative professionals (22%), 16 clerical workers (1%), 1,136 scientists and engineers (72%), and 79 technicians (5%). Compared to FY 2018, the total Glenn service employment decreased by 16 workers; the Administrative Professional category increased by 12, the Scientists & Engineers category increased by 20, the Clerical category was reduced by 16, and the Technician category was reduced by 32.
- The civil service employees at NASA Glenn are highly educated and skilled; 89% of civil service workers had a bachelor's degree or higher in FY 2019. Specifically, of total NASA Glenn's civil service employees, 18% held doctoral degrees, 38% held master's degrees, and 33% held bachelor's degrees.[2]
- In FY 2019, the largest occupational category was scientist and engineers. This category has continued to be the largest occupation over the last five years, a historical trend that has continued even before FY 2015. The scientists and engineers account for 72% of the civil service employees at NASA Glenn in FY 2019.
- The total number of NASA Glenn employees, including both civil service employees and local contractors in FY 2019, was 3,254. This showed a decrease of 27 from FY 2018. During the last five years, the highest total combined employment was 3,281 in FY 2018, and the lowest was 3,125 in FY 2015.
- The total compensation NASA Glenn civil service employees received in FY 2019 was $237.4 million. Total compensation included both payroll ($180.6 million) and benefits ($56.8 million).
- Total compensation to NASA Glenn civil service employees increased $1.7 million (0.7%) between FY 2018 and FY 2019, in nominal dollars. In the same time period, NASA Glenn's nominal payroll has increased by $0.7 million (0.4%).
- From 2015 to 2019, total compensation increased $9.4 million (4.1%), from $228.0 million to $237.4 million, respectively; and payroll marginally increased by $3.5 million (2.0%) in nominal dollars.
- In FY 2019, vendors from 46 states, the District of Columbia, Puerto Rico, and nine foreign countries received a portion of NASA Glenn's expenditures. These FY 2019 expenditures totaled $586.5 million, which is 23.6% higher than FY 2018 expenditures, increasing by $112.1 million in nominal dollars. This translates to an increase of $104.8 million (or 21.7%) between FY 2018 and FY 2019 when adjusting for inflation.
- Ohio continues to receive the largest share of the total expenditures, with $308.7 million going to the state vendors in FY 2019. Although there was an increase in total Ohio spending between FY 2018 and FY 2019, the share of expenditures for the state decreased from 61.3% in FY 2018 to 52.6% in FY 2019.
- Just over 90% of NASA Glenn's total expenditures in the State of Ohio were spent in Northeast Ohio in FY 2019, with the region receiving $279.2 million. Cuyahoga County received the largest share of expenditures paid both within Northeast Ohio and in the State of Ohio, receiving 99.0% and 89.6%, respectively.
- California received $92.6 million (15.8% of total expenditures), and Washington received $46.5 million (7.9% of total expenditures). Notably, expenditures in California increased 484%, or $76.7 million, between FY 2018 and FY 2019 in the nominal dollars. Spending in Washington increased 13.1% ($5.4 million) across this period.
- NASA Glenn's expenditures in foreign countries increased by 87.6% between FY 2018 and FY 2019. Foreign countries received $1.4 million, or 0.2%, of total spending in FY 2019. Great Britain

[2] These counts do not include Student Trainees

was the largest beneficiary of the foreign countries that received expenditures.

- In FY 2019, NASA Glenn awarded funding that totaled nearly $15.0 million to colleges and universities in 31 states. Grants accounted for $11.0 million of this total. Funding to academic institutions decreased by $1.1 million (6.9%) between FY 2018 and FY 2019, in nominal dollars. NASA Glenn also awarded $4.0 million in contracts to Ohio academic institutions in FY 2019 through on-site contracts. The academic funding allocated to the top five states – California, Ohio, Maryland, Michigan, and Texas – in FY 2019 accounted for 65.4% of the total awards, compared to 64.8% of total grants made to the top five states during FY 2018.
- Academic institutions in Ohio received $5.4 million in FY 2019, which accounted for the largest share (35.9%) of NASA Glenn's academic awards for the year. NASA Glenn's academic awards to Ohio decreased by 4.6% between FY 2018 and FY 2019.
- In FY 2019, California received $1.7 million of NASA Glenn's academic awards. Second only to Ohio, California received 11.6% of the total share. Maryland and Michigan were awarded the third and fourth largest shares overall, receiving $1.3 million (8.7%) and $0.7 million (4.7%), respectively, in funding to colleges and universities.
- Academic institutions in Ohio received $5.4 million in FY 2019, which accounted for the largest share (35.9%) of NASA Glenn's academic awards for the year. NASA Glenn's academic awards to Ohio decreased by 4.6% between FY 2018 and FY 2019.
- Northeast Ohio received 56.2% of the $5.4 million awarded to all of Ohio, totaling $3.0 million. Northeast Ohio received 20.2% of all academic funding given by NASA Glenn in FY 2019. Northeast Ohio's share of awards increased both at the state level (56.6% of total Ohio awards in FY 2018) and national level (19.8% of total awards in FY 2018).
- Of all Ohio academic institutions that received funding, Case Western Reserve University (CWRU) and the University of Toledo were awarded the most in FY 2019. CWRU received just over $2.2 million (41.6% of the total), and the University of Toledo received $1.8 million (32.7% of the total) in FY 2019. For CWRU, this was a $0.34 million or 18.1% increase in funding between FY 2015 and FY 2019. For the University of Toledo, this was a $0.87 million or 33.2% decrease during the last five years (adjusted to 2019 dollars). The two universities accounted for 74.3% of NASA Glenn awards to Ohio academic institutions in FY 2019.
- Ohio State University was awarded $480,523 (8.9% of the total) in FY 2019 and received the third-highest share of the total funding to Ohio academic institutions. The University of Akron received $431,278 (8.0%) and ranked fourth. The remainder of the FY 2019 awards from NASA Glenn to Ohio academic institutions went to the Kent State University ($177,019 or 3.3%), Cleveland State University ($162,745 or 3.0%), Ohio University ($75,837 or 1.4%), University of Cincinnati ($38,354 or 0.7%) and Cuyahoga Community College ($15,998 or 0.3%).
- In FY 2019, NASA Glenn's total revenue reached $996.2 million. Without adjusting for inflation, this translates to a 33.7% increase from FY 2018. NASA Glenn's revenues have increased by 48.4% in the last five years, ranging from $671.5 million in FY 2015 to $996.2 million in FY 2019 in nominal dollars. In FY 2019, the largest share of the revenue for reimbursable commitment came from federal funding, accounting for 82.5%. The Department of Defense accounted for the largest share of this federal funding in FY 2019, contributing 57.0%.
- NASA Glenn employees paid $9.4 million in income taxes at the state and local levels in FY 2019. This is a 3.2% increase from FY 2018, without adjustment for inflation. The amount of taxes paid to local and state governments has increased steadily over the past four years, rising from $8.8 million in FY 2016 to $9.4 million in FY 2019.

- NASA Glenn continues to be an essential institution influencing the economic life of both Northeast Ohio and the State of Ohio. NASA Glenn's employees are part of the knowledge-intensive labor force that advances the nation, generates wealth in the region and attracts other creative workers to reside in Ohio.

A. INTRODUCTION

This report presents an analysis of the economic impact of the National Aeronautics and Space Administration's (NASA) Glenn Research Center (Glenn) on the eight-county Northeast Ohio region and the State of Ohio during fiscal year (FY) 2019.[3] It uses the methodology of an input-output model, which reflects the buy-sell relationships among industries, the household sector, and the government sector in a region, to estimate the effect of NASA Glenn's spending on the economics of both Northeast Ohio and the state of Ohio.[4] Since NEO is a part of Ohio, this study is conducted using Multi-Regional Input-Output (MRIO) analysis, where economic impact accounts for both regions.

The report also provides an overview of NASA Glenn and describes some of its research and development (R&D) activities. It looks at changes in NASA Glenn's employees in terms of employment, payroll, occupation, and place of residence.

The report provides information on NASA Glenn's expenditures and revenues, awards to academic institutions, and taxes contributed by employees.

This analysis was conducted by the Center for Economic Development of Cleveland State University's Maxine Goodman Levin College of Urban Affairs. This FY 2019 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2019.[5]

[3] For purposes of this study, Northeast Ohio includes Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties.

[4] Output impact reflects the total value of all additional goods and services produced in the economy. For example, the output economic impact includes the total value of all professional scientific and technical services and all intermediary goods created to secure delivery of the scientific services. Value added impact reflects the value of only additional output produced in the region, which is calculated as total sales less intermediary goods which are not sold as final products. For example, the value added impact will account for the value of all professional scientific and technical services excluding intermediary goods produced to deliver these services. Such intermediary goods, among others, include research supplies, utilities, research services of intermediary steps of research, etc.

[5] All previous studies can be found on the Center for Economic Development's website: https://engagedscholarship.csuohio.edu/urban_cecde/

B. NASA GLENN RESEARCH CENTER: BACKGROUND

Located at Lewis Field (next to Cleveland Hopkins International Airport) and Plum Brook Station (Sandusky, Ohio), the NASA Glenn Research Center performs research, engineering development, and testing to advance aviation, enable exploration of the universe, and improve life on Earth. Its scientists and engineers deliver advanced technology and flight systems for spacecraft and improve efficiency in aircraft, often in partnership with U.S. companies, universities, and other government institutions. The center's core capabilities concentrate on air-breathing and in-space propulsion, power systems, aerospace communications, materials for extreme environments, biomedical technologies and high-value space experiments in the physical sciences - all focused on solving important, practical aerospace problems and opening new frontiers (scientific, technological, and economical) for our nation.[6]

B.1. NASA GLENN TEST FACILITIES

NASA Glenn's campuses include more than 198 buildings that contain a unique collection of world-class laboratories and test facilities. Since the groundbreaking for the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics (forerunner to NASA) on January 23, 1941, more than $930 million has been invested in the construction of NASA Glenn's campuses. The estimated current replacement value of Lewis Field and Plum Brook Station is approximately $4 billion.

Glenn's main campus, Lewis Field, is situated on 307 acres of land and contains more than 87 buildings. Lewis Field has a large inventory of facilities that supports research, development, testing, and evaluation activities. There are approximately 450 research and test facilities located at the Lewis Field site, including 24 major test facilities and over 100 research and development laboratories. The world-class facilities at Lewis Field include large and unique aero-propulsion wind tunnels, micro-gravity and free-fall research facilities, engine test cells, flight research facilities, space environment chambers, vacuum chambers and a host of additional research and development laboratories and test stands.

Glenn's Plum Brook Station is located 50 miles west of Cleveland in Sandusky, Ohio, on 6,740 acres of land. Plum Brook Station has large, unique facilities that simulate the environment of space. Most of these capabilities are world-unique, including an electric aircraft testbed for investigating flight weight hybrid electric power train systems, the world's largest thermal-vacuum space simulation chamber, the largest mechanical vibration table, the most powerful reverberant acoustic test chamber, the largest electromagnetic test chamber, the largest space simulation chamber which can test in planetary dust, the largest liquid hydrogen-capable space simulation chamber, and the only cold soak start/restart rocket engine test facility.

Both locations enable NASA, other governmental agencies, and academic and industry partners from across the country to perform specialized research and testing to support the Agency's Aeronautics, Space and Science Missions as well as the country's interests in these areas.

[6] For further information, use the following link: http://www.nasa.gov/centers/glenn/home/index.html#.U7R0kpRdUwA

B.2. NASA GLENN MISSION AREAS SUPPORTING NASA THEMES

During the period covered in this report, NASA Glenn has had several leadership roles that are critical to programs and projects in all of NASA's missions: Deep Space Exploration Systems, Low Earth Orbit and Spaceflight Operations, Science, Exploration Technology, and Aeronautics Research.

Deep Space Exploration Systems (Exploration Systems Development and Exploration Research and Development of the systems and capabilities needed for human exploration of the Moon and Mars)

- Provides significant management, design, development, test, integration, and production operations contributions within the Orion Program, including managing the European Service Module (ESM) development by the European Space Agency (ESA). The ESM provides power, propulsion, consumable water and gasses, and communications for the Orion spacecraft. Other technical support includes design and analysis of vehicle structures, ground handling, and related vehicle mission readiness activities such as integrating the ESM with the crewed portion of the Orion vehicle, the Crew Module (CM).
- Conduct Orion spacecraft qualification environmental testing at Glenn's Plum Brook Station (PBS) of the fully integrated Orion ESM-CM as part of the first Artemis I Mission, AM-1, uncrewed flight around the Moon.
- Providing overall technical and public-private partner leadership to manage the government team and the prime contractor responsible for the development of the Power and Propulsion Element (PPE), which will be the first of several elements or modules assembled in Lunar orbit to form the Gateway, the platform that will orbit the Moon and support future planned lunar landers and surface activities. This includes managing and developing next-generation Solar Electric Propulsion systems that, as part of the Gateway architecture, support sustainable exploration with humans reaching farther into space.
- Managing the government team and prime contractor developing the SLS Payload Fairing and the Universal Stage Adapter (USA) that connects the SLS Exploration Upper Stage to the Orion Crew and Service Module. This includes applying human spaceflight engineering and technical capabilities to perform a variety of analysis and integration tasks to support the development of the Space Launch System (SLS) and the Orion Crew Vehicle.
- Developing next-generation systems that enable exploration. NASA Glenn is leading projects to make advancements in spacecraft fire safety, including developing and launching payloads to test and observe flames, fire detection, and mitigation techniques in a microgravity environment; advanced modular power systems and components for efficient distribution architectures; and other enabling technologies to further exploration sustainability and science applications.

Low Earth Orbit and Space Flight Operations (Utilization and operations of the International Space Station and associated Space and Flight Support communications and navigation services)

- Leading the development of experiments and research apparatus in the physical science fields of combustion science and fluid physics and transport phenomena in microgravity, which is performed on the International Space Station.
- Managing several research and advanced technology development projects on the ISS and on Earth, in support of human

exploration, including biophysics experiments.

- Contributing to the Human Research Program, which performs research and technology related to human health, exercise development for exploration countermeasures, and medical devices, including computational modeling.
- Managing and overseeing the development of system upgrades for and supporting safe and reliable operation of the International Space Station's electrical power system, including Lithium-ion battery development and deployment.
- Leading the operation and utilization of new, advanced communications technology, including the SCaN Testbed - a demonstration already located on and in service on the International Space Station for software-defined radios and cognitive communications.
- Providing formulation leadership for public-private partnerships with industry for the demonstration of commercially provided satellite-based communication services to support NASA missions.

Science (Applying research capabilities and technology development for planetary and earth science missions)

- Managing the Radioisotope Power Systems Program and developing associated power technologies. Radioisotope Power Systems enable scientific missions where conventional power systems such as solar power or batteries are impractical. Examples include enhancing current thermoelectric technologies, and developing next generation capabilities, including more efficient dynamic power conversion systems using radioisotope heat sources.
- Managing Department of Energy production of radioisotope materials and fuel for NASA space missions.
- Developing and promulgating NASA-wide strategy for nuclear power and propulsion systems.
- Developing and testing, with industry for eventual commercialization, gridded-ion solar electric propulsion thrusters and power processing units to be provided as NASA equipment to forthcoming Space Science Missions, such as the Double Asteroid Redirection Test (DART).
- Contributions to the 2026 Mars Sample Return Mission to include the design and development of the Mars Spring Tire consisting of a wheel and tire assembly along with the Mars Sample Return Solar Arrays. In addition, GRC participates in lunar science activities by developing hardware to characterize the nature of lunar polar volatiles and to conduct a surface demonstration and validation of solar cells and a solar array equipped with NASA-developed plasma charging measurement circuitry.
- Supporting the Long-Life In-Situ Solar System Explorer (LLISSE) probe development to obtain science in harsh environments such as the atmosphere and surface of Venus.
- Conducting complex environmental testing utilizing the unique NASA Glenn Extreme Environments Rig (GEER) facility that can accurately simulate atmospheric conditions for any planet or moon in the solar system and beyond.
- Developing new scientific instruments and mission concepts for planetary surfaces (e.g., Venus, Mars) and Earth science (e.g., fresh water).
- Conduct airborne monitoring of harmful algal blooms, in fresh water such as Lake Erie, using hyperspectral sensors. This was conducted in collaboration with regional universities and institutes using both piloted and unpiloted techniques.
- Supporting NASA Headquarters with assessments and panel membership for

Planetary Science, including technology/tools coordination and science advisory groups.

Exploration Technology (Advancing the creation of novel technology investments to go, land, live, and explore the Moon, Mars, and beyond)

- Leading the development and testing of Solar Electric Propulsion technology that can enable future space-based exploration and scientific missions of the future.
- Leading the development of technologies for cryogenic fluids transfer and storage and associated propulsion systems analysis, for both application to the Space Launch System and future transportation systems. This includes ground testing and flight operations support for refueling techniques.
- Managing and developing kilowatt class nuclear power systems for in-space and lunar surface power, including a demonstration of a fission power system in partnership with DOE.
- The Space Technology Research Grants (STRG) program led by NASA Glenn accelerates the development of high risk/high payoff technologies to support the future space science and exploration needs of NASA, other government agencies and the commercial space sector. STRG challenges the spectrum of academic researchers from graduate students to tenured faculty members to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable.
- The Small Business Innovation Research (SBIR) program provide an opportunity for small, high technology companies and research institutions to participate in government-sponsored research and development efforts in key technology areas. NASA Glenn evaluates and awards more SBIR grants than any other center.
- NASA Glenn is very active in regional economic development through the Strategic Technology Partnership program, NASA's effort to spark economic growth by creating, contributing to, catalyzing, and supporting economic and innovative ecosystems across the country.
- NASA Glenn is engaged with NASA's Technology Transfer Program by ensuring technologies developed for missions in exploration and discovery are broadly available to the public, maximizing the benefit to the Nation. During 2016, NASA Glenn initiated more technology licenses than any other NASA center in the history of the Agency and in following years, Glenn has continued to contribute significantly to disseminating NASA technology. In 2019, twenty-three different NASA Glenn technologies were licensed through 10 license agreements.
- The NASA Innovative Advanced Concepts program has nurtured several NASA Glenn concepts and visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace architectures, systems, or missions.
- NASA Glenn stimulates and encourages creativity and innovation in a wide spectrum of fledgling technologies through the Center Innovation Fund while addressing the technology needs of NASA and the nation.

Aeronautics Research

- Managing the Advanced Air Transport Technology Project defining the most compelling technical challenges facing the air transport industry as envisioned for the 2030-2040-time horizon. The research explores and advances knowledge, technologies, and concepts to enable giant steps in energy efficiency and environmental compatibility resulting in less fuel burn and less direct impact with the atmosphere.

- Managing the hybrid electric propulsion investments, partnerships, performing technical research, development and testing for hybrid electric elements and subsystems including high power density materials, high efficiency, high power density megawatt class electric machines, more efficient, higher performing combustion and turbine systems.
- Managing and performing research, including testing for propulsion/airframe integration advances to enable changes in air vehicle shapes resulting in significant improvements in fuel efficiency.
- Managing and performing engine icing research and testing in the only facility in the world capable of replicating conditions for ice formation at altitude internal to combustion engines, to understand the physics and to provide the capability to certify commercial engines for operations in icing conditions.
- Managing, overseeing development and performing testing of advanced air-breathing combustion subsystems and systems to achieve higher efficiencies and reduce system emissions due to combustion.
- Managing the propulsion concepts within the Revolutionary Vertical Lift Technologies Project, defining the most compelling technical challenges facing the rotorcraft and vertical lift communities, and performing research, development and testing of hybrid electric propulsion, drive systems, transmissions, and turbomachinery for vertical lift vehicles.
- Managing the propulsion concepts supporting the Commercial Supersonic Technologies Project overseeing vehicle research, integration and testing in the development of tools, technologies and knowledge that will eliminate technical barriers preventing practical commercial supersonic flight. Performing research and development to design tools and innovative concepts for integrated supersonic propulsion systems that can meet airport noise regulations.
- Managing the Aeronautics Evaluation and Test Capabilities Project, combining research, analysis, and test capabilities necessary to achieve future air vehicle development and operations. Providing operations and maintenance oversight while also developing and implementing a construct to make future investment portfolio decisions for Aeronautics and Agency Aerosciences objectives.
- Managing and developing the communications protocols for the Unmanned Airspace Systems project by demonstrating secure and reliable unmanned aerial systems controlled communication via large-scale simulations and flight-testing to validate performance requirements for civil unmanned aerial systems.
- Managing the Convergent Aeronautics Solutions Project, pursuing short duration activities to establish early-stage concept and technology feasibility for high-potential solutions to major-system-level challenges that require NASA and the aviation community to think beyond current concepts, architectures and relationships. Performing technology developments include airframe structures accounting for power system elements and establishing voltage and power limits for hybrid electric aircraft options.
- Managing the Transformative Tools and Technology Project to develop new computer-based tools, models, and associated scientific knowledge that will provide first-of-a-kind capabilities to analyze, understand, and predict performance for a wide variety of aviation concepts. Performing research and technology development of ceramic matrix composite materials, advanced coatings, propulsion analysis, and design tools for future aeronautics concepts.

- Providing requirements and systems engineering approach to embed cyber-security into the future air traffic management system, including developing communications architectures and potential future communications elements, sensors and autonomy solutions, with test and verification, for future airspace operations concepts.
- Managing the propulsion content of the Hypersonics Project, supporting vehicle studies, performing propulsion testing, and developing high temperature seals and analytic tool development to advance hypersonic technology for the nation.

C. NASA GLENN RESEARCH CENTER: ECONOMIC OVERVIEW

This section provides a description of the NASA Glenn Research Center during FY 2019. This analysis represents the changes between FY2015 and FY2019 illustrated with indicators of payroll, revenues, expenditures, awards to academic institutions, occupational distribution, number of employees, employee residence locations, and income taxes paid by NASA Glenn employees. All these indicators illustrate the magnitude of a large research enterprise that provides a significant economic impact on Northeast Ohio and Ohio.

C.1. EMPLOYMENT AND OCCUPATIONS

The total employment of NASA Glenn Research Center includes two components: (1) civil service employees and (2) local contractors. This is common in federal laboratories to hire contracted employees since they allow for more flexibility in performance and labor costs. The number of contracted employees can be easily adjusted, aligning with Glenn's scope of work and new projects. The civil service employment has been relatively constant in order to retain workers with long-term core expertise. These workers are essential for NASA Glenn's operations, and they are retained for many years to secure continuity of research and efficiency of operation. NASA Glenn's civil service employment distribution is made up of four main occupational categories: (1) administrative professionals, (2) clerical staff, (3) scientists and engineers, and (4) technicians.

Table 1 presents the total number of NASA Glenn's civil service employees and the shares of the four categories. Between FY 2015 and FY 2019, the civil service workforce had average employment of 1,563. Over the last five years, Glenn civil service employment peaked in FY 2018 with 1,594 workers. Compared to FY 2018, the total Glenn service employment has decreased by 16 workers, increasing by 12 in the Administrative Professional category and 20 in the Scientists & Engineers category, while decreasing by 16 in the Clerical category and decreasing by 32 in the Technician category.

In FY 2019, NASA Glenn had 1,578 civil service employees, including 347 Administrative Professionals (22%), 16 Clerical workers (1%), 1,136 Scientists & Engineers (72%), and 79 Technicians (5%).

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2015-FY 2019

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
2015	1,563	23%	2%	69%	6%
2016	1,572	22%	2%	71%	5%
2017	1,508	22%	2%	71%	5%
2018	1,594	21%	2%	70%	7%
2019	1,578	22%	1%	72%	5%

Note: Table does not include local contractors.[7]

[7] A detailed listing of NASA Glenn's local contractors can be found at http://www.grc.nasa.gov/WWW/Procure/ContractorList/On-siteServiceContractorListing.htm

In FY 2019, the largest occupational category was Scientists & Engineers. This category has continued to be the largest occupation over the last five years, a historical trend that has continued even before FY 2015. The Scientists & Engineers account for 72% of the civil service employees at NASA Glenn in FY 2019.

The Administrative Professional category was the second-largest occupational group, accounting for 22% of NASA Glenn employees in FY 2019. This category of employment decreased from 23% in FY 2015 to 22% in FY 2019; this is a position that has been held in the last five years.

The number of technicians employed by NASA Glenn has decreased from 6% in FY2015 to 5% in FY2019. Compared to FY 2018, the share of technicians in FY 2019 decreased by 2%.

Over the last five years, the clerical category has maintained the smallest civil service employment category at NASA Glenn and comparatively steady share of NASA Glenn employment, ranging from 1% to 2%, ranging from 16 to 32 employees. The employment of clerical occupation peaked in 2018 with 32 employees (2%), dropping to 16 workers in 2019.

The civil service employees at NASA Glenn are highly educated and skilled; 89% of civil service workers had a bachelor's degree or higher in FY 2019. Of the total NASA Glenn's civil service workforce, 18% held doctoral degrees, 38% held master's degrees, and 33% held bachelor's degrees. Compared to FY 2018, the level of educational attainment of NASA Glenn's civil service employees has increased slightly. The number of workers holding bachelor's degrees or higher increased by 1% over the last two years.[8]

In addition to its own employment, Table 2 displays NASA Glenn on- or near-site contractors' employment over the last five years. NASA Glenn contracted work to 1,676 on- or near-site contractors in FY 2019. The number of contractors has grown between FY 2015 and FY 2019. The contractors had a peak of 1,687 employees in FY 2018, dropping to 1,676 in FY 2019.

The total number of NASA Glenn employees, including both civil service employees and local contractors in FY 2019, was 3,254. This showed a decrease of 27 from FY 2018 to FY 2019. During the last five years, the highest total combined employment was 3,281 in FY 2018, and the lowest was 3,125 in FY 2015.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2015-FY 2019

Fiscal Year	Employment of On- or Near-Site Contractors
2015	1,562
2016	1,625
2017	1,626
2018	1,687
2019	1,676

[8] These counts do not include Student Trainees and Temporary Employees.

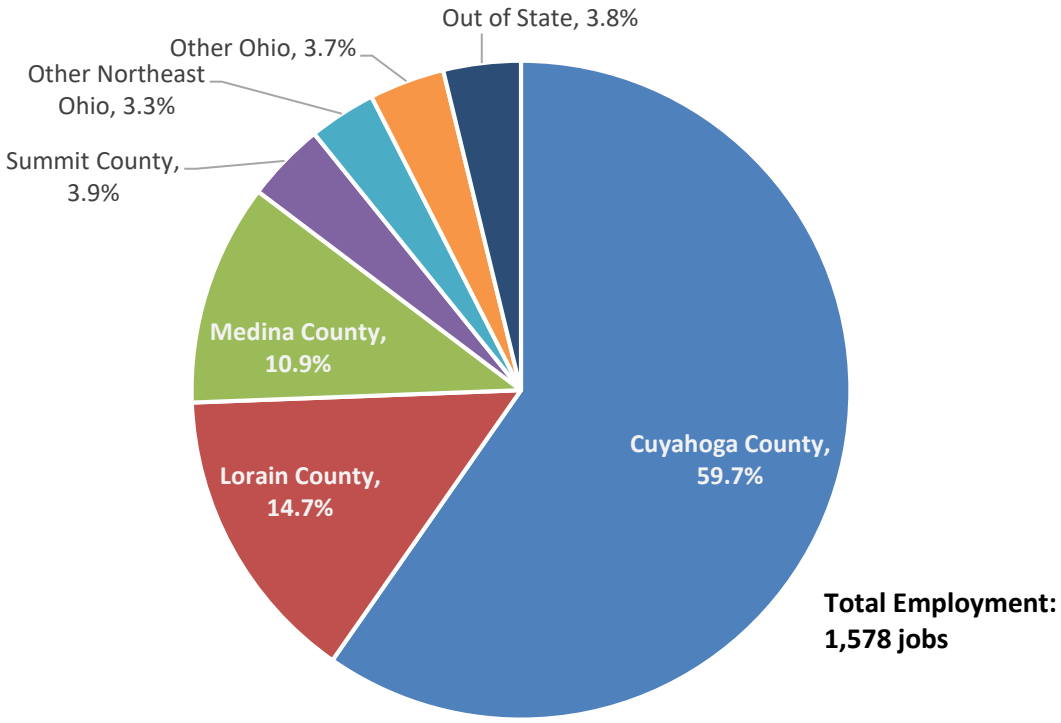
C.2. Place of Residence for Glenn Employees

NASA Glenn Lewis Field is located near Cleveland Hopkins International Airport in Cuyahoga County, the heart of Northeast Ohio. NASA Glenn also operates Plum Brook Station, located near Sandusky, Ohio, in Erie County to the west of Cleveland. Most civil service employees at NASA Glenn live in Cuyahoga County or the other surrounding counties that comprise Northeast Ohio. [9] Figure 1 shows NASA Glenn civil service employees by employees' postal addresses by geographic region. In FY 2019, 92.5% of NASA Glenn's civil service employees resided in Northeast Ohio.

Of the 1,578 total civil servants in FY 2019, 942 employees (59.7%) lived in Cuyahoga County, the same county as NASA Glenn Lewis Field. A significant number of NASA Glenn employees live in Lorain County (232 workers or 14.7%) and Medina County (172 workers or 10.9%). Summit County accounts for 3.9% (or 62 workers), and the other Northeast Ohio counties held 3.3% of NASA Glenn employee places of residence, and another 3.7% lived in Ohio Counties outside of Northeast Ohio. Only 3.8% of NASA Glenn employees resided outside Ohio.

Compared to FY 2018, the percentage of NASA Glenn employees who reside in Cuyahoga County has decreased by 0.6%. The distribution of NASA Glenn employment across regions within and outside of areas of study, Northeast Ohio and Ohio, structurally changed very little between FY 2015 and FY 2019.

Figure 1. NASA Glenn Civil Service Employees by Place of Residence, FY 2019



[9] Northeast Ohio includes Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties.

The places of residence of NASA Glenn civil service employees are shown by their occupations in Table 3. Cuyahoga County, where the NASA Glenn Lewis Field is located, served as the place of residence for the highest share of employees in each occupational category. More than 59.3% of Administrative Professional, 63.1% of Clerical, 60.4% of Scientists & Engineers, and 53.2% of NASA Glenn's Technicians lived in Cuyahoga County in FY 2019. Technicians were the most likely to live in Northeast Ohio, at 98.7%. All Clerical employees (100.0%) lived in Northeast Ohio. Approximately 6% and 8%, respectively of NASA Glenn's Administrative Professional and Scientist & Engineers, were living out of Northeast Ohio. Of the total NASA Glenn civil service employees, Scientists & Engineers were the most likely to live out of state, at 4.9%.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2019

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	94.3%	100.0%	91.7%	98.7%	92.5%
Cuyahoga County	59.3%	63.1%	60.4%	53.2%	59.7%
Lorain County	16.3%	31.6%	13.5%	22.1%	14.7%
Medina County	11.5%	5.3%	10.5%	16.9%	10.9%
Summit County	4.8%	0.0%	3.8%	2.6%	3.9%
Lake County	0.9%	0.0%	1.3%	1.3%	1.2%
Geauga County	0.0%	0.0%	1.3%	1.3%	1.0%
Portage County	1.5%	0.0%	0.9%	0.0%	1.0%
Ashtabula County	0.0%	0.0%	0.0%	1.3%	0.1%
Other Ohio	4.8%	0.0%	3.4%	1.3%	3.7%
Out of State	0.9%	0.0%	4.9%	0.0%	3.8%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

The total compensation NASA Glenn civil service employees received in FY 2019 was $237.4 million. Total compensation included both payroll ($180.6 million) and benefits ($56.8 million).

Total compensation increased $1.7 million (0.7%) between FY 2018 and FY 2019, in nominal dollars.[10] In this same time period, NASA Glenn's nominal payroll has increased by $0.7 million (0.4%). [11] Total compensation increased $9.4 million (4.1%) from $228.0 million in FY 2015 to $237.4 million in FY 2019 [12] , and payroll marginally increased by $3.5 million (2.0%) in nominal dollars[13].

There was a continual increase in employee benefits between FY 2015 and FY 2019. The percent of employee benefits in relation to total compensation has been increasing every year since FY 2015. Benefits were 22.3% ($51.0 million) of total compensation in FY 2015 and 23.9% ($56.8 million) of total compensation in FY 2019 in nominal dollars.[14]

The average wage per civil service employee increased from $112,853 to $114,442 between FY 2018 and FY 2019 (an increase of 1.4%). [15] There was a nominal increase of 1.0% (or $1,145) in total average wage per civil service employee between FY 2015 and FY 2019.[16]

[10] Total real compensation decreased by $0.6 million, or 0.3% between FY 2018 and FY 2019. Inflation for payroll was adjusted using CPI for the Cleveland-Akron-Lorain region).

[11] Total payroll has decreased by $1.0 million (or 0.6%) from 2018 and FY2019, after adjusting for inflation.

[12] In real dollars adjusted for inflation, total compensation increased by $4.1 million (or 1.7%) between FY 2015 and FY 2019.

[13] In real dollars adjusted for inflation, the payroll decreased by $0.6 million or 0.3% over the last five years.

[14] Real benefit was $52.1 million in FY2015.

[15] The average wage per employee in real terms increased 0.4%, or $502 between FY 2018 and FY 2019.

[16] The real average wage per employee slightly decreased by 1.3%, or $1,496 between FY 2015 and FY 2019.

C.4. NASA GLENN EXPENDITURES, FY 2019

In FY 2019, vendors from 46 states, the District of Columbia, Puerto Rico, and nine foreign countries received a portion of NASA Glenn's expenditures. These FY 2019 expenditures totaled $586.5 million, which is 23.6% higher than FY 2018 expenditures, increasing by $112.1 million in nominal dollars. This translates to an increase of $104.8 million (or 21.7%) between FY 2018 and FY 2019 when adjusting for inflation.[17] Between FY 2015 and FY 2019, expenditures increased by 36.4%, representing an increase of $156.4 million in constant 2019 dollars.[18]

The geographic distribution of NASA Glenn's spending during FY 2019 is illustrated in Figure 2. Ohio continues to receive the largest share of the total expenditures, with $308.7 million going to the state vendors in FY 2019. Although there was an increase in total expenditures spent in Ohio between FY 2018 and FY 2019, the share of expenditures to the state decreased from 61.3% in FY 2018 to 52.6% in FY 2019.[19]

Just over 90% of NASA Glenn's total expenditures in the State of Ohio were spent in Northeast Ohio in FY 2019, with the region receiving $279.2 million. Cuyahoga County received the largest share of expenditures spent both within Northeast Ohio and in the State of Ohio, receiving 99.0% and 89.6%, respectively. The county also received the largest share across the entire geographic distribution of NASA Glenn's total expenditures in FY 2019 (47.2%).

California and Washington received the second and third largest shares of NASA Glenn spending in FY 2019. California received $92.6 million (15.8% of total expenditures), and Washington received $46.5 million (7.9% of total expenditures). Notably, expenditures in California increased 484%, or $76.7 million, between FY 2018 and FY 2019 in the nominal dollar. Spending in Washington increased by 13.1% ($5.4 million) across this period. [20]

Alabama and Illinois received the fourth and fifth largest shares of expenditures in FY 2019. Alabama experienced an increase of $8.6 million, or 46.7%, in expenditures between FY 2018 and FY 2019. While Illinois received just 3.2% of NASA Glenn's total expenditures in FY 2019, spending to the state increased by $15.4 million between FY 2018 and FY 2019, or a 473.3% increase in the nominal dollar.[21] (See Appendix Table A.1 for more information on NASA Glenn spending by state.)

NASA Glenn's expenditures in foreign countries increased by 87.6% between FY 2018 and FY 2019. Foreign countries received $1.4 million, or 0.2%, of total spending in FY 2019. Great Britain was the largest beneficiary of the foreign countries that received expenditures. (See Appendix Table A.1 for more information on NASA Glenn foreign country expenditures).

[17] Inflation was adjusted using CPI-US, 251.1 for 2018 and 255.0 for 2019.

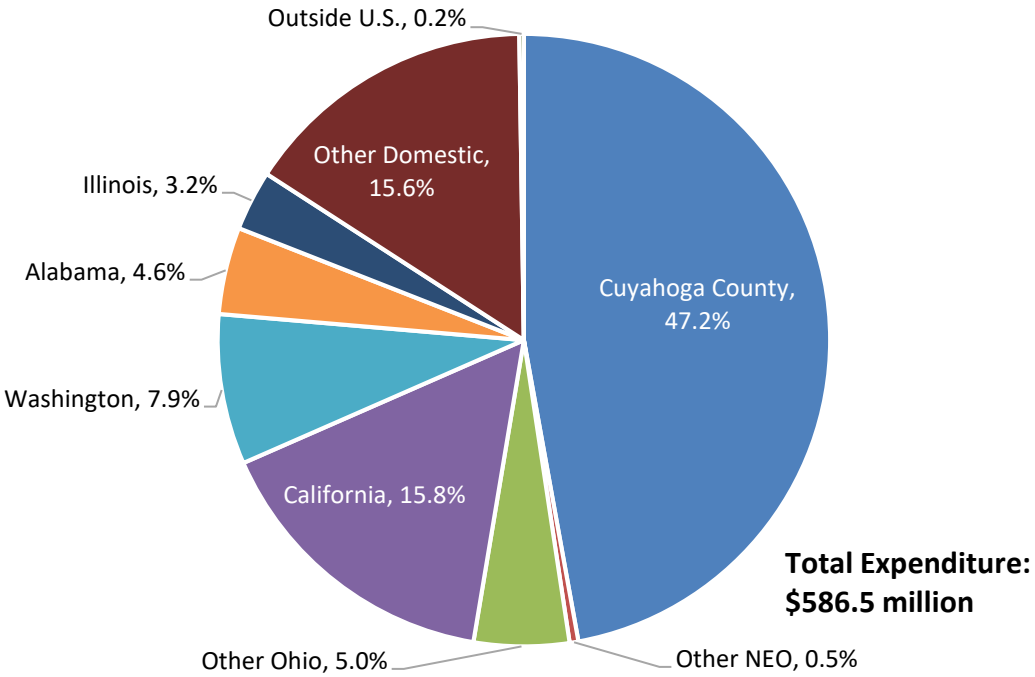
[18] Constant or real dollars is an adjusted for inflation value of currency used to compare dollar values from one period to another.

[19] Total expenditures increased by $18.0 million in nominal dollars and $13.4 million in real dollars adjusted for inflation between FY 2018 and FY 2019.

[20] After adjusting for inflation between FY 2018 and 2019, expenditures in California increased by 475.1% or $76.5, and spending in Washington increased 11.3% or 4.7 million.

[21] Spending in Alabama increased by 44.5% or $8.3 million and in Illinois by 464.7% or $15.3 million in real dollars last two years.

Figure 2. NASA Glenn Spending in Selected Regions, FY 2019



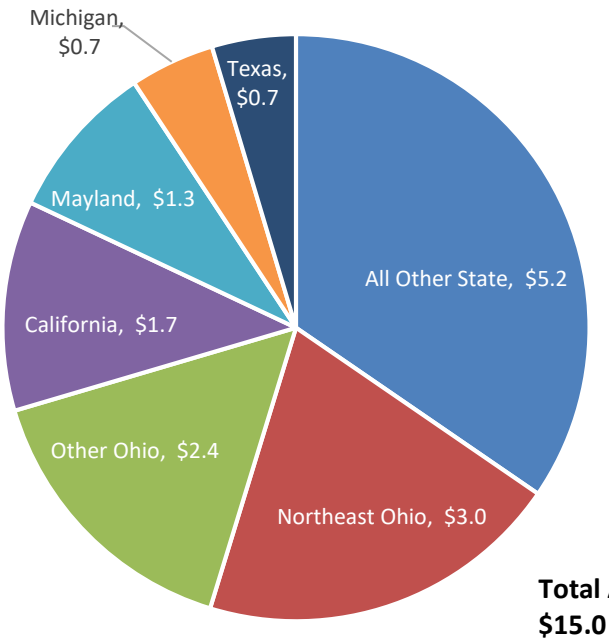
C.5. NASA Glenn Awards to Academic Institutions

NASA Glenn Research Center provides funding to colleges, universities, and other nonprofit institutions in the form of research and development contracts and grants for assisting NASA in their R&D projects. Funding to academic and other institutions is dependent upon NASA Glenn's year-to-year mission and goals.

In FY 2019, NASA Glenn awarded funding that totaled nearly $15.0 million to colleges and universities in 31 states. Grants accounted for $11.0 million of this total. Funding to academic institutions decreased by $1.1 million (6.9%) between FY 2018 and FY 2019, in nominal dollars. NASA Glenn also awarded $4.0 million in contracts to Ohio academic institutions in FY 2019 through on-site contracts.

Figure 3 displays the distribution of funding awarded to colleges and universities with emphases on select states that received a large share of the funding. The academic funding awarded in the top five states – California, Ohio, Maryland, Michigan, and Texas – in FY 2019 accounted for 65.4% of the total awards, compared to 64.8% of total grants made to the top five states during FY 2018. California experienced a 30.1% nominal increase in awards from $1.3 million in FY 2018 to $1.7 million in FY 2019. Maryland and Texas saw large decreases in awards between FY 2018 and FY 2019, losing 29.1% and 21.5%, respectively. Ohio and California saw marginal decreases in awards between these years. (See Appendix Table A.2. for more information).

Figure 3. NASA Glenn Academic Awards to Colleges and Universities, FY 2019 (in millions)



Total Academic Awards: $15.0 million

*Notes: F*igures in nominal dollars
"Other Ohio" refers to colleges and universities located outside the 8-county Northeast Ohio region

Academic institutions in Ohio received $5.4 million in FY 2019, which accounted for the largest share (35.9%) of NASA Glenn's academic awards for the year. NASA Glenn's academic awards to Ohio decreased by 4.6% between FY 2018 and FY 2019. Northeast Ohio received 56.2% of the $5.4 million awarded to all of Ohio, totaling $3.0 million. Northeast Ohio received 20.2% of all academic funding given by NASA Glenn in FY 2019. Northeast Ohio's share of awards increased both at the state level (56.6% of total Ohio awards in FY 2018) and national level (19.8% of total awards in FY 2018).

In FY 2019, California received $1.71 million of NASA Glenn's academic awards. The second only to Ohio, California received 11.6% of the total share. Maryland and Michigan were awarded the third and fourth largest shares overall, receiving $1.30 million (8.7%) and $0.70 million (4.7%), respectively, in funding to colleges and universities.

Table 4 presents the distribution of NASA Glenn awards to academic institutions in the State of Ohio from FY 2015 to FY 2019 (inflated to 2019 dollars).[22] The total amount of funding to Ohio academic institutions decreased by 17.1% between 2015 and 2019, falling from $6.5 million in FY 2015 to $5.4 million in FY 2019, after adjusting for inflation.[23] Total academic funding awarded in Ohio also slightly decreased between FY 2018 and FY 2019, falling by $0.33 million (or 6.2%). FY 2017 is the first year to include both academic grants and contract dollars in the totals.

Of all Ohio academic institutions that received funding, Case Western Reserve University (CWRU) and the University of Toledo were awarded the most in FY 2019. CWRU received just over $2.2 million (41.6% of the total), and the University of Toledo received $1.8 million (32.7% of the total) in FY 2019. For CWRU, this was a $0.34 million or 18.1% increase in funding between FY 2015 and FY 2019. For the University of Toledo, this was a $0.87 million or 33.2% decrease during the last five years (adjusted to 2019 dollars).[24] The two universities accounted for 74.3% of NASA Glenn awards to Ohio academic institutions in FY 2019.

Ohio State University was awarded $480,523 (8.9% of the total) in FY 2019 and received the third-highest share of the total funding to Ohio academic institutions. The University of Akron received $431,278 (8.0%) and ranked fourth. The remainder of the FY 2019 awards from NASA Glenn to Ohio academic institutions went to the Kent State University ($177,019 or 3.3%), Cleveland State University ($162,745 or 3.0%), Ohio University ($75,837 or 1.4%), University of Cincinnati ($38,354 or 0.7%) and Cuyahoga Community College ($15,998 or 0.3%).

[22] The methodology of collecting data for Table 4 has changed since FY 2017. The research team accounted not only for educational awards that were directly given to educational institutions; the total amount of awards also includes contract dollars that were passed to educational institutions through third-party entities.

[23] NASA Glenn decreased its total academic funding in Ohio by 12.2%, from $6.1 million in FY 2015 to 5.4 million in FY 2019 in nominal dollars.

[24] Academic funding awarded to CWRU increased by 25.1% or 0.45 million and to University of Toledo decreased by 29.3% or $0.73 million between FY 2015 and FY 2019 (in nominal dollar)

Table 4. NASA Glenn Total Awards in Ohio by Academic Institution, FY 2015-FY 2019

Ohio Colleges and Universities	FY2015	FY2016	FY2017	FY2018	FY2019	FY2019 Share
Case Western Reserve University	$1,888,893	$1,844,702	$2,420,660	$2,372,413	$2,231,694	41.6%
University Of Toledo	$2,631,524	$2,064,317	$1,920,888	$1,888,976	$1,757,614	32.7%
Ohio State University	$284,105	$372,206	$331,527	$374,895	$480,523	8.9%
The University Of Akron	$825,723	$573,377	$454,384	$447,100	$431,278	8.0%
Kent State University	$21,367	$41,733	$94,633	$135,358	$177,019	3.3%
Cleveland State University	$761,165	$340,876	$176,552	$165,404	$162,745	3.0%
Ohio University	$62,834	$81,745	$132,256	$76,836	$75,837	1.4%
University Of Cincinnati	-	-	$237,703	$135,637	$38,354	0.7%
Cuyahoga Community College	-	$165,900	$137,989	$108,660	$15,998	0.3%
TOTAL	$6,475,610	$5,484,856	$5,906,591	$5,705,279	$5,371,061	100.0%

Notes:
The table is sorted by FY 2019 column.
Data inflated to 2019 dollars (Inflation 237.4 based on CPI for the Midwest region).

C.6. NASA Glenn Revenues

In FY 2019, NASA Glenn's total revenue reached $996.2 million. Without adjusting for inflation, this translates to a 33.7% increase from FY 2018. NASA Glenn's revenues have increased by 48.4% in the last five years, ranging from $671.5 million in FY 2015 to $996.2 million in FY 2019 in nominal dollars.

Table 5 displays NASA Glenn's revenue by source from FY 2015 to FY 2019. NASA Glenn's revenue consists of two sources: NASA's direct authority and reimbursable commitments. Revenue from NASA's direct authority dipped from $624.6 million in FY 2015 to $623.4 million in FY 2016 (a 0.2% decrease) but raised to $655.9 million in FY 2017 (a 5.2% growth). Revenue from NASA's direct authority has continued to increase since FY 2017, with revenue rising to $697.4 million in FY 2018. There was a 33.1% increase in direct authority revenue between FY 2018 and FY 2019, rising from $697.4 million to $928.3 million. In addition to the $928.3 million in direct authority revenue in FY 2019, NASA Glenn also received $67.9 million in reimbursable commitments.

As shown in Table 5 below, reimbursable funding has fluctuated since FY 2015, reflecting the change in non-NASA customers doing business with NASA Glenn in recent years. NASA Glenn's revenues from reimbursable commitments have increased 41.7% in the past year alone, raising nearly $20.0 million from FY 2018 to FY 2019.

In FY 2019, the largest share of the revenue for reimbursable commitment came from federal funding, accounting for 82.5%. The Department of Defense accounted for the largest share of this federal funding in FY 2019, contributing 57.0%. Other Federal Agency accounted for the second-largest share (25.5%). There was a 4.3% decrease in reimbursable commitments from the Department of Defense between FY 2018 and FY 2019, largely attributable to a 3.1% decrease in funding from the U.S. Air Force.

Table 5. NASA Glenn Revenues, FY 2015-FY 2019 (in millions of nominal dollars)

Description	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
NASA Direct Authority	$624.6	$623.4	$655.9	$697.4	$928.3
Total Reimbursable Commitments	$46.9	$40.7	$35.2	$47.9	$67.9
Total FY Authority	$671.5	$664.1	$691.1	$745.3	$996.2
NASA Budget %	93.0%	93.9%	94.9%	93.6%	93.2%

Note: Data in millions of nominal dollars.

C.7. Taxes Paid by NASA Glenn Employees

The economies of both Northeast Ohio and of the state greatly benefit from the taxes paid by NASA Glenn employees. The distribution of income tax paid by employees is affected by NASA Glenn's Cleveland, Brook Park, and Fairview Park locations.

Table 6 shows the amount of income taxes NASA Glenn employees paid at the local, state, and federal levels. The table excludes taxes paid by NASA Glenn employees to local governments based on their place of residence. In FY 2019, the total income tax paid by NASA Glenn employees totaled $31.9 million. This is a slight decrease (0.2%) compared to FY 2018.

NASA Glenn employees paid $9.4 million in income taxes at the state and local levels in FY 2019. This is a 3.2% increase from FY 2018, without adjustment for inflation. The amount of taxes paid to local and state governments has increased steadily over the past four years, rising from $8.8 million in FY 2016 to $9.4 million in FY 2019.

The city of Brook Park and the State of Ohio received the majority (99.6%) of the taxes paid at the state and local levels in FY 2019. In FY 2019, 62.2% of the income taxes at the state and local levels went to the State of Ohio, totaling $5.9 million. Since 2015, NASA Glenn employees have paid an annual average of $5.7 million in income taxes to the State of Ohio.

The city of Brook Park received $3.5 million in income tax from NASA Glenn employees in FY 2019, representing a marginal increase (4.9%) compared to FY 2018. This accounts for 98.9% of the income taxes paid to the cities of Cleveland, Brook Park, and Fairview Park by NASA Glenn employees in FY 2019, at a total of $3.5 million. The taxes allocated to the city of Brook Park increased by 6.0% between FY 2015 and FY 2019. The city of Cleveland saw a notably high increase in income tax between FY 2015 and FY 2019; although the dollar amounts received were low compared to the city of Brook Park, income tax paid to Cleveland increased 44.7% in this 5-year span. NASA Glenn employees paid $14,046 in income taxes to the city of Cleveland, or an increase of 16.7% when compared to FY 2018.

Table 6. Income Taxes Paid by NASA Glenn Employees

Year	City of Brook Park	City of Cleveland	City of Fairview Park	State of Ohio	Federal	Total
2015	$3,323,048	$9,706	$27,596	$5,671,062	$24,038,165	**$33,069,577**
2016	$3,303,850	$10,107	$26,636	$5,498,587	$24,070,576	**$32,909,756**
2017	$3,322,949	$10,106	$24,514	$5,588,849	$24,497,919	**$33,444,336**
2018	$3,357,770	$12,039	$22,718	$5,749,268	$22,685,203	**$31,826,998**
2019	$3,522,660	$14,046	$26,332	$5,869,450	$22,467,112	$31,899,600
5-Year Total	**$16,830,277**	**$56,004**	**$127,796**	**$28,377,216**	**$117,758,975**	**$163,150,267**

D. ECONOMIC IMPACT OF NASA GLENN

This section describes the methodology and illustrates the results of research estimating the economic impact NASA Glenn had on Northeast Ohio and the State of Ohio in FY 2019.[25] The economic impact is measured in terms of output (sales), employment, value added, household earnings, and taxes contributed to local, state, and federal governments.

Each of the economic impact categories includes three types of impact: direct, indirect, and induced.[26] NASA Glenn's total impact on Northeast Ohio and the State of Ohio are presented as separate estimates.

D.1. METHODOLOGY

The main assumption to estimate NASA Glenn's economic impact is that NASA Glenn established its operations in the region at the beginning of FY 2019 and generated demand by purchasing goods and services for its operations from vendors located in Northeast Ohio and Ohio.

This new demand for goods and services is called "change in final demand," which represents the direct impact NASA Glenn spending has on the economy. [27] The initial NASA's expenditures (i.e., change in final demand) in the region result in economic impacts on both Northeast Ohio and Ohio. This study uses an input-output model that reflects the buy-sell relationships among all industry sectors within the region of study.

NASA Glenn purchases goods and services as intermediate inputs in the process of its research and development activities, which creates a direct impact. The assessment of intermediate goods purchasing is represented in the indirect portion of the economic impact.

Indirect impact measures the value of labor, capital, and other inputs of production needed to produce the goods and services that serve as the supplies required by NASA Glenn for its operation.

Additionally, the economic impact is assessed from the spending patterns of both NASA Glenn employees and employees of NASA Glenn's suppliers. This tertiary impact is reflected in the induced effects of the overall economic impact assessment. The induced impact measures local households' change in spending due to earnings by NASA Glenn employees and increased earnings of employees in local industries who produce goods and services for NASA Glenn and its suppliers.

To calculate direct value added and assess NASA Glenn's spending pattern and its multipliers, the institution is treated as a research and development industry. This makes the intermediate expenditure pattern of NASA Glenn similar to that of other comparable research institutions in the area.

Economic impact analysis accounts for inter-industry buy-sell relationships within the respective economy of the research area (Northeast Ohio or Ohio). These relationships determine how the economy responds to changes in buying and selling patterns among industries. Input-output (I-O) models estimate

[25] For this analysis, Northeast Ohio is delineated by eight counties: Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit.

[26] The change in final demand is the direct economic impact created by NASA Glenn in Northeast Ohio and Ohio.

[27] Change in final demand, or direct impact, is defined as the total purchases of goods and services for NASA Glenn's overall operations.

inter-industry relationships at the county, regional, state, or country level by measuring the distribution of inputs purchased and outputs sold by each industry, the government sector, and the household sector. By using I-O models' multipliers, it is possible to estimate the specific impact of one additional dollar spent by or one additional employee hired for NASA Glenn. This impact continues, creating additional expenditures and jobs. The economic multiplier measures the extent to which an initial expenditure affects the regional economy.[28]

This study utilizes regional I-O multipliers from the IMPLAN Professional model.[29] Specifically, SAM multipliers are used to estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.[30] Multi-Regional Input-Output (MRIO) analysis makes it possible to track how an impact on any of the 536 IMPLAN Industries in a Study Area region (i.e., NEO or Ohio) affect the production of all 536 Industries and household spending in these regions.[31]

For this study, we used the "bill of goods" method and applied it to industry change. We match each category of NASA Glenn's expenditures to the industry from which it purchases products. This technique enables the research to match goods and services purchased by NASA Glenn to goods and services produced by different industries in the region in question.

When estimating regional economic impact three factors need to be addressed: (1) the exclusion of purchases from companies located outside of the study's region, (2) how expenditures made in NEO create economic impact in NEO and Ohio, and how expenditures made in the remainder of Ohio create an economic impact on NEO and on the remainder of Ohio, and (3) what amount of revenues are received from local sources. For this analysis, NASA Glenn's economic impact on the Northeast Ohio economy is exclusively generated from purchases of goods produced by companies located in Northeast Ohio. Therefore, when estimating the impact on Northeast Ohio, the model excluded goods and services purchased from businesses and other entities located outside of the 8-county region. However, the model also accounts for the economic impact that purchases made in the remainder of Ohio (outside NEO) create on NEO through the supply-chain of Ohio companies located in NEO.

Following the same methodology, the economic impact on the State of Ohio is assessed from NASA Glenn purchases of goods and services produced only by companies located in Ohio. Likewise, all goods and services purchased from businesses and entities located outside of the state were

[28] For example, suppose that Company "A" reports sales of $1 million. From the revenues, the company pays its suppliers and workers, covers production costs, and takes a profit. Once the suppliers and employees receive their payments, they will spend a portion of their money in the local economy purchasing goods and services, while another portion of the monies will be spent outside the local economy (leakage). By evaluating the chain of local purchases that result from the initial infusion of $1 million, it is possible to estimate a regional economic multiplier.

[29] IMPLAN (IMpact analysis for PLANning) was originally developed by two federal agencies, the Department of Agriculture and the Department of the Interior, to assist in land and resource management planning. The Minnesota IMPLAN Group Inc. later commercialized the model as a software package. The company was then sold and rebranded as IMPLAN Group LLC.

[30] IMPLAN type SAM (Social Accounting Matrices) multipliers are used in this study. SAM multipliers are based on information in a social account matrix that considers commuting, institutional savings, inter-institutional transfers, and social security and income tax leakages.

[31] MRIO: Considerations when using Multi-Regional Input-Output Analysis. https://implanhelp.zendesk.com/hc/en-us/articles/115009713348-MRIO-Considerations-when-using-Multi-Regional-Input-Output-Analysis

excluded when estimating the statewide impact of NASA Glenn.

IMPLAN measures economic impact using five variables: employment, labor income, value added, output, and taxes:

- Employment impact measures the number of jobs created in the region as a result of NASA Glenn expenditures.
- Labor income impact measures the additional labor earnings created in the region due to NASA Glenn expenditures.
- Value added impact measures the additional value added created in the region as a result of NASA Glenn expenditures. Value added is calculated as output less the value of intermediary goods.[32]
- Output impact measures the additional value of all goods and services produced in the region as a result of NASA Glenn expenditures.
- Tax impact measures the additional federal, state, and local tax revenues collected in the region as a result of NASA Glenn expenditures.

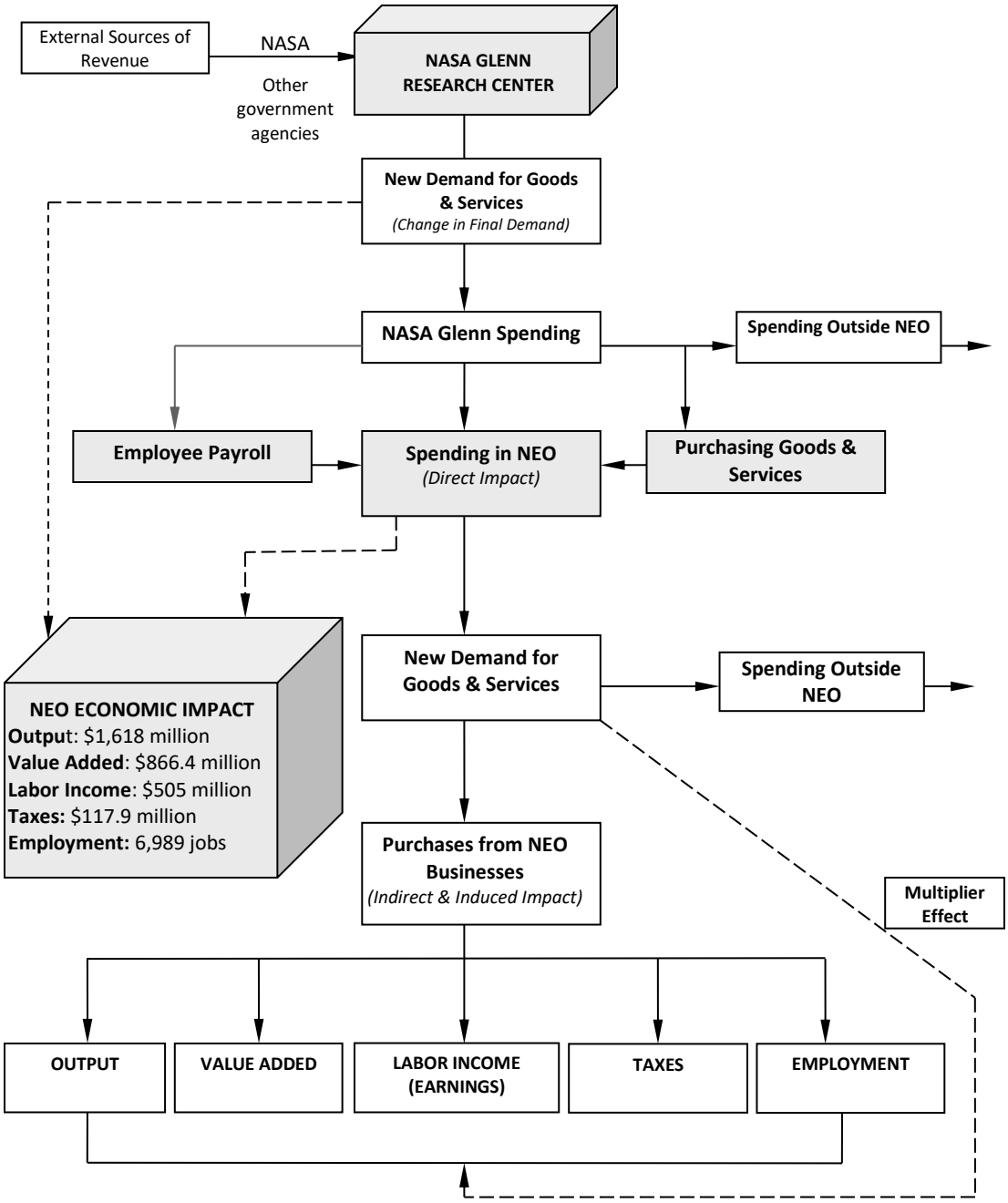
The employment, labor income, value added impact, and output impact are each a summation of three components: direct impact, indirect impact, and induced impact.[33] Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio's economy through its spending in the region in FY 2019.

Through its attraction of federal dollars external to NEO and Ohio economies, NASA Glenn created new demand for goods and services (change in final demand, which is also treated as a direct impact). Some of this demand was generated for goods and services provided by vendors outside Northeast Ohio and Ohio, resulting in dollars leaving the regional and state economies. However, most goods and services necessary for NASA Glenn operations were purchased locally.

[32] Intermediary goods and services—such as energy, materials, and purchased services—are purchased for the production of other goods and services rather than for final consumption.

[33] The summation of direct, indirect, and induced impacts across industries in the impact tables (Tables 7-14) and following figures may reflect rounding discrepancies created by multiple iterations of IMPLAN modeling. According to IMPLAN, discrepancies of up to 3% are due to rounding during multiple iterations of data calculations in the model.

Figure 4. Economic Impact of NASA Glenn Research Center on Northeast Ohio, FY 2019



D.2. Economic Impact on Northeast Ohio, FY 2019

This section illustrates the economic impact of NASA Glenn on the economy of Northeast Ohio in FY 2019. The economic impact is measured by the changes in output (sales), employment, labor income (earnings), value added, and federal, state, and local tax revenues paid and generated by Glenn activities.

D.2.1. Output Impact on Northeast Ohio, FY 2019

NASA Glenn's expenditures were divided into three brackets of spending: (1) goods and services purchased from companies and institutions located in Northeast Ohio, (2) spending for goods and services from businesses and other institutions located outside Northeast Ohio but still in Ohio (we called this region Remainder of Ohio), and (3) spending outside of Ohio. The first and second groups of spending create an economic impact on the economy of Northeast Ohio, while the third group is considered a regional leakage (or loss). While the second group of purchases made to companies located in the Remainder of Ohio does not affect NEO directly, the economic impact is created through the multiple chains of suppliers located within NEO and selling their product to the companies located in the Remainder of Ohio. The regional leakages – purchases made outside of Ohio - are not included in calculating the output impact on Northeast Ohio. Local spending is then categorized by products purchased from different industries in the regional economy, based on an IMPLAN industry classification system that differentiates spending across 546 sectors. IMPLAN sectors are similar to the description of industries used in the North American Industry Classification System (NAICS) but do not fully correspond to the NAICS system. Appendix Table A.3. provides detailed NASA Glenn expenditures in Northeast Ohio by industry.

About 45% of NASA Glenn's total expenditures in Northeast Ohio went towards employee compensation. NASA Glenn's largest expenditures on goods and services in Northeast Ohio in FY 2019 were made on professional, scientific, and technical services (33.1%), including about 20.8% of total expenditures on scientific research and development services. NASA Glenn's spending in Northeast Ohio has a significant regional economic impact.

Table 7 illustrates the total output impact of NASA Glenn on the economy of Northeast Ohio, detailed by economic sectors. This output is comprised of direct impacts, indirect impacts, and induced impacts. NASA Glenn's total operational expenditures represent direct output impact for Northeast Ohio, including the regional margin of purchases from the retail industry. The indirect impact is estimated by summing the contributions of individual industries that provide to the producers of the goods and services that are ultimately consumed by NASA Glenn. Induced impact is derived from measuring the spending of employees as a result of the demand for products and services created by Glenn. Induced impact is calculated by measuring the spending of employees as a result of the demand for products and services created by NASA Glenn. The total output impact is derived by summing the change in final demand (direct impact), indirect impact, and induced impact.

Table 7. Output Impact in Northeast Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$108,450	$241,885	$350,335
Mining		$1,000,698	$647,979	$1,648,677
Utilities		$13,288,048	$7,370,441	$20,658,489
Construction		$29,508,582	$3,424,462	$32,933,044
Manufacturing		$6,584,559	$6,001,028	$12,585,587
Wholesale Trade		$7,291,305	$16,477,700	$23,769,006
Retail Trade		$3,739,027	$30,825,135	$34,564,162
Transportation and Warehousing		$5,852,588	$9,747,175	$15,599,763
Information		$8,932,486	$14,519,439	$23,451,925
Finance and Insurance		$10,775,110	$50,672,762	$61,447,872
Real Estate and Rental		$22,037,911	$61,096,039	$83,133,950
Professional, Scientific, and Tech Services		$211,174,219	$18,478,125	$229,652,344
Management of Companies		$9,052,279	$5,559,619	$14,611,898
Administrative and Waste Services		$85,306,342	$11,780,941	$97,087,282
Educational Services		$11,696,115	$5,389,438	$17,085,553
Health and Social Services		$1,605,696	$64,145,381	$65,751,077
Arts, Entertainment, and Recreation		$662,150	$6,845,903	$7,508,053
Accommodation and Food Services		$3,754,366	$19,147,696	$22,902,062
Other Services		$3,802,521	$21,232,928	$25,035,448
Government & non-NAICs	$823,876,339	$1,568,142	$3,215,873	$828,660,353
Total Output	**$823,876,339**	**$437,740,594**	**$356,819,949**	**$1,618,436,882**

Notes: For output impact, the change in final demand or direct impact ($823,876,339) equals the total spending of NASA Glenn for goods and services in and outside of Northeast Ohio, including wages and benefits with minor discrepancies due to IMPLAN rounding errors. The results of the economic impact are shown in 2019 dollars.

The total output impact of NASA Glenn on Northeast Ohio was $1.6 billion in FY 2019. NASA Glenn's spending of $823.9 million resulted in an output (sales) change of $1.6 billion across all industry sectors (Table 7). For example, Glenn spending caused a $229.7 million increase in total sales (direct, indirect, and induced) by the Professional, Scientific, and Technical Services industry and a $12.6 million increase in sales by the Manufacturing industry. NASA Glenn was also responsible for a $97.1 million increase in total sales by the Administrative and Waste services industry. If NASA Glenn did not exist in Northeast Ohio, the region would lose the output generated by its spending. The three given examples illustrate the idea that the regional impact of NASA Glenn's operation can be best described as the increase in output of affected industries in comparison to the *hypothetical* absence of NASA Glenn in Northeast Ohio.

Of the total output impact, 50.9% ($823.9 million in 2019 dollars) is accounted for by NASA Glenn's direct spending, which constitutes the direct economic impact to Northeast Ohio. Approximately $437.7 million (27.0%) of the total output impact is a result of indirect spending by NASA Glenn. The remaining output impact of $356.8 million (22.0%) is attributed to the induced impact from NASA Glenn purchases rippling through the regional economy.

Further analysis of the IMPLAN model's results indicated that the indirect and induced portions of the economic impact (totaled $794.6 million, or 49.1% of total output) could be divided into three broad categories: NASA Glenn-driven industries, consumer-driven industries, and other industries.

NASA Glenn-driven industries are those that increase sales, employment, and earnings primarily, but not exclusively, due to NASA Glenn's operations. They include utilities; construction; information; professional and scientific services; administrative and waste services; and education services. The total increase in output due to indirect and induced economic impacts from the aforementioned industries in FY 2019 was $420.9 million or 53.0% of NASA Glenn's overall indirect and induced impact on Northeast Ohio.

Consumer-driven sectors are those that increase sales, employment, and earnings primarily due to spending by Glenn employees and other workers who produce goods and services for NASA Glenn and their suppliers. These industries include other real estate; hospitals; monetary authorities and depository credit intermediation; insurance carriers, except direct life; offices of physicians, and other consumer-driven industries (see figure 6). The increase in output due to indirect and induced economic impacts for these five industries in FY 2019 was $111.6 million or 44.2% of the total impact.

Other industries are driven by both NASA Glenn and consumer spending, and their impact is split between NASA Glenn and consumer spending, they should not be attributed to NASA Glenn operations only. These industries include: mining; manufacturing; agriculture; government enterprises; wholesale trade; and transportation and warehousing. The total increase in output due to indirect and induced economic impacts for these industries in FY 2019 was $121.6 million or 15.3% of the total impact.

The output distributions for select Glenn- and consumer-driven industries are shown in Figures 5 and 6, respectively. In figure 5, industries with additional sales of at least $19 million, or 4.0% of the total sale, were selected to be presented. Industries with additional sales of at least $11 million (4.0%

of total) were selected to be presented in figure 6.

The scientific research and development services industry generated the largest output in FY 2019, increasing by $120.9 million due to NASA Glenn's operations (Figure 5). This amount is the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn's spending on research services. The increase of $120.9 million represented 29% of the $420.6 million increase in output for all NASA Glenn-driven industries. Other industries shown in Figure 5 can be interpreted in a similar manner.

Figure 6 presents the consumer-driven industries of the economy that saw the largest increases in sales. Of these consumer-driven industries, the real estate industry saw the largest increase in sales (by $33.9 million). This amount is the summation of the indirect and induced impacts generated primarily by NASA Glenn employees and other workers for rental activities. The increase of $33.9 million accounted for 13% of the $252.4 million increase in output for all consumer-driven industries.

Figure 5. Increase in Sales for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2019

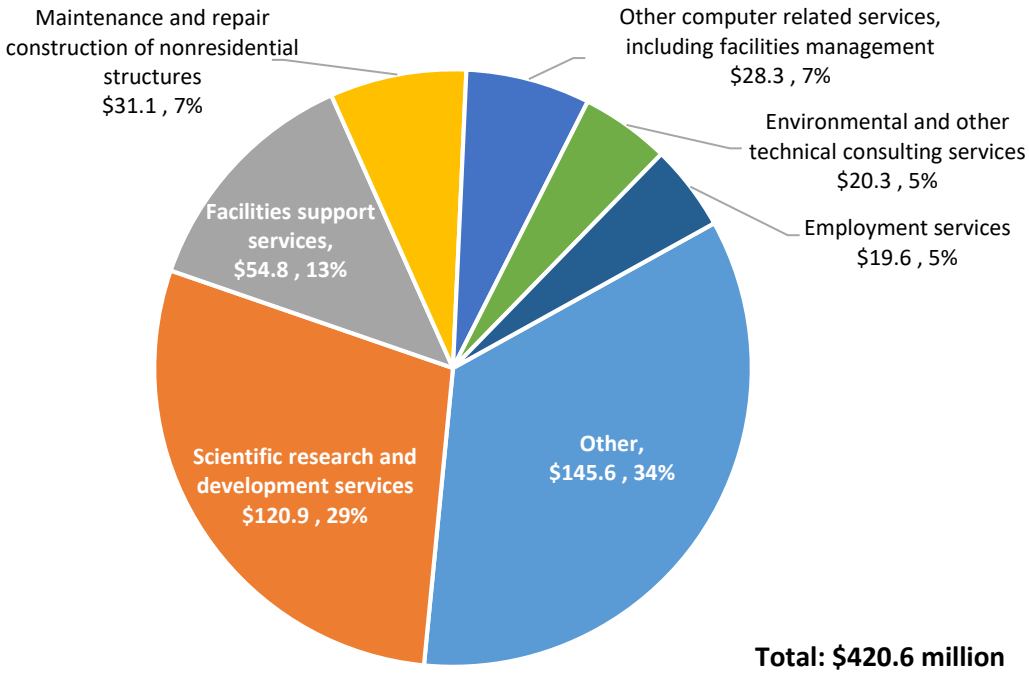
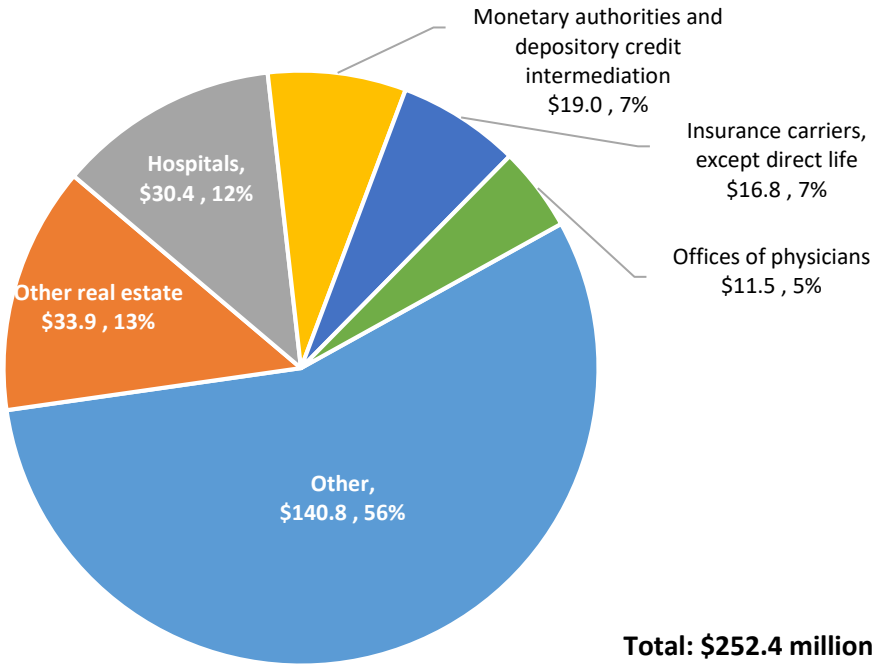


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2019



Total: $252.4 million

D.2.2. Employment Impact on Northeast Ohio, FY 2019

In addition to its own employment (direct impact), NASA Glenn's presence in Northeast Ohio has supported and created new full-time and part-time jobs outside of NASA Glenn. FY 2019 spending resulted in retained workers in NASA Glenn directly and increased employment in its supplier industries (indirect impact).

In addition, money spent by NASA Glenn employees as well as by employees of companies with which NASA Glenn does business created jobs in various other industries (induced impact). The total employment impact equals the sum of NASA Glenn's employment (direct impact) and the indirect and induced components. Table 8 shows the number of jobs supported and created by the industry sector.

Table 8. Employment Impact in Northeast Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		4	6	9
Mining		2	1	3
Utilities		26	7	33
Construction		190	17	206
Manufacturing		21	15	36
Wholesale Trade		23	52	76
Retail Trade		41	335	376
Transportation and Warehousing		44	76	120
Information		19	33	53
Finance and Insurance		26	168	194
Real Estate and Rental		112	118	230
Professional, Scientific, and Tech Services		1,167	114	1,282
Management of Companies		43	27	70
Administrative and Waste Services		855	137	992
Educational Services		339	90	430
Health and Social Services		18	544	562
Arts, Entertainment, and Recreation		13	73	86
Accommodation and Food Services		59	284	343
Other Services		43	254	297
Government & non-NAICs	1,578	5	10	1,593
Total Employment	**1,578**	**3,050**	**2,361**	**6,989**

Notes: For employment impact, the change in final demand (direct impact) equals the number of employees working for NASA Glenn.

Employment in Northeast Ohio increased by 6,989 employees in FY 2019 due to NASA Glenn's spending. Of these jobs, 1,578 (22.6%) were directly employed at NASA Glenn. New jobs were also created as a result of NASA Glenn's indirect economic impact. This spending on goods and services caused an additional 3,050 full-time and part-time jobs (43.6%) in NEO. The remaining 2,361 (33.8%) new jobs were created as induced impact due to purchases made by NASA Glenn and suppliers' employees. These industries produce products that are typically within a consumer purchasing pattern of the region.

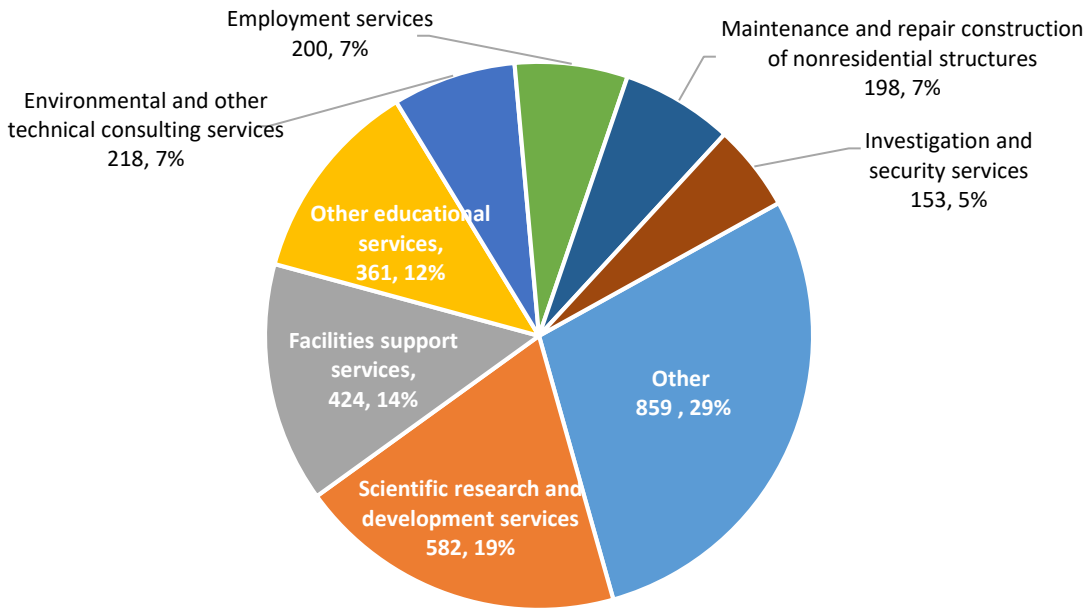
Of the 5,411 jobs created and supported in Northeast Ohio due to the indirect and induced impacts, 2,995 (55.4%) were found in the NASA Glenn-driven industries, 1,922 (35.5%) were in the consumer-driven industries, and 493 (9.1%) were in other industries.[34] The job distribution for select NASA Glenn and consumer-driven industries are shown in Figure 7 and 8, respectively. The industries displayed in Figures 7 and 8 have the highest increases in employment, with a minimum of 150 employees (or over 5.0%) per sector in Figure 7 and a minimum of 59 (or over 3.1%) in Figure 8.

NASA Glenn's scientific research and development service industry generated the largest number of additional jobs among NASA Glenn-driven industries. Companies engaged in scientific R&D saw an increase of 582 jobs in FY 2019 due to NASA Glenn's operation in Northeast Ohio (Figure 7). These jobs equal the total of direct, indirect, and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in Northeast Ohio's R&D contractors' sector. The 582 R&D jobs accounted for just over 19% of the 2,995 NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted in a similar manner.

Of all consumer-driven industries, the real estate industry saw the largest increase in jobs; the industry saw an increase of 182 jobs in FY 2019 as a result of NASA Glenn's spending (Figure 8). These jobs are the summation of the indirect and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in the Northeast Ohio real estate sector. The 182 jobs represent just over 9% of the 1,922 jobs created across all consumer-driven industries.

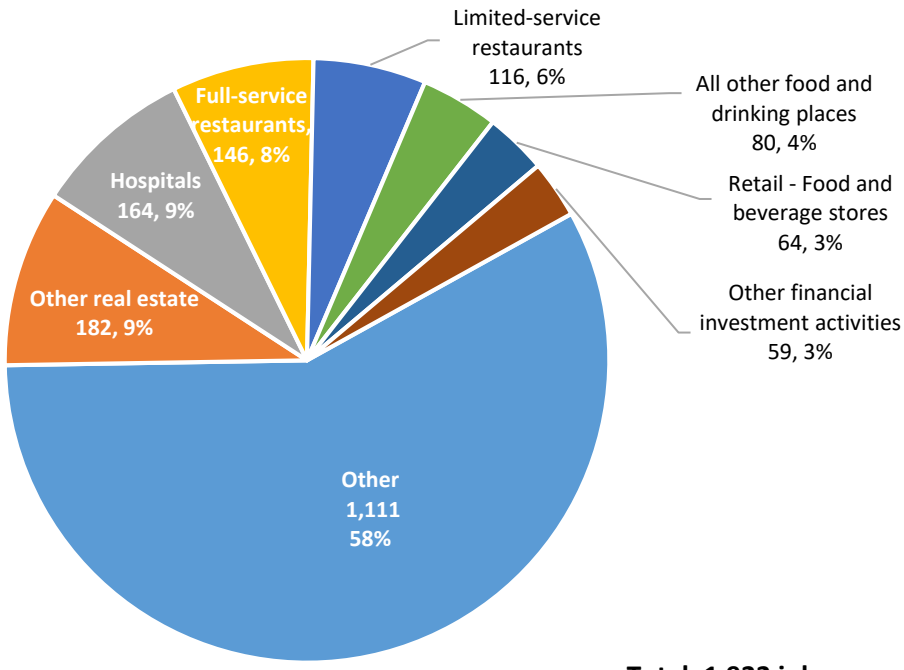
[34] NASA Glenn-driven industries include utilities, construction, information, education, professional and scientific services, and administrative and support services. Consumer-driven industries include retail, healthcare, real estate, other services, owner-occupied buildings, and finance and insurance.

Figure 7. Increase in Jobs for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2019



Total: 2,995 jobs

Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2019



Total: 1,922 jobs

D.2.3. Labor Income Impact on Northeast Ohio, FY 2019

Labor income impact is described as the estimated earnings received by NASA Glenn employees and the change in earnings of employees of its supply chain companies in Northeast Ohio due to NASA Glenn's spending on goods and services in the region. Wages and benefits paid to NASA Glenn employees and to other suppliers of goods and services represent the direct earnings impact. The indirect impact is estimated by totaling the wages and benefits paid to those who work for companies that provide inputs to producers of the goods and services consumed by NASA Glenn.

Induced impact is defined as the wages and benefits paid to employees across all industries that are selling their products to employees of NASA Glenn and employees of the NASA Glenn suppliers. The total earnings impact includes the wages and benefits received by NASA Glenn employees (change in final demand), indirect, and induced impacts. Table 9 displays the earnings impact by industry sector.

Table 9. Labor Income Impact in Northeast Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$55,062	$79,791	$134,853
Mining		$505,561	$64,533	$570,094
Utilities		$1,840,699	$884,007	$2,724,705
Construction		$10,136,774	$1,022,465	$11,159,239
Manufacturing		$1,490,077	$978,772	$2,468,849
Wholesale Trade		$2,212,412	$4,985,984	$7,198,396
Retail Trade		$1,380,854	$11,411,122	$12,791,975
Transportation and Warehousing		$2,573,709	$4,351,186	$6,924,895
Information		$1,644,363	$2,708,033	$4,352,396
Finance and Insurance		$2,202,772	$10,909,099	$13,111,871
Real Estate and Rental		$2,194,679	$2,431,964	$4,626,642
Professional, Scientific, and Tech Services		$85,543,274	$9,456,196	$94,999,470
Management of Companies		$5,502,620	$3,379,532	$8,882,153
Administrative and Waste Services		$30,272,422	$5,583,060	$35,855,481
Educational Services		$6,651,706	$3,336,450	$9,988,156
Health and Social Services		$766,903	$34,045,857	$34,812,761
Arts, Entertainment, and Recreation		$300,647	$2,706,855	$3,007,502
Accommodation and Food Services		$1,503,644	$6,715,925	$8,219,569
Other Services		$2,384,985	$10,852,507	$13,237,492
Government & non-NAICs	$228,586,949	$469,114	$965,971	$230,022,034
Total Labor Income	**$228,586,949**	**$159,632,278**	**$116,869,307**	**$505,088,534**

Notes: Labor income constitutes economic impact through households of NASA employees and those affected by NASA operations throughout the economy.
The economic impact is shown in 2019 dollars.

Total labor income in Northeast Ohio increased by $505.1 million as a result of NASA Glenn spending in FY 2019. Of this total, $228.6 million (45.3%) was made up of wages and benefits paid directly to NASA Glenn employees (i.e., the direct effect measured in 2019 dollars). The indirect impact, or the wages and benefits paid to employees if companies in Northeast Ohio who supply goods and services to NASA Glenn, represented $159.6 million (31.6%) of the total amount. The remaining labor income impact is represented by the induced impact of $116.9 million (23.1%). This impact comes from the spending of both NASA Glenn and suppliers' employees made in industries throughout the regional economy.

Of the $276.5 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, $159.0 million (57.5%) was reported in NASA Glenn-driven industries, $85.4 million (30.9%) was generated in consumer-driven industries, and $32.0 million (11.6%) was reported in other industries.[35]

The labor income distribution for select NASA Glenn-driven and consumer-driven industries are shown in Figures 9 and 10, respectively. Selected industries that added over $8.0 million (5.0%) are displayed in Figure 9, and industries that added over $2.5 million (3.0%) are displayed in Figure 10.

Within NASA Glenn-driven industries, those who were engaged in scientific research and development services saw their labor income increase by $41.8 million in FY 2019 (Figure 9). These earnings are the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn using scientific research and development services in Northeast Ohio. The $41.8 million spent on scientific R&D represents 26% of the $159.0 million total increase in labor income reported by all the NASA Glenn-driven industries in FY 2019.

Of all consumer-driven industries, private hospitals saw the largest increase of earnings in FY 2019. Earnings in this industry totaled $14.0 million, making up 16% of the $85.4 million consumer-driven total. These earnings are a result of totaling the indirect and induced impacts that are generated by consumer spending on doctors' services.

[35] See section D.2.1. Output Impact on Northeast Ohio for definitions of Glenn-driven, consumer-driven, and other industries.

Figure 9. Increase in Labor Income for NASA Glenn-Driven Industries in Northeast Ohio, FY 2019

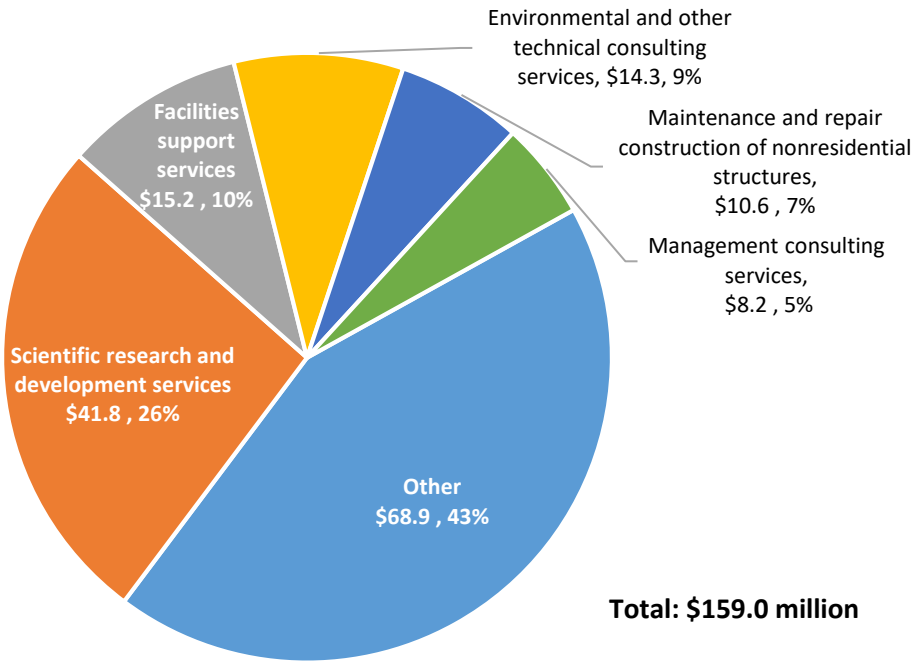
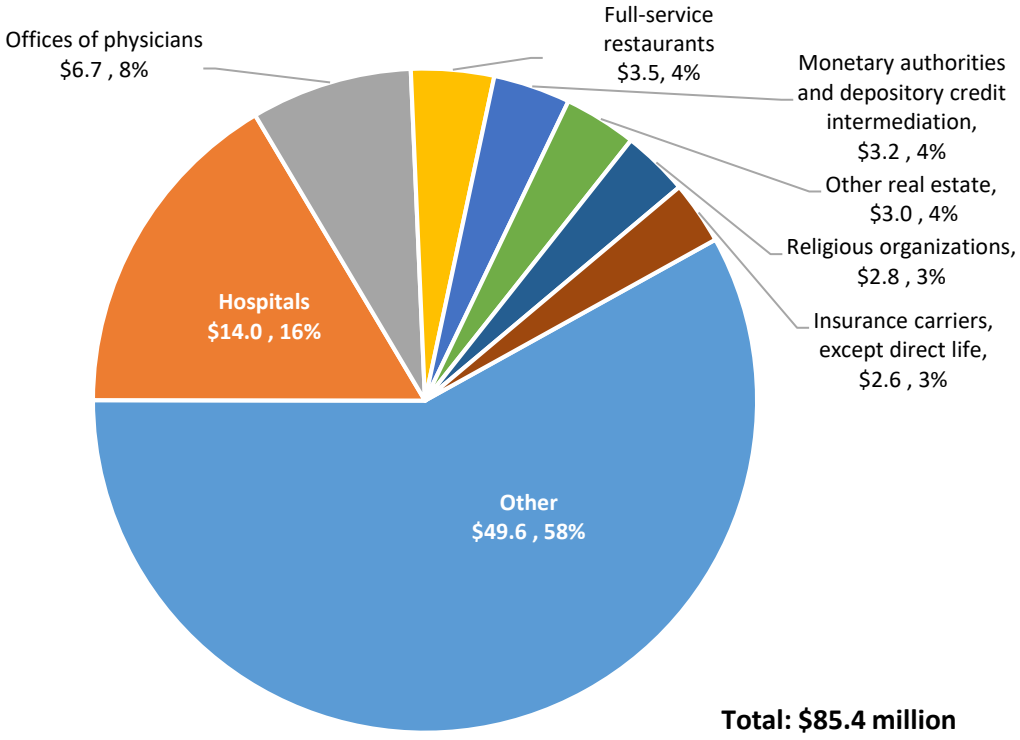


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2019



D.2.4. Value Added Impact on Northeast Ohio, FY 2019

The total value added[36] impact in Northeast Ohio was $866.4 million in FY 2019. This total resulted from NASA Glenn's regional spending on goods and services. NASA Glenn spending led to an $866.4 million increase in sales (direct, indirect, and induced impacts) by all industries, excluding intermediary goods and services. The total output excluding intermediate expenditures constituted the change in final demand (or direct impact) for value added - $436.7 million in FY 2019. The sales from companies and other suppliers of goods and services to NASA Glenn, excluding the value for intermediary goods and services, represented the indirect value added impact.

Induced impact represents the sales (excluding intermediary goods and services) in all industries that produced products for the consumption of employees of NASA Glenn and employees of its suppliers through regular household spending. Total value added impact was found by summing the direct, indirect, and induced impacts. Table 10 displays the value added impact by the industry sector.

[36] "Value added" measures the economic impact of all goods and services produced in Northeast Ohio because of the operation of NASA Glenn, excluding intermediary goods which are goods used in the production of other goods and not for final consumption.

Table 10. Value Added Impact in Northeast Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$54,387	$72,904	$127,292
Mining		$687,414	$329,164	$1,016,578
Utilities		$6,198,259	$3,257,597	$9,455,856
Construction		$13,119,985	$1,394,447	$14,514,432
Manufacturing		$2,467,521	$1,902,011	$4,369,533
Wholesale Trade		$4,198,733	$9,505,912	$13,704,645
Retail Trade		$2,438,554	$18,976,475	$21,415,029
Transportation and Warehousing		$2,882,085	$4,836,583	$7,718,668
Information		$4,118,026	$7,068,103	$11,186,129
Finance and Insurance		$6,661,027	$25,623,541	$32,284,568
Real Estate and Rental		$8,955,542	$42,575,663	$51,531,205
Professional, Scientific, and Tech Services		$109,148,928	$11,983,398	$121,132,325
Management of Companies		$6,293,664	$3,865,366	$10,159,029
Administrative and Waste Services		$40,839,498	$7,000,967	$47,840,465
Educational Services		$6,255,580	$3,563,828	$9,819,408
Health and Social Services		$900,668	$38,450,504	$39,351,172
Arts, Entertainment, and Recreation		$431,690	$4,551,324	$4,983,014
Accommodation and Food Services		$2,107,045	$9,887,317	$11,994,361
Other Services		$2,633,264	$12,072,442	$14,705,706
Government & non-NAICs	$436,654,460	$791,391	$1,597,214	$439,043,065
Total Value Added	**$436,654,460**	**$221,183,260**	**$208,514,760**	**$866,352,480**

Notes: For value added impact, the change in final demand or direct impact equals the total output less intermediate expenditures. For this study, we treated NASA Glenn as any other research and development institution, assuming that NASA Glenn's intermediate expenditure pattern is the same as that of any other research institution in Northeast Ohio. For an average research institution in Northeast Ohio, the intermediate expenditures accounted for 53% of total output.
The economic impact is shown in 2019 dollars.

Total value added in Northeast Ohio increased by $866.4 million in FY 2019 as a result of NASA Glenn's spending on goods and services. Of this total amount, $436.7 million (50.4%) represented the change in final demand (direct impact), calculated as total output less intermediate expenditures. In the case of NASA Glenn, the large portion of the value added are the wages and salaries paid to the employees. An additional $221.2 million (25.5%) represented the value of goods and services, excluding intermediary goods, of companies in Northeast Ohio that supply NASA Glenn (i.e., indirect impact). The remaining value added impact (the induced component) was estimated at $208.5 million (24.1%). This value occurred as the result of the ripple effects NASA Glenn's spending had on the Northeast Ohio economy.

Of the $429.7 million increase in value added attributed to Northeast Ohio due to the indirect impacts ($221.2 million) and induced impacts ($208.5 million), $213.8 million (49.8%) was observed in NASA Glenn-driven industries, $141.3 million (32.9%) has occurred in consumer-driven industries, and $74.5 million (17.3%) was reported in other industries.[37]

The value added distribution for select NASA Glenn-driven industries can be found in Figure 11. The value added distribution for select consumer-driven industries can be found in Figure 12. Each of the select industries shown in Figures 11 and 12 added at least $8.5 million (or 4%) and $5.0 million (or 3.5%), respectively.

Of the NASA Glenn-driven industries, the scientific research and development services industry saw the largest value added increase in FY 2019 ($57.6 million). This amount is the result of summing the indirect and induced impacts that were generated by NASA Glenn's spending. This $57.6 million increase in the scientific R&D industry represented a 27% share of the $213.8 million increase in value added across all NASA Glenn-driven industries. The other industries shown in Figure 11 can be similarly interpreted.

Within the consumer-driven industries, those who worked in the private hospital industry saw their value added increase by $16.6 million in FY 2019. This increase is a result of summing indirect and induced impacts that were generated primarily, though not exclusively, by NASA Glenn's spending at hospital establishments. This $16.6 million increase accounted for 12% of the $141.3 million value added growth that occurred across all consumer-driven industries.

[37] See section D.2.1. Output Impact on Northeast Ohio for definitions of NASA Glenn-driven, consumer-driven, and other industries.

Figure 11. Increase in Value Added for NASA Glenn-Driven Industries in Northeast Ohio, FY 2019

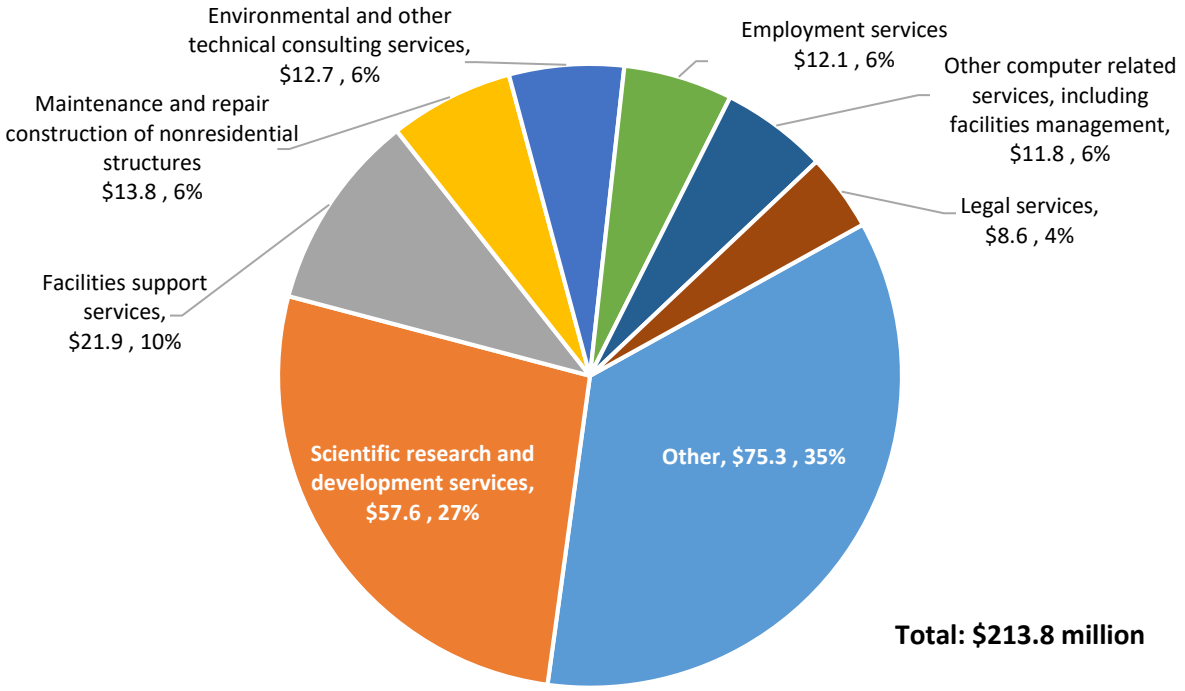
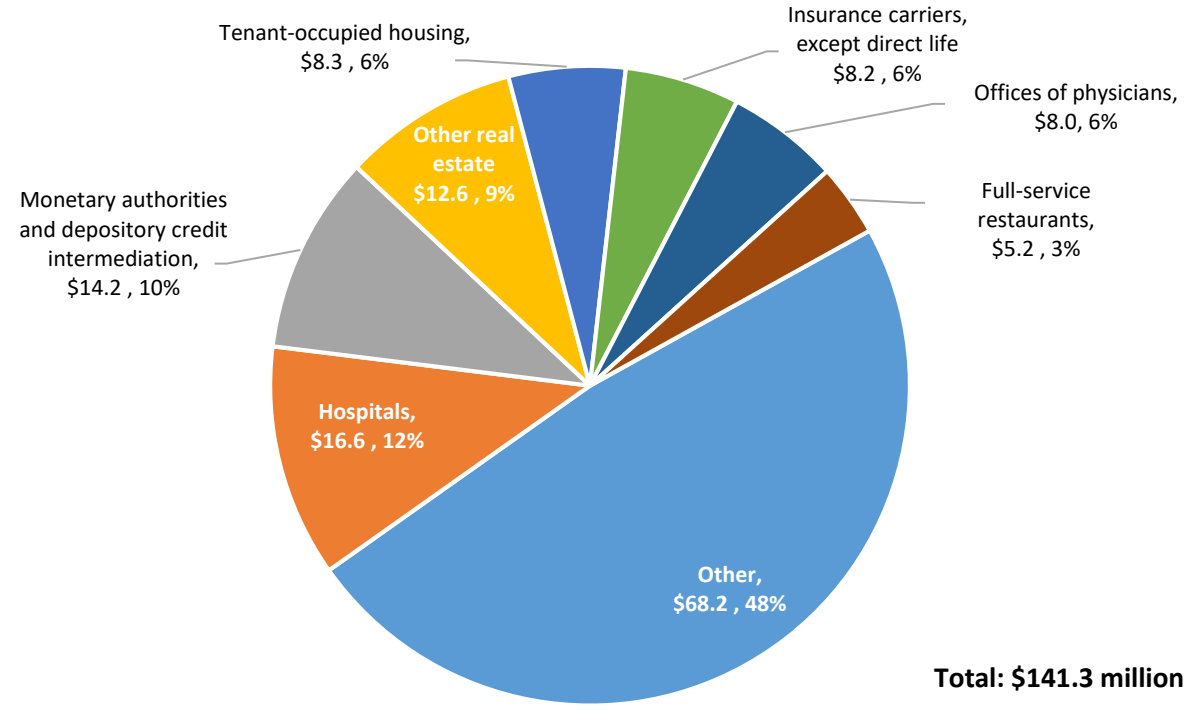


Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2019



D.2.5. Tax Impact on Northeast Ohio, FY 2019

NASA Glenn's operations and economic impact on Northeast Ohio in FY 2019 increased tax revenues by $117.9 million. Of this total, the direct tax impact paid by NASA Glenn's employees was $31.9 million in 2019 dollars.

D.2.6. FY 2019 Northeast Ohio Impact Summary

The economic activity generated by Glenn Research Center created the following economic impact on Northeast Ohio:

- Total Output Impact: $1,618.4 M
- Total Employment Impact: 6,989 jobs
- Total Labor Income Impact: $505.1 M
- Total Value Added Impact: $866.4 M
- Total Tax Impact: $117. 9M

The impact of NASA Glenn's expenditures on Northeast Ohio reflects the benefits of total expenditures of $507.8 million. These expenditures include a total amount of $279.2 million spent on purchases in Northeast Ohio in FY 2019 and expenditures on labor income paid to employees living in or commuting to Northeast Ohio in the amount of $228.6 million.

Excluding expenditures on labor income, 60.2% (about $168 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 21.9% ($61.1 million) was spent on administrative and support services, and 9.7% ($27.2 million) was spent on construction – the three largest groups of NASA Glenn expenditures in Northeast Ohio.[38] These three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio and, together, represented a 92.0% share ($256.3 million) of all NASA Glenn's FY 2019 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, educational service represented at 4.0% share and utilities at 2.7%. Other sectors' expenditures were less than 1%.

Businesses across many industries benefited from spending by NASA Glenn personnel and workers of NASA Glenn suppliers. Labor income received by NASA Glenn personnel and other workers was spent following typical consumer spending patterns. This includes expenditures on food service, real estate companies, hospitals and healthcare services, motor vehicle dealers, commercial banks, accounting services, and other miscellaneous retailers.

[38] Amounts in parentheses detailing percentage numbers are presented in 2019 dollars and correspond to Appendix Table A.3.

D.3. ECONOMIC IMPACT ON THE STATE OF OHIO, FY 2019

This section provides an assessment of the economic impact of NASA Glenn operations on the State of Ohio's economy in FY 2019. This impact analysis followed a similar methodology used to assess NASA Glenn's economic impact on Northeast Ohio, as described in Section D.2. The primary difference between the two sections was that the model used for Section D.3. accounted for *all* purchases made by NASA Glenn from companies in the State of Ohio, rather than only companies located in Northeast Ohio.

D.3.1. Output Impact on the State of Ohio, FY 2019

This economic impact analysis used IMPLAN multipliers to identify the buy-sell relationship between industries in Ohio. The multipliers applied to the spending in the State of Ohio are generally larger than those that are applied to expenditures in Northeast Ohio. This is simply due to more purchases being accounted for within a larger geographic area. The larger geographic area also results in less leakage from the economy.

NASA Glenn expenditures were divided into two categories. First is the spending on goods and services purchased from companies and other entities located in the State of Ohio (local). The second category included the spending for goods and services from businesses located outside of the State of Ohio. Local spending is further categorized by products and services that originated within the local economy, based on an IMPLAN classification system of industries that produced the products. The spending is then assigned to 546 IMPLAN sectors similar to the NAICS code industrial classification. Table A.4. in Appendix A lists detailed NASA Glenn expenditures by a specific industry in the State of Ohio.

Table 11 details the total output impact and its components. The total amount of purchases for all NASA Glenn operations represented the direct output impact (change in final demand). The indirect impact is estimated by totaling the contributions of individual industries that provide inputs to the producers of the goods and services that are ultimately consumed by NASA Glenn. The induced impact was then estimated by measuring the spending of employees of NASA Glenn and supplying industries as a result of Glenn's increased demand for products and services. Totaling the direct impact, indirect impact, and induced impact resulted in the total output impact. Table 11 details output impacts by industry sector, illustrating how NASA Glenn's sending across the State of Ohio affects different sectors of the state economy.

Table 11. Output Impact in the State of Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$307,128	$526,473	$833,601
Mining		$1,633,664	$1,269,512	$2,903,175
Utilities		$15,507,877	$9,382,180	$24,890,056
Construction		$29,781,020	$4,074,625	$33,855,644
Manufacturing		$14,420,049	$11,757,438	$26,177,486
Wholesale Trade		$8,418,067	$19,145,556	$27,563,622
Retail Trade		$4,138,004	$35,126,593	$39,264,597
Transportation and Warehousing		$7,412,197	$12,346,097	$19,758,294
Information		$9,830,178	$16,462,034	$26,292,213
Finance and Insurance		$12,160,763	$57,754,000	$69,914,764
Real Estate and Rental		$25,082,781	$69,121,854	$94,204,636
Professional, Scientific, and Tech Services		$243,514,702	$20,602,098	$264,116,800
Management of Companies		$10,219,235	$6,287,882	$16,507,117
Administrative and Waste Services		$88,988,847	$13,553,070	$102,541,917
Educational Services		$12,358,948	$5,963,951	$18,322,899
Health and Social Services		$1,605,846	$72,409,935	$74,015,781
Arts, Entertainment, and Recreation		$853,632	$7,796,679	$8,650,311
Accommodation and Food Services		$4,160,503	$21,770,716	$25,931,219
Other Services		$4,121,489	$24,036,466	$28,157,955
Government & non-NAICs	$823,876,339	$1,805,876	$3,645,007	$829,327,222
Total Output	**$823,876,339**	**$496,320,805**	**$413,032,166**	**$1,733,229,309**

Notes:

Direct impact of NASA Glenn is a change in final demand that is applied to a sector of NASA Glenn's industry, NAICS 9271 – Space Research and Technology, which is a part of a larger industry sector NAICS 92 – Public Administration (Government & non-NAICs).

For output impact, the change in final demand or direct impact equals the spending of NASA Glenn for goods and services within and outside Ohio, including wages and benefits. The direct output is adjusted for inflation and shown in the table in 2019 dollars.

In FY 2019, the total output impact of NASA Glenn on the State of Ohio was $1,733.2 million. NASA Glenn's expenditures of $823.9 million worth of expenditures resulted in an output (sales) change of $1,733.2 million across all industry sectors (Table 11). For example, NASA Glenn's spending caused a $264.1 million increase in total sales within the Professional, Scientific, and Technical Services industry and a $102.5 million increase in the Administrative and Waste Services industry.

Of the total output impact, 47.5% ($823.9 million) is accounted for by NASA Glenn's direct spending, which constitutes the direct economic impact to the State of Ohio. Indirect spending from NASA Glenn's purchases of goods and services within the State of Ohio made up $496.3 (28.6%) of the total output impact. The remaining $413.0 million (23.8%) of the total output impact is due to the induced impact of NASA Glenn's spending throughout the state.

A detailed analysis of the IMPLAN model shows that the $909.4 million increase in sales generated by the indirect and induced impacts can be divided into three broad categories: NASA Glenn-driven ($469.7 million, 51.6%), consumer-driven ($285.4 million, 31.4%), and other industries ($154.3 million, 17.0%).[39]

Figures 13 and 14 display the output distributions for select NASA Glenn- and consumer-driven industries, respectively. Selected industries in Figure 13 added over $15.0 million (3.0%), and selected industries in Figure 14 added over $9.0 million (3.0%).

The scientific research and development industry generated the largest output impact; it increased by $149.1 million in FY 2019 due to NASA Glenn's operations (Figure 13). This amount is the result of totaling the indirect and induced impacts generated primarily by NASA Glenn's spending on research services. This increase of $149.1 million accounted for 32% of the $469.7 million increase in output of all Glenn-driven industries. Other industries shown in Figure 13 can be interpreted similarly.

In consumer-driven industries (displayed in Figure 14), the real estate establishments industry generated the largest output impact. This industry increased by $38.3 million in FY 2019 and represented a 13% share of the $284.5 million increase in output for all consumer-driven industries. The increase of $38.3 million within the real estate industry is a result of totaling the indirect and induced impact components generated primarily by NASA Glenn employees and other workers. Other industries shown in Figure 14 can be interpreted similarly.

[39] NASA Glenn-driven industries are industries that increase sales, employment, and earnings primarily, but not exclusively, due to NASA Glenn's spending. Among these industries are utilities, construction, information, professional and scientific services, administrative and support services, and education. The consumer-driven industries are those that increase sales, employment, and earnings primarily due to spending by NASA Glenn employees and other workers who produce goods and services for NASA Glenn and their suppliers. These industries include retail, healthcare, real estate, other services, owner-occupied buildings, finance and insurance, and entertainment and food. Other industries are those that are driven by both NASA Glenn and consumer spending, that their impact is split between NASA Glenn and other businesses in the region. These industries include mining, manufacturing, agriculture, government enterprises, wholesale trade, and transportation and warehousing.

Figure 13. Increase in Sales for Select NASA Glenn-Driven Industries in Ohio, FY 2019

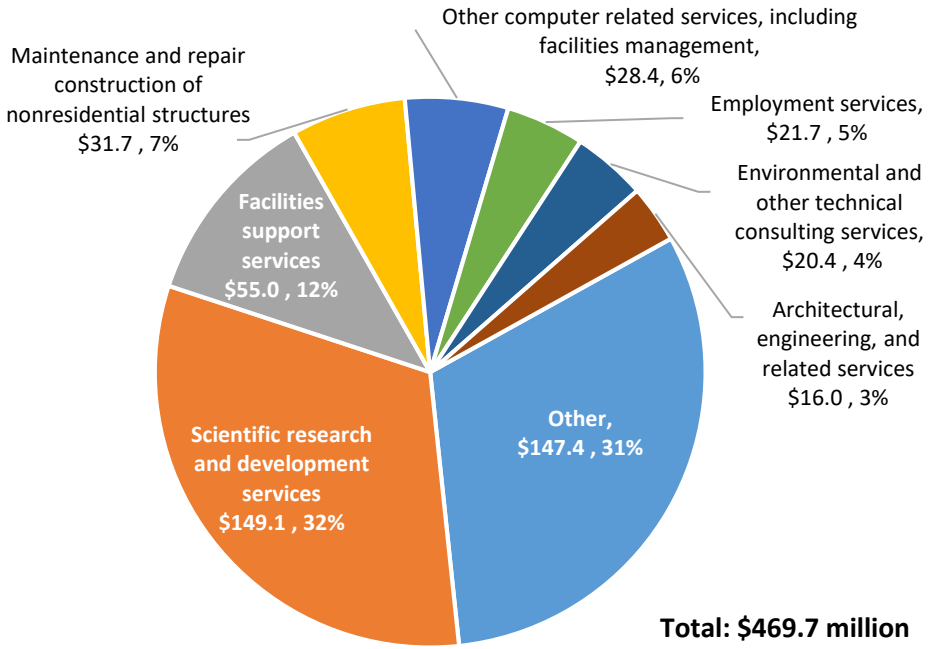
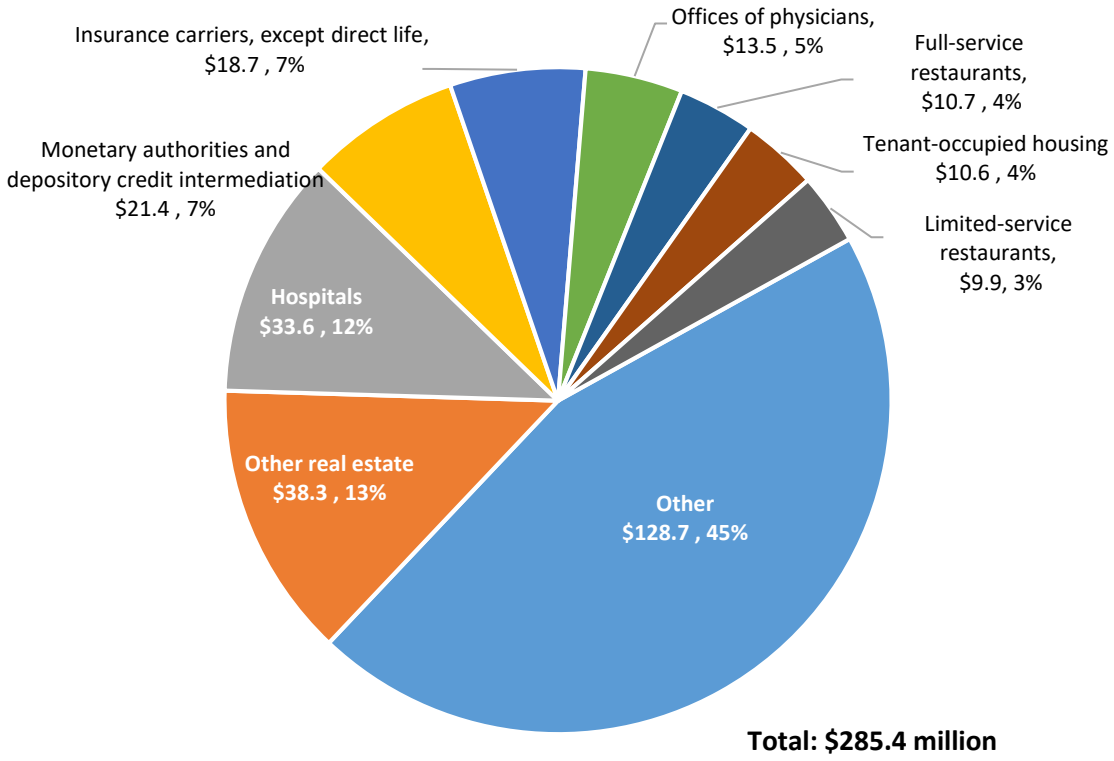


Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2019



D.3.2. Employment Impact on the State of Ohio, FY 2019

NASA Glenn's activities affect job creation beyond Glenn's hiring of its own employees (change in final demand, or direct impact). Glenn's spending creates employment across the State of Ohio in industries from which it purchases goods and services (indirect impact).

Money spent by NASA Glenn employees and employees of supply chain companies created jobs in various other industries that sell products and services to the household of the employees of NASA Glenn and their suppliers (induced impact). The total employment impact equals the sum of NASA Glenn's employment (direct impact) and the indirect and induced components. Table 12 shows the number of jobs supported and created by the industry sector.

Table 12. Employment Impact in the State of Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		6	9	15
Mining		3	2	4
Utilities		29	8	38
Construction		191	20	211
Manufacturing		39	25	64
Wholesale Trade		26	60	86
Retail Trade		48	382	429
Transportation and Warehousing		53	95	148
Information		21	38	59
Finance and Insurance		30	192	222
Real Estate and Rental		128	133	261
Professional, Scientific, and Tech Services		1,334	129	1,463
Management of Companies		49	30	79
Administrative and Waste Services		907	156	1,064
Educational Services		349	100	449
Health and Social Services		18	616	634
Arts, Entertainment, and Recreation		18	88	106
Accommodation and Food Services		65	323	388
Other Services		46	288	334
Government & non-NAICs	1,578	7	11	1,596
Total Employment	**1,578**	**3,368**	**2,705**	**7,651**

NASA Glenn's spending in FY 2019 resulted in an increase of 7,651 jobs within the State of Ohio. Of the total employment, 1,578 people (20.6%) were directly employed at NASA Glenn Research Center. As a result of NASA Glenn's spending on goods and services purchased in Ohio through their supply industries, 3,368 full- time and part-time jobs (44.0%) were supported and created in the region as indirect economic impact. The remaining 2,705 jobs (35.4%) were created as induced impact due to purchases made by NASA Glenn and suppliers' employees. These industries produce products that are typically within a consumer purchasing pattern of the region.

Of the 6,073 jobs created in the State of Ohio due to the indirect and induced effects, 3,284 (54.1%) were found in the NASA Glenn-driven sector, 2,182 (35.9%) were in consumer-driven sectors, and 607 (10.0%) were created in other sectors.[40]

The job distribution for select NASA Glenn-driven and consumer-driven sectors are shown in Figures 15 and 16, respectively. Each of the industries shown in Figure 15 supported or added over 180 jobs (5.0%). Each of the industries shown in Figure 16 supported or added over 68 jobs (3.0%).

Of all NASA Glenn-driven industries, the scientific research and development industry generated the highest number of additional jobs (Figure 15). Companies engaged in scientific R&D (professional, scientific, and technical services sector) saw an increase of 717 jobs and accounted for a 22% share of the 3,284 jobs created across all NASA Glenn-driven industries in FY 2019. This increase in value added is the result of totaling the indirect and induced impacts that were generated primarily, though not exclusively, by NASA Glenn's use of scientific research and development services within the State of Ohio.

The real estate industry saw the largest increase among consumer-driven industries in FY 2019; the increase of 206 jobs was due to NASA Glenn's spending generating labor income in regional supply industries (Figure 16). These jobs equal to the total of the direct, indirect, and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in the State of Ohio's real estate sector. These 206 jobs represent a 10% share of the 2,182 jobs that were created across all consumer-driven industries in the state.

[40] Glenn-driven industries include utilities, construction, information, education, professional and scientific services, and administrative and support services. Consumer-driven industries include retail, healthcare, real estate, other services, owner-occupied buildings, finance and insurance, and entertainment and food.

Figure 15. Increase in Jobs for Select NASA Glenn-Driven Industries in Ohio, FY 2019

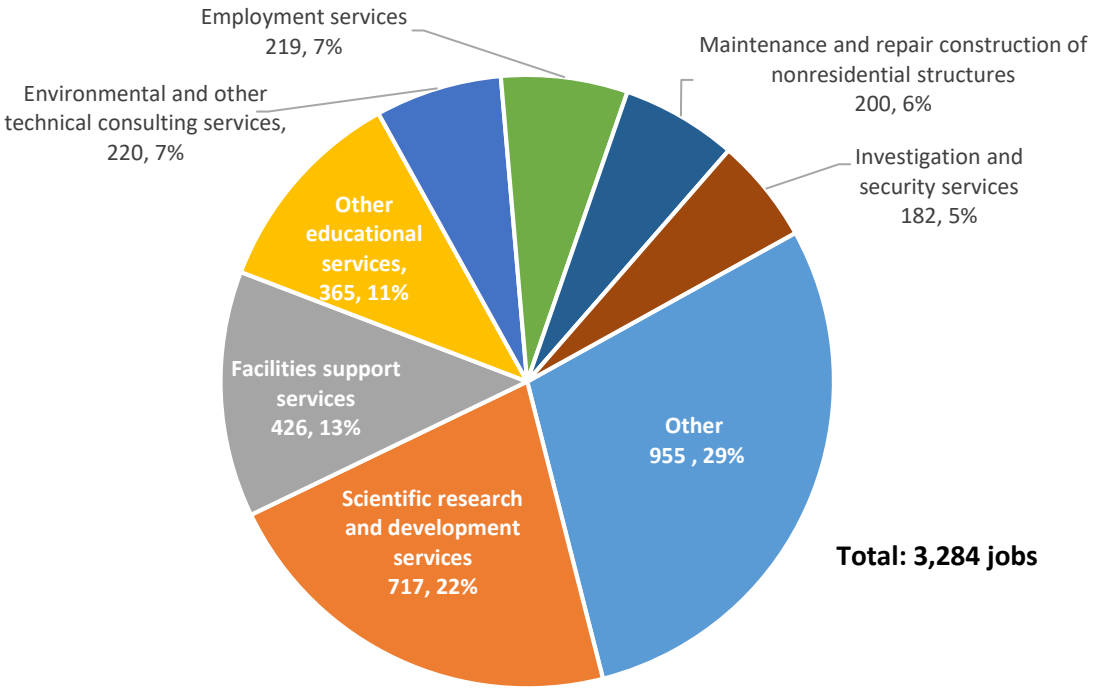
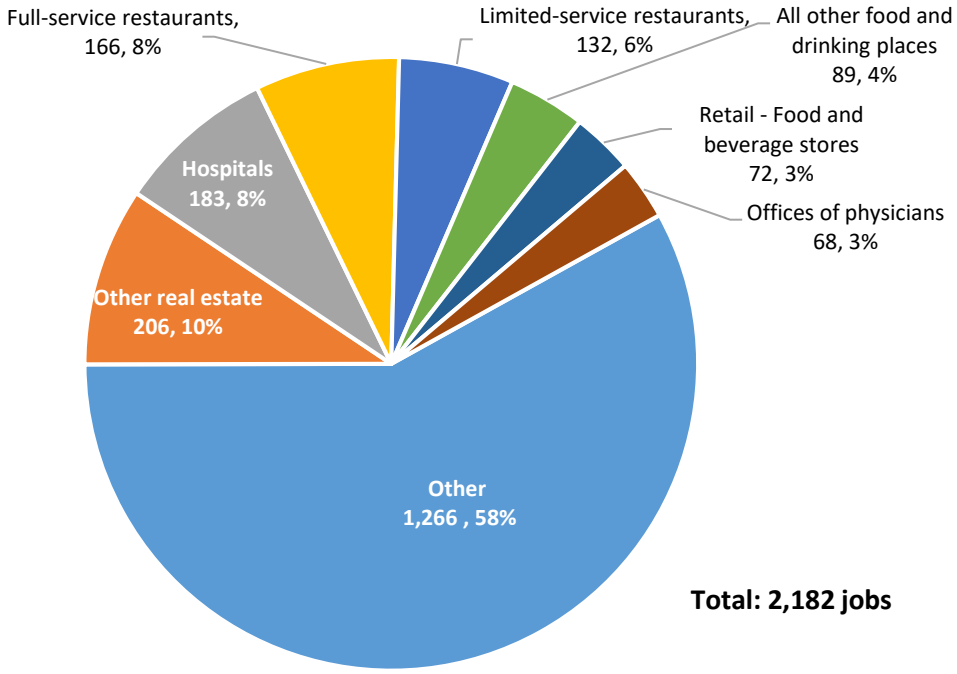


Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2019



D.3.3. Labor Income Impact on the State of Ohio, FY 2019

Labor income is the estimated change in earnings received by NASA Glenn employees and employees of its supply companies in the state of Ohio. The increase in the labor income is happening due to NASA Glenn's spending on goods and services purchased in the state. The total wages and benefits paid to all NASA Glenn employees constituted the change in final demand or direct impact of NASA Glenn in Ohio measured in labor income.

Wages and benefits paid to the employees of the companies from which NASA Glenn buys its supplies and the suppliers of these companies make up the indirect earnings impact. The induced impact was generated through the spending of workers in all industries who were employed as a result of the increased demand for products and services created by NASA Glenn. The total earnings impact includes the wages and benefits received by NASA Glenn employees (the direct effect), indirect, and induced impacts. The labor income impact by industry is described in Table 13.

Table 13. Labor Income Impact in the State of Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$101,102	$113,544	$214,646
Mining		$544,834	$78,980	$623,813
Utilities		$2,138,992	$1,114,956	$3,253,948
Construction		$10,223,738	$1,217,715	$11,441,453
Manufacturing		$2,811,343	$1,658,560	$4,469,904
Wholesale Trade		$2,480,053	$5,648,345	$8,128,398
Retail Trade		$1,521,034	$12,914,775	$14,435,809
Transportation and Warehousing		$3,247,882	$5,521,686	$8,769,568
Information		$1,814,398	$3,057,840	$4,872,238
Finance and Insurance		$2,494,820	$12,510,727	$15,005,547
Real Estate and Rental		$2,606,818	$2,873,978	$5,480,796
Professional, Scientific, and Tech Services		$97,498,778	$10,487,361	$107,986,139
Management of Companies		$6,213,349	$3,823,077	$10,036,427
Administrative and Waste Services		$32,126,290	$6,401,821	$38,528,111
Educational Services		$7,005,336	$3,673,682	$10,679,018
Health and Social Services		$766,978	$38,367,874	$39,134,852
Arts, Entertainment, and Recreation		$412,510	$3,141,975	$3,554,485
Accommodation and Food Services		$1,661,613	$7,618,739	$9,280,352
Other Services		$2,560,569	$12,230,859	$14,791,429
Government & non-NAICs	$237,417,129	$615,403	$1,094,491	$235,690,227
Total Labor Income	**$**237,417,129	**$178,845,842**	**$133,550,984**	**$549,813,955**

Notes: For labor income impact, the change in final demand or direct impact equals the wages and benefits paid to NASA Glenn employees. The direct labor income is shown in 2019 dollars.

In FY 2019, total labor increased by $549.8 million in the State of Ohio as a result of NASA Glenn's spending on goods and services. Of this amount, $237.4 million (43.2%) originated from wages and benefits paid directly to NASA Glenn employees (change in final demand, or direct effect measured in 2019 dollars). Of the $549.8 million in total labor income, $178.8 million (32.5%) represented the money paid to employees of companies in the State of Ohio that supply goods and services to NASA Glenn (indirect impact). The remaining induced earnings, estimated to be $133.6 million (24.3%), was the result of NASA Glenn's spending rippling through the Ohio economy via wages of Glenn's employees and wages of their supply companies.

Of the $312.4 million increase in labor income generated across the State of Ohio due to indirect and induced impacts, $176.7 million (56.6%) was reported in Glenn-driven industries, $96.6 million (30.9%) was observed in consumer-driven industries, and $39.1 million (12.5%) occurred in other industries.[41]

Figure 17 describes the labor income distribution for select NASA Glenn-driven industries. The labor income distribution for select consumer-driven industries is shown in Figure 18. The select industries shown in Figures 17 and 18 each added over 4.0% ($7.5 million) and 3.0% ($ 2.9 million) share each in Figures 17 and 18, respectively.

Of the NASA Glenn-driven industries, employees in the scientific research and development services industry saw the largest increase in labor income in FY 2019 (Figure 17). Labor income in this sector increased by $51.6 million and accounted for 29% of the $176.7 million total increase in labor income reported by all NASA Glenn-driven industries. These earnings are the result of totaling the indirect and induced impacts generated by NASA Glenn's purchases of computer-related services.

Private hospitals saw the largest increase in labor income across all consumer-driven industries in FY 2019 (Figure 18). Increasing by $15.4 million, labor income in the private hospitals' sector represented a 16% share of the $96.6 million labor income increase that occurred across all consumer-driven industries. These earnings are the summation of the indirect and induced impacts that occurred by consumer spending on doctors' services.

[41] See section D.2.1. Output Impact on Northeast Ohio, FY 2019 for detailed definitions of NASA Glenn-driven, consumer-driven, and other industries.

Figure 17. Increase in Labor Income for Select NASA Glenn-Driven Industries in Ohio, FY 2019

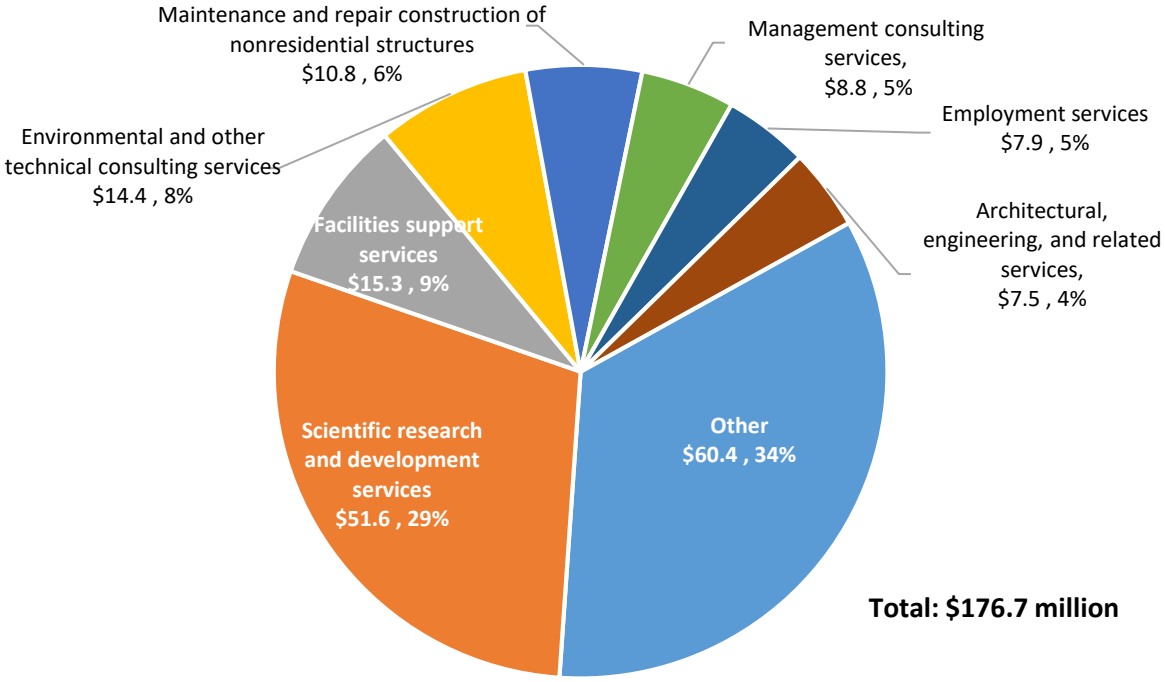
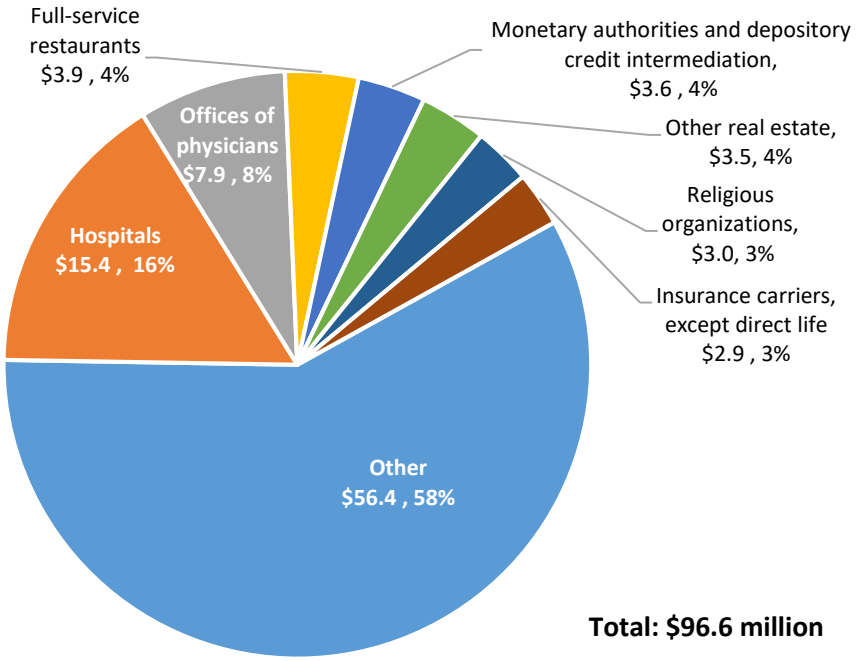


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2019



D.3.4. Value Added Impact on the State of Ohio, FY 2019

NASA Glenn's spending in FY 2019 created an increase of $914.9 million in value added for all industries.[42] Of this total, $428.4 million (46.8%) was the change in final demand, or direct impact, calculated as total output less intermediate expenditures. Wages and salaries paid to NASA Glenn employees make up the largest portion of the total value added. Another $248.7 (27.2%) represented the indirect impact – value of goods and services, less intermediary goods, of companies in Ohio that supply to NASA Glenn. The remaining value added impact (the induced component) was estimated at $237.8 million (26.0%). It occurred as a result of NASA Glenn's spending rippling through the Northeast Ohio economy. The total value added impact is a result of totaling direct, indirect, and induced impacts (Table 14).[43]

Table 14. Value Added Impact in the State of Ohio, FY 2019

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$143,181	$152,822	$296,003
Mining		$1,085,800	$733,341	$1,819,141
Utilities		$7,244,609	$4,149,480	$11,394,089
Construction		$13,231,683	$1,659,753	$14,891,436
Manufacturing		$5,025,396	$3,595,105	$8,620,502
Wholesale Trade		$4,869,397	$11,034,868	$15,904,265
Retail Trade		$2,658,195	$21,590,722	$24,248,918
Transportation and Warehousing		$3,728,466	$6,236,143	$9,964,610
Information		$4,523,096	$7,991,891	$12,514,987
Finance and Insurance		$7,485,822	$29,284,113	$36,769,935
Real Estate and Rental		$10,171,120	$48,193,295	$58,364,415
Professional, Scientific, and Tech Services		$125,160,373	$13,250,775	$138,411,148
Management of Companies		$7,106,657	$4,372,731	$11,479,387
Administrative and Waste Services		$43,121,384	$8,062,064	$51,183,448
Educational Services		$6,734,753	$3,926,107	$10,660,860
Health and Social Services		$900,753	$43,341,152	$44,241,905
Arts, Entertainment, and Recreation		$566,743	$5,167,295	$5,734,037
Accommodation and Food Services		$2,333,137	$11,226,367	$13,559,504
Other Services		$2,845,004	$13,648,741	$16,493,745
Government & non-NAICs	$428,415,696	-$276,996	$202,247	$428,340,947
Total Value Added	**$428,415,696**	**$248,658,573**	**$237,819,012**	**$914,893,281**

[42] "Value added" measures the economic impact of all goods and services produced in the state of Ohio due to NASA Glenn's operation (excluding intermediary goods).

[43] For value added impact, the change in final demand (direct impact) equals total output less the intermediate expenditures. For this study, we treated NASA Glenn as any other research and development institution, assuming that NASA Glenn's intermediate expenditure pattern is the same as that of any other research institution in Ohio. For an average research institution in Ohio, the intermediate expenditures accounted for 52% of total output. Negative values in Value Added effect suggest that costs of creating products and providing services in this sector are greater than revenues. Value added consists of employee compensation, proprietor income, other property type income and taxes on production and imports. Any of these values could be negative.

Total value added in the State of Ohio increased by $914.9 million as a result of NASA Glenn's spending for goods and services in FY 2019. Of this total amount, a large portion close to $428.4 million (46.8%) included the wages and benefits paid directly to NASA Glenn employees (change in final demand or direct impact). Another $248.7 million (27.2%) represented the value of goods and services (less intermediary goods) companies in Ohio to NASA Glenn (indirect impact). The remaining value added impact (induced component), estimated to be $237.8 million (26.0%), occurred as the effects of NASA Glenn's spending rippled through the Ohio economy.

Of the $488.7 million increase in value added generated across Ohio due to indirect and induced impacts, $238.9 million (48.9%) was reported in NASA Glenn-driven industries, $159.5 million (32.6%) was generated in consumer-driven industries, and $90.4 million (18.5%) was reported in other industries.

Figure 19 details the value added distribution for select NASA Glenn-driven industries, and Figure 20 shows the value added distribution for select consumer-driven industries. Select industries in Figure 19 and Figure 20, each added at least $11.0 million (4.5%) and $5.5 million (3.5%), respectively.

The scientific research and development services industry saw the largest increase in value added of all NASA-Glenn driven industries, with its value added totaling $71.1 million (Figure 19). This increase in value added is the result of totaling indirect and induced impacts that are generated primarily, though not exclusively, by NASA Glenn's spending on facilities support services. The $71.1 million accounted for 30% of the $238.9 million value added increase that was reported across all NASA Glenn-driven industries.

In the consumer-driven industries, employees working in private hospitals saw their value added increase by $18.2 million in FY 2019 (Figure 20). This value added increase is a result of totaling the indirect and induced impacts generated by consumer spending within the industry. The increase of $18.2 million accounted for 11% of the $159.5 million value added increase that occurred across all consumer-driven industries.

Figure 19. Increase in Value Added for NASA Glenn-Driven Industries in Ohio, FY 2019

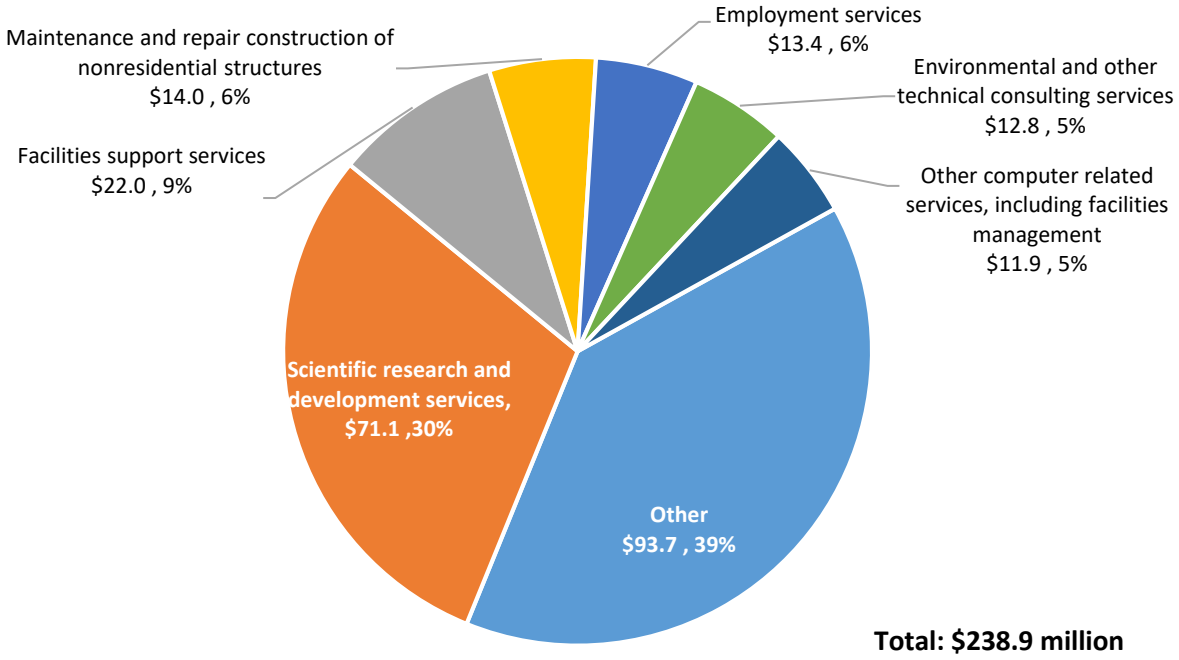
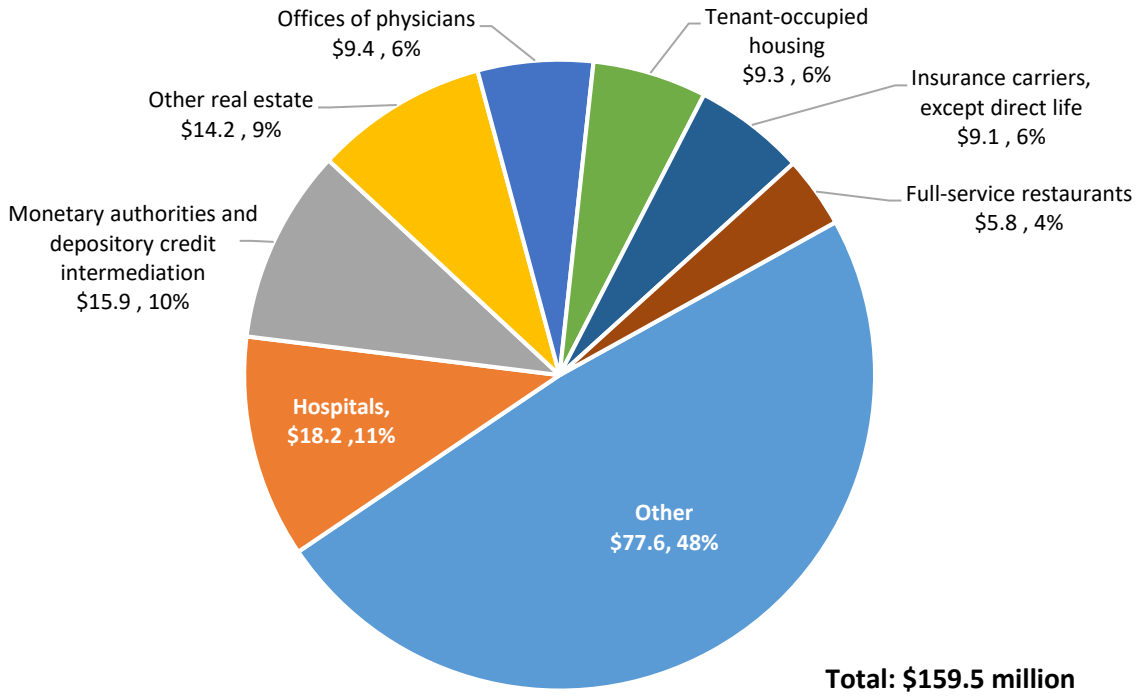


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2019



D.3.5. Tax Impact on the State of Ohio, FY 2019

NASA Glenn's operations and economic impact on the state of Ohio in FY 2019 increased tax revenues by a total of $129.3 million. Of this total amount, direct tax impact was $31.9 million in Glenn's employee taxes on wages.

D.3.6. FY 2019 Ohio Impact Summary

The economic activity of NASA Glenn generated the following total economic impact on the State of Ohio:

- Total Output Impact: $1,733.2 M
- Total Employment Impact: 7,651 jobs
- Total Labor Income Impact: $549.8 M
- Total Value Added Impact: $914.9 M
- Total Tax Impact: $129.3 M

NASA Glenn's expenditures on the state of Ohio is only slightly higher than the economic impact on Northeast Ohio because the models capture more buy-sell relationships in the larger geographic area. The majority of NASA Glenn's expenditures in Ohio were spent in Northeast Ohio.

In FY 2019, NASA Glenn's expenditures in the State of Ohio totaled $546.1 million, including labor income (adjusted for commuter spending). The total expenditures in all of Ohio were $38.3 million more than in the total expenditures in Northeast Ohio.

Compared to the expenditures made in Northeast Ohio in FY 2019, the largest share of the total payments, excluding labor income, was spent on professional, scientific, and technical services in Ohio (62.7% in Ohio, compared to 60.2% in Northeast Ohio). More than 92% of NASA Glenn spending in Ohio ($283.1 million), excluding labor income, went to the following industry sectors: professional, scientific and technical services ($193.6 million); administrative and support and waste management and remediation services ($62.3 million); and construction ($27.2 million).[44]

NASA Glenn's statewide expenditure pattern is similar to the expenditures in Northeast Ohio. Because NASA Glenn is a large institution that employs highly qualified and provides highly paid labor, Glenn is accountable for a large part of the economic impact through the spending of its employees. The businesses that benefited the most from spending by NASA Glenn personnel and other workers whose earnings were due in part to NASA Glenn's expenditures are typical, considering consumer spending patterns. These businesses include the following industries: food services, accounting services, commercial banks, motor vehicle dealers, educational institutions, and hospitals and other healthcare services.

[44] Amounts in parentheses detailing percentage numbers are presented in 2019 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2019

Region	Total	Share
Ohio	$308,706,141	52.8%
California	$92,600,841	15.8%
Washington	$46,532,419	8.0%
Alabama	$26,945,710	4.6%
Illinois	$18,611,269	3.2%
Maryland	$14,887,412	2.5%
Massachusetts	$7,655,176	1.3%
Texas	$6,333,318	1.1%
Connecticut	$6,225,797	1.1%
Missouri	$5,979,185	1.0%
Florida	$5,592,407	1.0%
New York	$5,124,979	0.9%
Indiana	$4,611,123	0.8%
Pennsylvania	$4,605,788	0.8%
Virginia	$3,832,822	0.7%
Arizona	$3,218,373	0.6%
Michigan	$3,123,674	0.5%
New Hampshire	$2,913,331	0.5%
New Mexico	$2,907,194	0.5%
New Jersey	$2,110,928	0.4%
Colorado	$2,008,290	0.3%
Oregon	$1,696,157	0.3%
Delaware	$1,402,894	0.2%
Georgia	$1,153,111	0.2%
Minnesota	$1,029,828	0.2%
North Carolina	$988,055	0.2%
District of Columbia	$866,850	0.1%
Iowa	$674,147	0.1%
Tennessee	$508,732	0.1%
Montana	$468,482	0.1%
Kansas	$338,245	0.1%
Wisconsin	$265,208	0.0%

Region	Total	Share
Utah	$183,171	0.0%
South Carolina	$165,411	0.0%
Arkansas	$104,254	0.0%
Vermont	$102,633	0.0%
Nevada	$99,244	0.0%
Rhode Island	$94,553	0.0%
Kentucky	$80,372	0.0%
Mississippi	$70,264	0.0%
Louisiana	$68,019	0.0%
Wyoming	$64,627	0.0%
South Dakota	$47,855	0.0%
Idaho	$34,008	0.0%
Nebraska	$28,183	0.0%
Puerto Rico	$1,074	0.0%
West Virginia	$928	0.0%
Alaska	$0	0.0%
U.S. Total (No ND)	**$585,062,481**	**99.8%**
Great Britain	$448,733	0.1%
Germany	$303,967	0.1%
Switzerland	$249,619	0.0%
Canada	$186,004	0.0%
France	$151,780	0.0%
Taiwan	$37,150	0.0%
Japan	$20,875	0.0%
Australia	$2,202	0.0%
Spain	-$3,600	0.0%
Foreign Total	$1,396,729	100.0%
Grand Total	**$586,459,210**	**100.0%**

Table A.2. NASA Glenn Grants Allocated to Academic Institutions by State, FY 2019

State	College / University	Share
California	$1,732,958	15.8%
Ohio	$1,365,803	12.4%
Maryland	$1,302,940	11.9%
Michigan	$699,152	6.4%
Texas	$692,557	6.3%
Massachusetts	$582,159	5.3%
Georgia	$578,531	5.3%
New York	$556,351	5.1%
Illinois	$430,878	3.9%
Colorado	$339,257	3.1%
Indiana	$319,235	2.9%
Connecticut	$305,097	2.8%
New Jersey	$254,688	2.3%
Kansas	$235,209	2.1%
Oregon	$200,203	1.8%
Arizona	$151,045	1.4%
North Carolina	$149,369	1.4%
Tennessee	$146,076	1.3%
Pennsylvania	$127,030	1.2%
Virginia	$122,785	1.1%
Florida	$112,095	1.0%
Iowa	$94,082	0.9%
Missouri	$93,585	0.9%
South Carolina	$82,927	0.8%
Washington	$72,423	0.7%
Minnesota	$69,182	0.6%
Mississippi	$59,825	0.5%
Kentucky	$47,779	0.4%
Idaho	$21,977	0.2%
South Dakota	$17,167	0.2%
Wisconsin	$8,732	0.1%
Outside US	$0	0.0%
Total	**$10,971,099**	**100%**

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2019

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$7,449,764**
	Electric power transmission and distribution	47	$4,786,276
	Natural gas distribution	48	$459,608
	Water, sewage and other systems	49	$2,203,880
Construction			**$27,178,513**
	Maintenance and repair construction of nonresidential structures	60	$27,178,513
Manufacturing			**$1,072,232**
	Printing	152	$6,392
	Other rubber product manufacturing	196	$29
	Crown and closure manufacturing and metal stamping	230	$24,408
	Sheet metal work manufacturing	239	$14,700
	Hardware manufacturing	245	$39,407
	Machine shops	247	$579,182
	Turned product and screw, nut, and bolt manufacturing	248	$19,455
	Metal heat treating	249	$5,980
	Valve and fittings, other than plumbing, manufacturing	252	$15,192
	Pump and pumping equipment manufacturing	285	$52,733
	Industrial process furnace and oven manufacturing	294	$6,800
	Audio and video equipment manufacturing	304	$75,565
	Electricity and signal testing instruments manufacturing	316	$97,596
	Watch, clock, and other measuring and controlling device manufacturing	319	$57,061
	Carbon and graphite product manufacturing	338	$14,039
	Blind and shade manufacturing	375	$63,692
Wholesale Trade & Retail Trade			**$1,402,767**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$48,660
	Retail - Miscellaneous store retailers	412	$1,354,107
Transportation and Warehousing			**$28,791**
	Truck transportation	417	$12,664
	Transit and ground passenger transportation	418	$16,127
Real Estate and Rental and Leasing			**$48,657**
	Commercial and industrial machinery and equipment rental and leasing	453	$33,511
Professional, Scientific, and Technical Services			**$168,047,053**
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,170,594
	Architectural, engineering, and related services	457	$7,777,369
	Other computer related services, including facilities management	461	$27,357,790
	Management consulting services	462	$3,641,485

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
	Environmental and other technical consulting services	463	$19,002,440
	Scientific research and development services	464	$105,660,135
	Marketing research & all other miscellaneous professional, scientific, & technical services	468	$437,239
Administrative and Support and Waste Management and Remediation Services			**$61,109,273**
	Facilities support services	471	$53,082,619
	Business support services	473	$125,000
	Investigation and security services	475	$5,535,823
	Services to buildings	476	$2,129,589
	Waste management and remediation services	479	$236,241
Educational Services			**$11,298,551**
	Junior colleges, colleges, universities, and professional schools	481	$723,426
	Other educational services	482	$10,575,125
Health Care and Social Assistance			**$1,571,246**
	Medical and diagnostic laboratories	487	$303,392
	Other ambulatory health care services	489	$1,257,853
	Hospitals	490	$10,000
Other Services (except Public Administration)			**$27,256**
	Commercial and industrial machinery and equipment repair and maintenance	515	$23,456
	Other local government enterprises	534	$3,800
Labor Income			**$228,586,949**
	Employee Compensation (c)		$228,586,949
TOTAL EXPENDITURES IN NEO			**$507,805,906**

a. Sector: Industry classification code used by IMPLAN. It is analogous to the North American Industry Classification System (NAICS). IMPLAN provides a cross-reference table bridging their sector numbers and NAICS codes.
b. Expenditure: Actual dollar value for a product or service spent by NASA Glenn in FY 2019. Values shown in Table A-3 are limited to expenditures made in Northeast Ohio.
c. Labor Income: Labor income includes wages and benefits of Glenn employees living in Northeast Ohio and accounts for commuters' local spending.

Table A.4. NASA Glenn Detailed Expenditures in the State of Ohio, FY 2019

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$7,624,477**
	Electric power transmission and distribution	47	$4,786,276
	Natural gas distribution	48	$459,608
	Water, sewage and other systems	49	$2,378,593
Construction			**$27,178,513**
	Maintenance and repair construction of nonresidential structures	60	$27,178,513
Manufacturing			**$2,348,311**
	Printing	152	$6,392
	Plastics material and resin manufacturing	164	$59,980
	Other rubber product manufacturing	196	$29
	Miscellaneous nonmetallic mineral products manufacturing	214	$11,641
	Crown and closure manufacturing and metal stamping	230	$24,408
	Sheet metal work manufacturing	239	$14,700
	Metal tank (heavy gauge) manufacturing	242	$87,840
	Hardware manufacturing	245	$39,407
	Machine shops	247	$607,432
	Turned product and screw, nut, and bolt manufacturing	248	$19,455
	Metal heat treating	249	$10,985
	Valve and fittings, other than plumbing, manufacturing	252	$561,474
	Pump and pumping equipment manufacturing	285	$52,733
	Industrial truck, trailer, and stacker manufacturing	290	$31,452
	Ornamental and architectural metal work manufacturing	240	$6,814
	Scales, balances, and miscellaneous general purpose machinery manufacturing	297	$10,252
	Audio and video equipment manufacturing	304	$75,565
	Industrial process variable instruments manufacturing	314	$407,420
	Electricity and signal testing instruments manufacturing	316	$108,096
	Analytical laboratory instrument manufacturing	317	$63,458
	Watch, clock, and other measuring and controlling device manufacturing	319	$57,061
	Carbon and graphite product manufacturing	338	$14,039
	Other motor vehicle parts manufacturing	352	$13,985
	Blind and shade manufacturing	375	$63,692
Wholesale Trade & Retail Trade			**$1,968,227**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$169,282
	Retail - Building material and garden equipment and supplies stores	405	$26,784
	Retail - Miscellaneous store retailers	412	$1,772,161
Transportation and Warehousing			**$31,027**
	Truck transportation	417	$14,900
	Transit and ground passenger transportation	418	$16,127
Real Estate and Rental and Leasing			**$33,511**
	Commercial and industrial machinery and equipment rental and leasing	453	$33,511

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Professional, Scientific, and Technical Services			**$193,571,563**
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,170,594
	Architectural, engineering, and related services	457	$8,946,842
	Custom computer programming services	459	$7,385
	Computer systems design services	460	$23,200
	Other computer related services, including facilities management	461	$27,357,790
	Management consulting services	462	$3,641,485
	Environmental and other technical consulting services	463	$19,002,440
	Scientific research and development services	464	$129,925,366
	Marketing research & all other miscellaneous professional, scientific, & technical services	468	$496,460
Administrative and Support and Waste Management and Remediation Services			**$62,343,916**
	Facilities support services	471	$53,106,300
	Business support services	473	$125,000
	Investigation and security services	475	$6,746,785
	Services to buildings	476	$2,129,589
	Waste management and remediation services	479	$236,241
Educational Services			**$11,940,928**
	Junior colleges, colleges, universities, and professional schools	481	$1,365,803
	Other educational services	482	$10,575,125
Health Care and Social Assistance			**$1,571,246**
	Medical and diagnostic laboratories	487	$303,392
	Other ambulatory health care services	489	$1,257,853
	Hospitals	490	$10,000
Other Services (except Public Administration)			**$94,423**
	Commercial and industrial machinery and equipment repair and maintenance	515	$23,456
	Other federal government enterprises	528	$67,167
	Other local government enterprises	534	$3,800
Labor Income			**$237,417,129**
	Employee Compensation (c)		$237,417,129
TOTAL EXPENDITURES IN OHIO			**$546,123,270**

a. Sector: Industry classification code used by IMPLAN. It is analogous to the North American Industry Classification System (NAICS). IMPLAN provides a cross-reference table bridging their sector numbers and NAICS codes.
b. Expenditure: Actual dollar value for a product or service spent by NASA Glenn in FY 2019. Values shown in Table A-4 are limited to expenditures made in Ohio.
c. Labor Income: Labor income includes wages and benefits of Glenn employees living in Ohio and accounts for commuters' local spending.