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The NASA Glenn Research Center: An Economic Impact Study Fiscal Year 2018

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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 and development to advance aviation, enable exploration of the universe, and improve life on Earth. Its scientists and engineers deliver advanced flight systems for spacecraft and improve efficiency and safety 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, aerospace power systems, aerospace communications, materials for extreme environments, biomedical technologies and high-value space experiments featuring advanced 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 220 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 NASA Glenn's campuses. The estimated replacement cost is approximately $3.6 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.

- 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, Exploration Research and Development, Low Earth Orbit and Spaceflight Operations, Space Science, and Aeronautics Research. Within the Deep Space Exploration Systems mission portfolio, NASA Glenn provided technical management and integration, engineering and testing to support development of the Orion Multi-Purpose Crew Vehicle and Space Launch System. In addition, GRC is leading the development of the Power and Propulsion Element which is the critical first spacecraft element of the Lunar Orbital Platform - Gateway. NASA Glenn is also contributing technological advancements for future robotic and human exploration missions beyond low Earth orbit, including technology development projects in spacecraft fire safety, advanced modular power systems, and in-situ resource utilization.

- As part of NASA's Low Earth Orbit and Spaceflight Operations areas, GRC led microgravity combustion science and fluid physics research on the International Space Station as well as leadership and technical contributions for the station's electric power system operation. In addition, NASA Glenn provided vital technical support to the Space Communication and Navigation program and led spectrum management for the agency.

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

- NASA Glenn's Science mission support included managing the Radioisotope Power Systems Program and developing associated thermoelectric technologies, including managing the Dynamic Radioisotope Power Systems project. The development of the NASA's Evolutionary Xenon Thruster – Commercial (NEXT-C), a gridded-ion electric propulsion system that will enhance future Discovery space missions is also managed by NASA Glenn. In addition, NASA Glenn utilizes unique capabilities to develop the Long-Life In-Situ Solar System Explorer with complex environmental testing, advanced new scientific instruments, and determine mission concepts for planetary surfaces (e.g. Venus, Mars) and Earth science (e.g. fresh water). Technical support is provided to NASA Headquarters with assessments and panel membership for Planetary Science which includes technology/tools coordination and science advisory groups.

- In support of **Space Exploration Research and Technology Development** missions, NASA Glenn led aspects of the Human Research Program, which performs research and development of medical capabilities in support of astronaut health. Also, NASA Glenn led technology demonstration projects to advance solar electric propulsion capability as well as cryogenic fluid management technologies to enable future missions. NASA Glenn also led game-changing technology projects for advanced space power systems, nuclear fission power systems, and other technologies for challenging mission applications. The Space Technology Research Grants 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. The Small Business Innovation Research (SBIR) program provides 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 its Strategic Technology Partnership (STP) 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 the 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. 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.

- In support of the Aeronautics mission, NASA Glenn continues to build on its world-class aeronautics heritage through its leadership of a wide variety of propulsion research, engineering and testing as related to acoustics, combustion, turbo-machinery, electrified aircraft propulsion, power management, propulsion systems analysis, materials and communications for subsonic, supersonic, hypersonic, and vertical lift aircraft systems. Through its program management efforts, NASA Glenn is supporting efficient, quiet, and reliable flight from urban air mobility to large commercial transports at any speed regime. A vast array of research and technology development projects in support of these attributes are performed by NASA Glenn, culminating in partnerships to test integrated systems to demonstrate capabilities meeting long-term

objectives for the Aeronautics Mission Directorate's Strategic Implementation Plan.

- The report structure is as follows: Sections A and B consist of the report's introduction and background. Section C provides an economic overview of NASA Glenn, including information related to employment and occupations, employee residences, payroll, expenditures, awards to academia and other institutions, revenues, and taxes paid by NASA Glenn employees. Section D provides estimates of the economic impact generated by NASA Glenn for an 8-county Northeast Ohio region and the State of Ohio during FY 2018. This report is an update of several earlier studies that estimated and measured NASA Glenn's economic impact on Northeast Ohio and Ohio.

Economic Impact Generated by NASA Glenn Research Center Spending

Economic impact estimates the benefits within the regional economy generated by an economic activity of an entity for an affected region. This study uses an 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 the same methodology to measure NASA Glenn's impact on the economies of Northeast Ohio and Ohio as was used for the previous studies. This report accounts for diverse economic sectors and illustrates what impact it makes 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 2018.

Economic Impact	Northeast Ohio	State of Ohio
Output	$1,456.3 million	$1,516.6 million
Value Added	$758.2 million	$776.6 million
Employment	7,185 jobs	7,563 jobs
Labor Income	$501.0 million	$520.3 million
Taxes	$119.2 million	$124.4 million

Note: Labor income accounts for the income of all NASA Glenn employees, both residents of the study area and those who live outside of the study area and spend only a portion of their income in the region (commuter spending). 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 $697.4 million worth of direct spending originating primarily from outside of the region resulted in an output (Sales) change of $1,456 million across all industry sectors. The value added increased by $758.2 million as a result of NASA Glenn's activities. In addition, 7,185 jobs were created and supported in the region, and labor income in Northeast Ohio increased by $501.0 million. NASA Glenn's activities in Northeast Ohio also generated $119.2 million in local, state, and federal taxes.
- NASA Glenn's activities in Ohio in FY 2018, stimulated by $697.4 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 $1,516 million.
- Ohio value added increased by $776.6 million as a result of NASA Glenn's activities in the state. In addition, 7,563 jobs were created and supported in Ohio, and labor income across the state increased by $520.3 million. NASA Glenn operations in Ohio also generated $124.4 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 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 2018, NASA Glenn civil service employment totaled 1,594. Compared to FY 2017, the total Glenn employment increased by 86 employees. Over the last five years, Glenn civil service employment had a peak of 1,624 employees in 2014. Overall, NASA Glenn's civil service employment has decreased by 1.8% from FY 2014 to FY 2018.
- The employees at NASA Glenn highly educated and highly skilled civil service workers. In FY 2018, 88% of NASA Glenn's employees possessed bachelor's degrees or higher. Of all NASA Glenn's civil service employees, 18% held doctoral degrees, 39% held master's degrees, and 31% held bachelor's degrees.[2]
- In FY 2018, scientists and engineers continue to be the largest occupational category. This occupational category account for 70% of the civil service employees at NASA Glenn. The share of scientists and engineers has continually increased since FY 2014 with the exception of a slight decrease from the share of 71% in 2017 to 70% in FY 2018, even though the total number of NASA Glenn's employees increased between 2017 and 2018.
- Combining civil service employees and local contractors, the total number of employees at NASA Glenn was 3,281 in FY 2018. This was an increase of 147 total employees from FY 2017. From FY 2014 to FY 2018, the highest total combined employment was 3,297 in FY 2014 and the lowest was 3,197 in FY 2016.
- NASA Glenn civil service employees received total compensation of $235.8 million in FY2018. In this report, total compensation included both payroll ($179.9 million) and employee benefits ($55.9 million). Between FY 2017 and FY 2018, total compensation increased by $3.4 million (or 1.5%) in nominal dollars. Also, NASA Glenn's nominal payroll has increased by $2.2 million (or 1.2%) during that same period. Additionally, between FY 2014 and FY 2018, total compensation increased by $8.9 million (or 3.9%), and the payroll also slightly increased by $2.0 million (1.1%) in nominal dollars.
- NASA Glenn's total revenue in FY 2018 reached $745.3, which 7.9% increased from FY 2017 without adjustment for inflation. During the last five years, NASA Glenn revenues ranged from $664.1 million in FY 2016 to $745.3 million in FY 2018. Overall, NASA Glenn's revenue has increased by $67.4 million (9.9%) from FY 2014 to FY 2018 in nominal dollars.
- NASA Glenn's expenditures totaled $474.4 million in FY 2018. Vendors in 48 states and ten foreign counties received a portion of NASA Glenn expenditures. In nominal dollars, the FY 2018 total expenditures were $32.4 million higher than that in FY 2017, illustrating a 7.3% increase. When adjusted for inflation to 2018 dollars, NASA Glenn expenditures increased by $21.7 million, or 4.8%, from FY 2017 to FY 2018. Between FY 2014 and FY 2018, expenditures increased by 9.8% representing a difference of $40.4 million in constant 2018 dollars.
- Ohio continues to be the largest beneficiary of expenditures, receiving $290.8 million of NASA Glenn's total expenditures in FY 2018. With a $4.52 million decrease in nominal dollars compared to FY 2018. The share of NASA Glenn's expenditures in Ohio decreased from 66.8% in FY 2017 to 61.3% in FY 2018.
- Northeast Ohio received $266.4 million of NASA Glenn's total expenditures in Ohio, accounting for 91.6% of total Ohio expenditures in FY 2018. Northeast Ohio accounted for 56.2% of NASA Glenn's total spending in FY 2018.
- After Ohio, the states that received the largest portions of NASA Glenn expenditures in FY 2018 were Washington and Maryland. Washington received $41.2 million, or 8.7% of total FY 2018 spending, and Maryland received $26.8 million, or 5.6% of total expenditures. These two states received the second and third largest portions of

[2] These counts do not include Student Trainees

NASA Glenn expenditures in FY 2018. Between FY 2017 and FY 2018, expenditures in Washington increased by $10.8 million, or 35.5%, in nominal dollars. Over the same time, spending in Maryland increased by $2.1 million, or 8.4%.

- NASA Glenn increased its expenditures in foreign countries by 6.0% compared to FY 2017. Foreign countries received $0.7 million, accounting for 0.2% of NASA Glenn's total expenditures in FY 2018. Among foreign countries, the largest beneficiary was Canada (See Appendix Table A.1 for more information on NASA Glenn out of country expenditures).
- NASA Glenn's funding to colleges and universities in 33 states and Great Britain, totaled $16.1 million. Grants accounted for $11.9 million of this total. In comparison to FY 2017, the total amount of funding to academic institutions decreased by $2.0 million in FY 2018, a decrease of -11.2% (in nominal dollars). NASA Glenn also awarded $4.2 million in contracts to Ohio academic institutions in FY 2018 through on-site contracts. The academic funding awarded in the top five states – Ohio, Maryland, California, Illinois, and Texas – in FY 2018 collectively accounted for 64.8% of the total awards, compared to the top five states representing 63.2% of total grants during FY 2017.
- Academic institutions in Ohio received $5.6 million, which accounted for the largest share (35.0%) of NASA Glenn's academic awards in FY 2018. Among the states outside Ohio, the state of Maryland received $1.84 million, which accounted for the second largest share (11.4%) of NASA Glenn's academic awards. California and Texas ranked third and fourth, receiving $1.33 million and $0.88 million, respectively, in funding to academic institutions, or 8.3% and 5.5% of total awards.
- Within the State of Ohio, the total amount of funding to Ohio academic institutions has decreased by $200,557 (or 3.4%) between FY2017 to FY2018, after adjusting for inflation. Case Western Reserve University (CWRU) and University of Toledo received most funding to Ohio academic institutions. CWRU received $2.3 million, representing the highest amount of funding in FY 2018, and University of Toledo received $1.9 million in FY 2018.
- NASA Glenn continues to be an important 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) 2018.[3] It uses 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]

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 payroll, occupation, and place of residence.

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

This analysis was conducted by the Glenn Research Center in conjunction with the Cleveland State University's Maxine Goodman Levin College of Urban Affairs. This FY 2018 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2018.[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: http://urban.csuohio.edu/economicdevelopment/publications/

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 220 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 over $3.6 billion.

Glenn's main campus, Lewis Field, is situated on 307 acres of land and contains more than 106 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 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: Exploration, Science, Space Operation, Space Technology, and Aeronautics Research.

Deep Space Exploration Systems (Systems development for human spaceflight beyond low earth orbit, to the moon and beyond)

- 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 testing at Glenn's Plum Brook Station (PBS) of the Ascent Abort flight test article for acoustic characterization and instrumentation checkout. Other Orion testing at PBS includes preparation for full integrated ESM-CM space qualification environmental testing as part of the first Exploration Mission, EM-1, uncrewed flight around the Moon.
- Providing overall technical and public-private partner leadership for the development of the Power and Propulsion Element (PPE) demonstration which will be the first of several elements or modules assembled in Lunar orbit to form the Lunar Orbital Platform - Gateway. 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 Universal Stage Adapter (USA) connecting the SLS Exploration Upper Stage to the Orion Crew and Service Module, and applying human spaceflight engineering and technical capabilities to perform a variety of analysis and integration tasks to support 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 in-situ resource utilization 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 support infrastructure)

- Leading 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.
- 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 pre-formulation leadership for public-private partnership with industry for development of next generation communication services for NASA missions.

Space Exploration Research and Technology (R&T) Development (Advancing R&T applications for NASA missions, including fostering commercial and academic innovation)

- 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.
- Leading the development and testing of Solar Electric Propulsion technology that can enable future space-based exploration and scientific missions of the future.
- Leading 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 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 the 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.
- 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.

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).
- 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.

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 presents an economic overview of the NASA Glenn Research Center during FY 2018. This analysis offers information of changes between FY 2014 and 2018 in terms of payroll, revenues, expenditures, awards to academic institutions, occupational distribution, number of employees, employee residence locations, and income taxes paid by NASA Glenn employees.

C.1. EMPLOYMENT AND OCCUPATIONS

The total labor force of NASA Glenn Research Center includes two types, civil service employees and local contractors. Federal laboratories commonly contract companies and individuals to conduct specific tasks and services, which allows for more flexibility in performance and their labor costs. The number of contracted employees can be easily adjusted aligning with the Glenn's scope of work and new projects. In comparison with contracted employees, the NASA civil service employment has been relatively constant in order to retain highly skilled workers with long-term core expertise. These workers are essential for efficient and effective execution of aerospace projects that often last many years. Over the last five years, the civil service workforce at Glenn had an average employment of 1,572.

Table 1 shows the total number of NASA Glenn's civil service employees and the shares of the four main occupational categories between FY 2014 and FY 2018. In FY 2018, NASA Glenn had 1,594 civil service employees, which is 86 people more than in FY 2017 (5.7%). During the last five years, Glenn civil service employment peaked in FY 2014 with a total of 1,624 employees. The increase breaks a four-year downward trend of total employees with the exception of a slight increase in FY 2016. Overall, civil service employment declined by 1.8% over the last five years.

NASA Glenn's civil service employment includes four main occupational categories: (1) administrative professionals, (2) clerical staff, (3) scientists and engineers, and (4) technicians. The occupational structure of NASA Glenn's employment has seen only minor changes during the past five years.

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2014-FY 2018

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
2014	1,624	21%	3%	68%	8%
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%

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 2018, scientist and engineers continue to be the largest occupational category. This occupational category account for 70% of the civil service employees at NASA Glenn. This is the highest percentage of representation for this category in the five-year study period, a historical trend that has continued even before FY 2014. The share of scientists and engineers has continually increased since FY 2014 with the exception of a slight decrease from the share of 71% in 2017 to 70% in FY 2018, even though the total number of NASA Glenn's employees increased between 2017 and 2018.

The second largest occupational category is administrative professionals, representing 21% of NASA Glenn employees in FY 2018, a position which has been held in all prior study years. This category has maintained a comparatively steady share of NASA Glenn employment over the last five years, ranging from 21% to 23% of total civil service employees.

The technicians accounted for 7% of NASA Glenn's civil service employees in FY 2018, an increase from 5% in FY 2017. NASA Glenn employed 112 technicians in FY 2018. This is up 36 employees from the FY 2017's total of 75 (48%). This category of employment had decreased from 8% in FY 2014 to 5% in FY 2017.

The smallest civil service employment category at NASA Glenn is the clerical employees, which represented 2% of total employment in FY 2018. During the past five years, clerical staff had a peak of 55 employees in 2014, dropping to 33 workers in 2015. The number of employees has maintained a relatively steady for the last four years, ranging from 30 to 32 workers.

The employees at NASA Glenn highly educated and highly skilled civil service workers. In FY 2018, 88% of NASA Glenn's employees possessed bachelor's degrees or higher. Of all NASA Glenn's civil service employees, 18% held doctoral degrees, 39% held master's degrees, and 31% held bachelor's degrees. Compared to FY 2014, the level of educational attainment of NASA Glenn's civil service employees has increased, as the number of employees holding bachelor's degrees or higher increased 3% between FY 2014 and FY 2018.[8]

In addition to its own employment, NASA Glenn engaged 1,687 on- or near-site contractors in FY 2018, and it peaked the highest engagement with local contractors during last five years (Table 2). The civil sector employment fell between FY 2014 and FY 2015 by 111 employees (-6.6%), but the local contractor employment has been increased since FY 2015.

Combining civil service employees and local contractors, the total number of employees at NASA Glenn was 3,281 in FY 2018. This was an increase of 147 total employees from FY 2017. From FY 2014 to FY 2018, the highest total combined employment was 3,297 in FY 2014 and the lowest was 3,197 in FY 2016.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2014-FY 2018

Fiscal Year	Employment of On- or Near-Site Contractors
2014	1,673
2015	1,562
2016	1,625
2017	1,626
2018	1,687

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

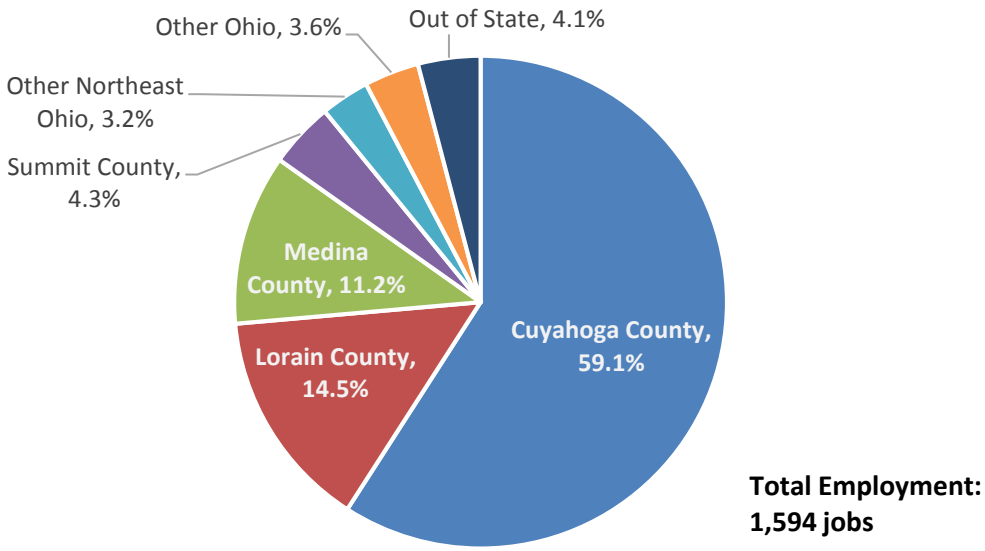
C.2. Place of Residence for Glenn Employees

Regarding the regions of study, NASA Glenn Research Center is located in Cuyahoga County, the heart of Northeast Ohio. The geographic site of NASA Glenn is located near Cleveland Hopkins International Airport in the Greater Cleveland Area. NASA Glenn also includes Plum Brook Station, located near Sandusky, Ohio, west of the main facility. Most civil service employees working at NASA Glenn live in Cuyahoga County or the other surrounding counties that comprise Northeast Ohio.[9] Figure 1 displays the breakdown of employees' postal addresses by geographic region. During FY 2018, almost all of NASA Glenn's civil service employees (1,471 employees; 92.3%) resided in Northeast Ohio.

Of the 1,594 civil servants working at NASA Glenn in FY 2018, 59.1% (or 942 workers) lived in Cuyahoga County, the same county as NASA Glenn Lewis Field. The second largest counties of residence for civil service employees were Lorain County with 14.5% (or 231 employees) of FY 2018 employees. The next largest counties of residence for NASA Glenn employees were Medina County (11.2%; 179 employees), and Summit County (4.3%; 69 employees). The other Northeast Ohio counties account for 3.2% of NASA Glenn employee places of residence, and another 3.6% lived in Ohio Counties outside of Northeast Ohio. Only 4.1% of NASA Glenn employees resided outside Ohio.

In comparison to FY 2017, there was a 0.8% increase in the percentage of NASA Glenn employees residing in Northeast Ohio, going from 91.5% in FY 2017 to 92.3% in FY 2018. The percentage of NASA Glenn employees who reside in Cuyahoga County has increased by 0.9%, while those classified as living out of state decreased by 1.1%. However, the distribution of NASA Glenn employment across regions within and outside of areas of study, Northeast Ohio and Ohio, structurally changed not much over the last five study period.

Figure 1. NASA Glenn Civil Service Employees by Place of Residence, FY 2018



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

Table 3 shows the distribution NASA Glenn civil service employees by occupation and place of residence. Cuyahoga County served as the place of residence for the highest share of employees in each occupational category. More than 55% of NASA Glenn's Technicians, 59% of Scientist & Engineers and Administrative Professional, and 62% of clerical employees lived in Cuyahoga County in FY 2018. 92.3% of NASA Glenn employees lived in Northeast Ohio. All Clerical employees lived in Northeast Ohio, and Technicians employees were the most likely to reside in Northeast Ohio, at 98.7%. Administrative Professional were the most likely occupational category to live outside Northeast Ohio, at 5.0%, and Scientists & Engineers were the most likely to live out of state, at 5.4%.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2018

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	93.6%	100.0%	91.5%	98.7%	92.3%
Cuyahoga County	59.9%	62.5%	59.2%	55.5%	59.1%
Lorain County	14.9%	33.3%	13.7%	18.5%	14.5%
Medina County	10.2%	4.2%	11.2%	18.5%	11.2%
Summit County	5.6%	0.0%	4.1%	2.5%	4.3%
Lake County	1.2%	0.0%	1.1%	1.2%	1.1%
Geauga County	0.3%	0.0%	1.3%	1.2%	1.1%
Portage County	1.5%	0.0%	0.8%	0.0%	0.9%
Ashtabula County	0.0%	0.0%	0.0%	1.2%	0.1%
Other Ohio	5.0%	0.0%	3.2%	1.3%	3.6%
Out of State	1.5%	0.0%	5.4%	0.0%	4.1%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

NASA Glenn civil service employees received total compensation of $235.8 million in FY2018. In this report, total compensation included both payroll ($179.9 million) and employee benefits ($55.9 million).

Between FY 2017 and FY 2018, total compensation increased by $3.4 million (or 1.5%) in nominal dollars.[10] Also, NASA Glenn's nominal payroll has increased by $2.2 million (or 1.2%) during that same period.[11] Additionally, between FY 2014 and FY 2018, total compensation increased by $8.9 million (or 3.9%)[12], and the payroll also slightly increased by $2.0 million (1.1%) in nominal dollars.[13]

During FY 2018, the employee benefits were growing, continuing the trend from FY 2014. The cost of benefits experienced greater increase rate than salary.[14] Percent of benefits in relation to total compensation has been increasing year over year since FY 2014. In 2014, benefit made up 23.7% of total compensation ($49 million). By 2018, this share had increased to 23.7% (55.9 million) in nominal dollars.[15]

Between FY 2017 and FY 2018, the average wage per civil service employee saw nominal decline from $117,863 to $112,853, a 4.2% drop.[16] Between FY 2014 and FY 2018, there was a nominal increase of 3.0% in the total average wage per civil service employees (or $3,339).[17]

[10] In real dollars adjusted for inflation, total compensation increased by $0.5 million, or 0.2% between FY 2017 and FY 2018.

[11] Total payroll has decreased by $58,750 (or 0.03%) between FY 2017 and FY 2018, after adjusting for inflation.

[12] Total real compensation increased by $5.9 million (or 2.6%) over the last five years.

[13] In real dollars adjusted for inflation, the payroll decreased by $0.3 million (or 0.2%) from FY 2014 to FY 2018.

[14] Total real benefits increased by $0.6 million, or 1.1%, between FY 2017 and FY 2018, and $6.2 million, or 12.5%, from FY 2014 to FY2018.

[15] Real benefit was $49.6 million in 2014.

[16] The average wage per employee in real terms decreased 5.4%, or $6,475 between FY 2017 and FY 2018.

[17] The real average wage per employee slightly increased by 1.7%, or $1,890 between FY 2014 and FY 2018.

C.4. NASA GLENN EXPENDITURES, FY 2018

NASA Glenn's expenditures totaled $474.4 million in FY 2018. Vendors in 48 states and ten foreign countries received a portion of NASA Glenn expenditures. In nominal dollars, the FY 2018 total expenditures were $32.4 million higher than that in FY 2017, illustrating a 7.3% increase. When adjusted for inflation to 2018 dollars, NASA Glenn expenditures increased by 21.7 million, or 4.8%, from FY 2017 to FY 2018.[18] Between FY 2014 and FY 2018, expenditures increased by 9.8% representing an increase of $40.4 million in constant 2018 dollars.[19]

Figure 2 displays the geographic distribution of NASA Glenn's spending during FY 2018. Ohio continues to be the largest beneficiary of expenditures, receiving $290.8 million of NASA Glenn's total expenditures in FY2018. With a $4.52 million decrease in nominal dollars compared to FY 2018, the share of NASA Glenn's expenditures in Ohio decreased from 66.8% in FY 2017 to 61.3% in FY 2018.[20]

Northeast Ohio received $266.4 million of NASA Glenn's total expenditures in Ohio, accounting for 91.6% of total Ohio spending in FY 2018. Northeast Ohio accounted for 56.2% of NASA Glenn's total spending in FY 2018. Cuyahoga County was by far the largest recipient of NASA Glenn spending in Northeast Ohio, accounting for 97.6% of said spending, Additionally, Cuyahoga County represented 89.4% of spending in Ohio as well as 54.8% of total NASA Glenn spending in FY 2018.

After Ohio, the states that received the largest portions of NASA Glenn spending in FY 2018 were Washington and Maryland. Washington received $41.2 million, or 8.7% of total FY 2018 spending, and Maryland received $26.8 million, or 5.6% of total spending. These two states received the second and third largest portions of NASA Glenn spending in FY 2018. Between FY 2017 and FY 2018, spending in Washington increased by $10.8 million, or 35.5%, in nominal dollars. Over the same time, spending in Maryland increased by $2.1 million, or 8.4%.

Aside from Ohio and the two states listed above, Alabama experienced the largest nominal dollar increase in expenditures at $17.3 million, and Illinois saw the largest nominal dollar decline at $2.0 million. In addition to Texas ($4.7 million), Kansas ($3.0 million), California ($2.7 million), New Hampshire ($1.1 million), and Massachusetts ($1.0 million) all saw an increase in NASA Glenn spending totaling more than $1 million last two years. (See Appendix Table A.1 for more information on NASA Glenn spending by state.)

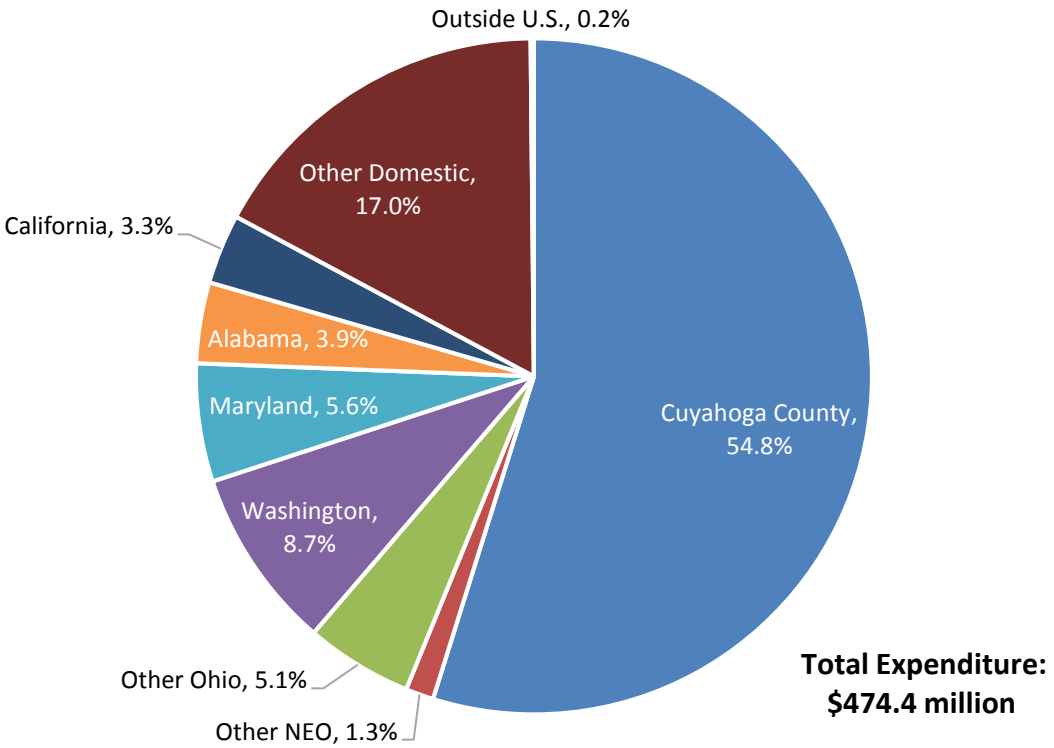
In FY 2018, NASA Glenn increased its expenditures in foreign countries by 6.0% compared to FY 2017. Foreign countries received $0.7 million, accounting for 0.2% of NASA Glenn's total spending in FY 2018. Among foreign countries, the largest beneficiary was Canada (See Appendix Table A.1 for more information on NASA Glenn out of country expenditures).

[18] Inflation was adjusted using CPI-U for the United States.

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

[20] Total expenditures decreased by $11.72 million in real dollars adjusted for inflation between FY 2017 and FY 2018.

Figure 2. NASA Glenn Spending in Selected Regions, FY 2018



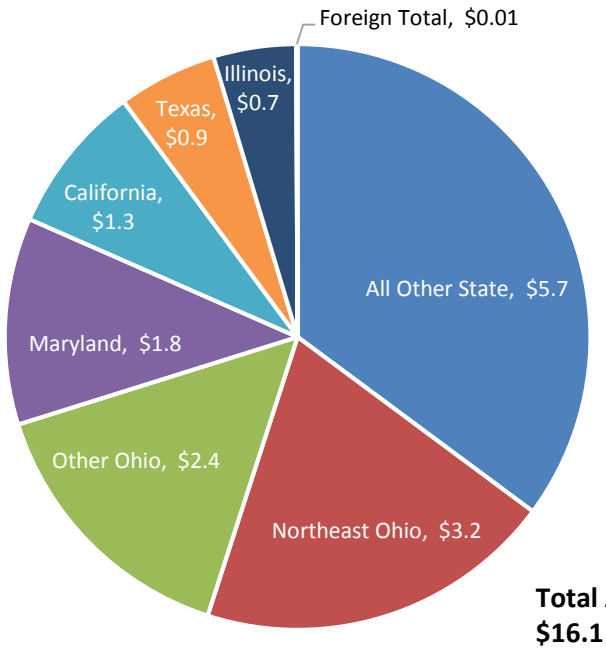
C.5. NASA Glenn Awards to Academic Institutions

NASA Glenn Research Center funds colleges, universities, and other nonprofit institutions using R&D contracts and grants for assisting NASA in their own R&D activities. The amount of NASA Glenn's funding to academic and major institutions is driven by NASA Glenn's goals and mission for each year.

In FY 2018, NASA Glenn's funding to colleges and universities in 33 states and Great Britain, totaled $16.1 million. Grants accounted for $11.9 million of this total. In comparison to FY 2017, the total amount of funding to academic institutions decreased by $2.0 million in FY 2018, a decrease of -11.2% (in nominal dollars). NASA Glenn also awarded $4.2 million in contracts to Ohio academic institutions in FY 2018 through on-site contracts.

Figure 3 displays the distribution of funding awarded to colleges and universities with emphasis on select states that received a large share of the funding. The academic funding awarded in the top five states – Ohio, Maryland, California, Illinois, and Texas – in FY 2018 collectively accounted for 64.8% of the total awards, compared to the top five states representing 63.2% of total grants during FY 2017. Maryland experienced a 24.5% of nominal increase in awards from $1.4 million in FY 2017 to $1.8 million in FY 2018, while the other four states saw a nominal decline in awards (See Appendix Table A.2. for more information).

Figure 3. NASA Glenn Academic Awards to Colleges and Universities, FY 2018 (in million)



Total Academic Awards: $16.1 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 $5.6 million, which accounted for the largest share (35.0%) of NASA Glenn's academic awards in FY 2018. NASA Glenn's academic awards to Ohio decreased by 1.6% between FY 2017 and FY 2018. Of 5.6 million awarded to Ohio academic institutions in FY 2018, 3.2 million went to academic institutions in Northeast Ohio. Northeast Ohio received 56.6% of the total academic awards granted in the state of Ohio and 19.8% of all NASA Glenn academic awards. In comparison to FY 2017, Northeast Ohio's share of awards increased both at the state level (55.6% of total Ohio awards in FY 2018), and national level (17.6% of total awards in FY 2018).

In FY 2018, among the states outside Ohio, the state of Maryland received $1.84 million, which accounted for the second largest share (11.4%) of NASA Glenn's academic awards. California and Texas ranked third and fourth, receiving $1.33 million and $0.88 million, respectively, in funding to academic institutions, or 8.3% and 5.5% of total awards.

Table 4 presents the distribution of NASA Glenn awards to academic institutions in the State of Ohio from FY 2014 to FY 2018 (inflated to 2018 dollars).[21] During the past five years, the total amount of funding to Ohio academic institutions decreased by 7.5%, going from $6.1 million in FY 2014 to $5.6 million in FY 2018, after adjusting for inflation.[22] Total academic funding awarded in Ohio has decreased by $200,557 (or 3.4%) between FY 2017 to FY 2018. FY 2017 is the first year to include both academic grants and contract dollars in the totals.

Case Western Reserve University (CWRU) and University of Toledo received most funding to Ohio academic institutions. CWRU received $2.3 million, representing the highest amount of funding in FY 2018, and University of Toledo received $1.9 million in FY 2018. For CWRU, this was a $0.3 million or 15.7% increase in funding between FY 2014 and FY 2018. For University of Toledo, this was a $0.8 million or 29.2% decrease during last five years (adjusted to 2018 dollars).[23] Combined, the two universities accounted for 74.7% of NASA Glenn awards to Ohio academic institutions in FY 2018.

In FY 2018, the University of Akron received $441,243, and ranked the third share of the total funding to Ohio academic institutions and Ohio State University received $369, 984 and ranked fourth. The remainder of the FY 2018 awards from NASA Glenn to Ohio academic institutions went to Cleveland State University ($369,984), University of Cincinnati ($133,860), Kent State University ($133,585), Cuyahoga Community College ($107,237), and Ohio University ($75,829).

[21] 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.

[22] NASA Glenn decreased its total academic funding in Ohio by 3.8%, from $5.9 million in FY 2014 to 5.6 million in FY 2018 in nominal dollars.

[23] Academic funding awarded to CWRU increased by 20.3% or 0.4 million and to University of Toledo decreased by 26.4% or $0,7 million between FY 2014 and FY 2018 (in nominal dollar)

Table 4. NASA Glenn Total Awards in Ohio by Academic Institution, FY 2014-FY 2018

Ohio Colleges and Universities	FY2014	FY2015	FY2016	FY2017	FY2018	FY2018 Share
Case Western Reserve University	$2,023,376	$1,864,750	$1,821,124	$2,389,720	$2,341,334	41.6%
University Of Toledo	$2,632,113	$2,597,889	-	$1,896,335	$1,864,230	33.1%
The University Of Akron	$1,218,101	$815,169	$566,048	$448,576	$441,243	7.8%
Ohio State University	$18,715	$280,474	$367,448	$327,289	$369,984	6.6%
Cleveland State University	$120,169	$751,436	$336,519	$174,295	$163,237	2.9%
University Of Cincinnati	-	-	-	$234,665	$133,860	2.4%
Kent State University	-	$21,094	$41,200	$93,423	$133,585	2.4%
Cuyahoga Community College	-	-	$163,780	$136,226	$107,237	1.9%
Ohio University	$71,737	$62,031	$80,700	$130,565	$75,829	1.3%
TOTAL	$6,084,211	$6,392,841	$3,376,819	$5,831,095	$5,630,538	100.0%

Notes:
Table is sorted by FY 2018 column.
Data inflated to 2018 dollars (Inflation 234.4 based on CPI for the Midwest region).

C.6. NASA Glenn Revenues

NASA Glenn's total revenue in FY 2018 reached $745.3 million, which increased 7.9% from FY 2017 without adjustment for inflation. During the last five years, NASA Glenn revenues ranged from $664.1 million in FY 2016 to $745.3 million in FY 2018. Overall, NASA Glenn's revenue has increased by $67.4 million (9.9%) from FY 2014 to FY 2018 in nominal dollars.

Table 5 displays NASA Glenn's revenue by source from FY 2014 to FY 2018. NASA Glenn's revenue consists of two sources: NASA direct authority and reimbursable commitments. The share of revenue from NASA's direct authority steadily increased between FY 2014 and FY 2017 before dropping from 94.9% in FY 2017 to 93.6% in FY 2018. In FY 2018, NASA Glenn received $697.4 million of revenue directly from NASA and an additional $47.9 million from reimbursable commitments.

As shown in Table 5 below, reimbursable funding has changed between FY 2014 and FY 2018, reflecting the fluctuation of non-NASA customers doing business with NASA Glenn in recent years. In the past year alone, Glenn's revenues from reimbursable commitments have increased by 36% or $12.7 million in normal dollars from FY 2017 to FY 2018.

Federal funding remains the largest source of revenue for reimbursable commitment, accounting for 83.6%. Between FY 2017 and FY 2018, the Department of Defense accounted for the largest share of total reimbursable commitment (61.3%) and Other Federal Agency had the second-largest share of the total reimbursable commitment (22.3%). Last two years, reimbursable commitments from the Department of Defense saw a 10.1% increase, driven largely by the U.S. Air Force, which had shown a 6.0% increase.

Table 5. NASA Glenn Revenues, FY 2014-FY 2018 (in millions of nominal dollars)

Description	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
NASA Direct Authority	$618.8	$624.6	$623.4	$655.9	$697.4
Total Reimbursable Commitments	$59.1	$46.9	$40.7	$35.2	$47.9
Total FY Authority	$677.9	$671.5	$664.1	$691.1	$745.3
NASA Budget %	91.3%	93.0%	93.9%	94.9%	93.6%

Note: Data in thousands of nominal dollars.

C.7. Taxes Paid by NASA Glenn Employees

The taxes paid by NASA Glenn employees directly to local and state governments contribute substantially to the Northeast Ohio regional economy and the economy of the state. NASA Glenn is located in the cities of Brook Park, Fairview Park, and Cleveland, which affects the distribution of income tax paid by Glenn employees.

Table 6 shows the amount of income taxes NASA Glenn employees paid at the local, state, and federal levels. The table does not include taxes paid by NASA Glenn employees to local governments based on their place of residence. Total income tax paid by NASA Glenn employees in FY 2018 amounted to $31.8 million, a slight decrease (4.8%) compared to FY 2017 (in a nominal dollar comparison).

In FY 2018, NASA Glenn employees paid $9.1 million in income taxes at the state and local levels, an increase of 2.2% from FY 2017, without adjustment for inflation. The amount of taxes paid to local and state governments has increased slightly every year since FY 2016, going from $8.8 million in FY 2016 to $9.1 million in FY 2018.

Of the taxes paid at the state and local level, the clear majority (99.6%) went to the city of Brook Park and the State of Ohio in FY 2018. The State of Ohio received 62.9% of the income taxes at the state and local level in FY 2018 with a total of $5.7 million. Over the past five years, NASA Glenn employees paid annually an average of more than $5.6 million in income taxes to the state of Ohio.

At the local level, the city of Brook Park received $3.4 million in income tax from NASA Glenn employees in FY 2018, a slight increase (1.0%) compared to FY 2017. This amount of taxes account for 99.0% of income taxes paid to the three listed cities by NASA Glenn employees in FY 2018, a total of $3.4 million. The taxes received by the city of Brook Park increased 0.5% between FY 2014 and FY 2018. In addition, income tax paid to the city of Cleveland remained low, but it increased by 71.8% between FY 2014 and FY 2018. In FY 2018, NASA Glenn employees paid $12,039 in income taxes to the city of Cleveland, an increase of 19.1% when compared to FY 2017.

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
2014	$3,339,884	$7,009	$25,180	$5,731,492	$23,964,173	**$33,067,738**
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**
5-Year Total	**$16,647,501**	**$48,967**	**$126,644**	**$28,239,258**	**$119,256,036**	**$164,318,405**

D. ECONOMIC IMPACT OF NASA GLENN

This section provides details on the methodology and illustrates results of research on the economic impact NASA Glenn had on Northeast Ohio and the State of Ohio in FY 2018.[24] 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.[25] NASA Glenn's total impact on Northeast Ohio and the State of Ohio are presented as separate estimates.

D.1. METHODOLOGY

Estimates of NASA Glenn's economic impact assume that NASA Glenn established its operations in the region at the beginning of FY 2018 and generated a 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. [26] The initial NASA's expenditures (i.e. change in final demand) in the region results 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 the direct impact. 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, 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

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

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

[26] 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.[27]

This study utilizes regional I-O multipliers from the IMPLAN Professional model.[28] Specifically, SAM multipliers are used to estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.[29] 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 the commuting patterns of NASA Glenn employees living outside the study area contributes to total payroll accounting for additional income spent within a region of study, 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. 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 excluded when estimating the statewide impact of NASA Glenn.

Adjustments by commuting pattern were made to total payroll amounts to account for local spending by employees residing outside of the 8-county region and outside of the state for the Northeast Ohio and Ohio portions of the economic impact, respectively. IMPLAN considers the difference between the average regional share of commuting employees and the institution's share of employees living outside of the region. The model adjusts the total payroll by this difference, assuming that the commuting employees still spend a portion of their income near their employer. Because all of NASA Glenn's revenues came from

[27] 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.

[28] 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.

[29] 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.

federal sources (from outside of the study area), no further adjustments were required.

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.[30]
- 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.

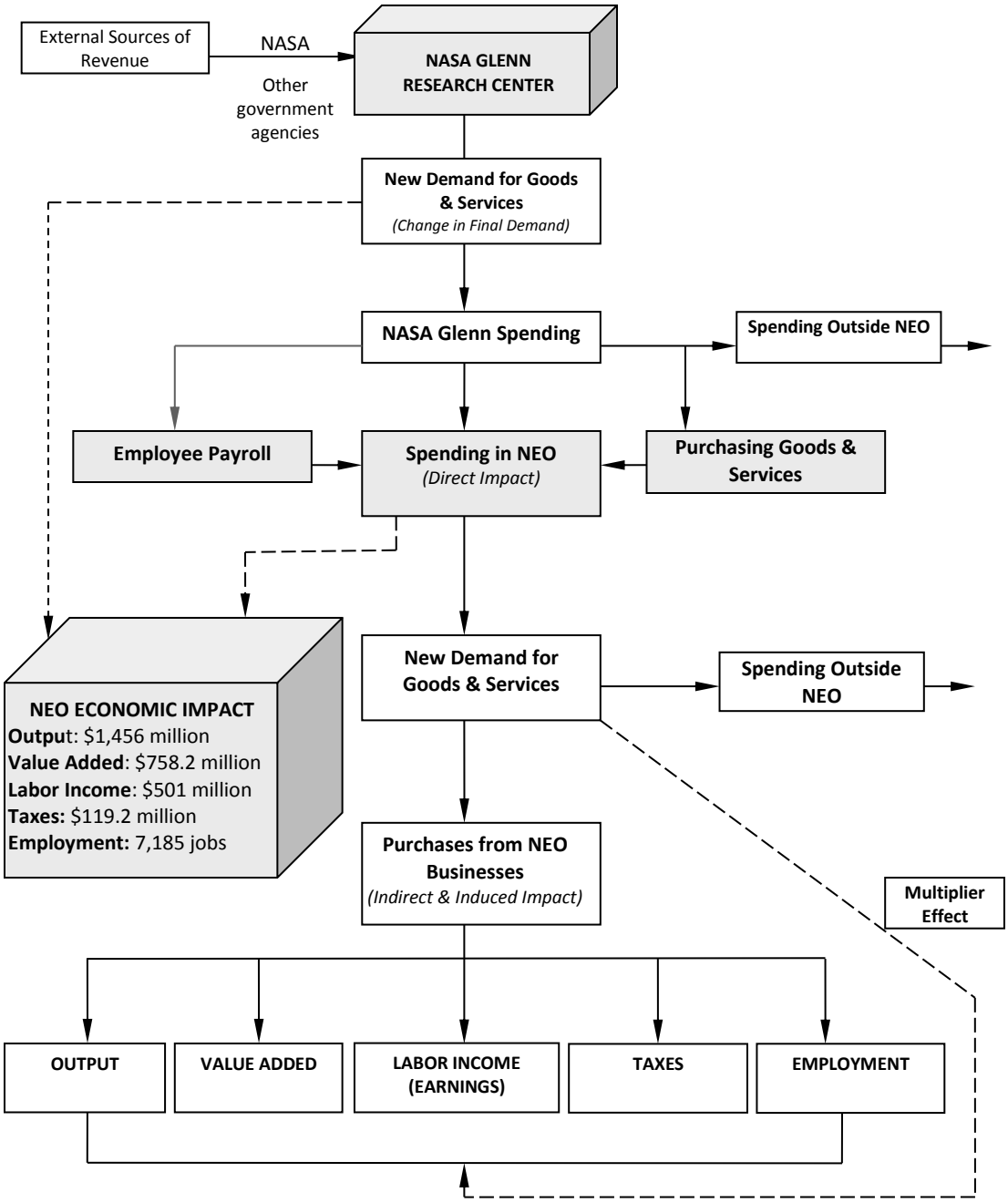
The employment, labor income, value added impact, and output impact are each a summation of three components: direct impact, indirect impact, and induced impact.[31] Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio's economy through its spending in the region in FY 2018.

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.

[30] 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.

[31] 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 2018



D.2. Economic Impact on Northeast Ohio, FY 2018

This section details the effects NASA Glenn had on the economy of Northeast Ohio in FY 2018. These effects are encompassed 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 2018

To calculate an output income, NASA Glenn's expenditures were divided into two baskets of spending: (1) goods and services purchased from companies and institutions located in Northeast Ohio and (2) spending for goods and services from businesses and other institutions located outside Northeast Ohio. The first group of spending creates an economic impact on the economy of Northeast Ohio, while the second group is considered a regional "leakage"; therefore, these expenditures are not included in calculating the output impact on Northeast Ohio. Local spending is then categorized by products produced by different industries in the regional economy, based on an IMPLAN industry classification system that differentiates spending across 536 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., illustrates detailed NASA Glenn expenditures in Northeast Ohio by industry.

About 47% of NASA Glenn total expenditures in Northeast Ohio went towards employee compensation. NASA Glenn's largest expenditures on goods and services in Northeast Ohio in FY 2018 were made on professional, scientific and technical services (30.5%), including about 21.2% of total expenditures on scientific research and development services. NASA Glenn's spending in Northeast Ohio has a significant regional economic impact.

Table 7 presents the total output impact of NASA Glenn on the economy of Northeast Ohio, disaggregated into direct impacts, indirect impacts, and induced impacts. NASA Glenn's total operational expenditures represent direct output impact for Northeast Ohio. This impact includes the regional margin of purchases from the retail industry. Indirect impact is estimated as all direct purchases of goods and services made from industries in Northeast Ohio and the contributions of individual industries acting as suppliers for the producers of the goods and services consumed by NASA Glenn. Lastly. Induced impact is derived from measuring the spending of employees as a result of the demand for products and services created by Glenn.

Table 7. Output Impact in Northeast Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$45,911	$204,861	$250,772
Mining		$537,084	$534,255	$1,071,339
Utilities		$16,365,609	$7,191,697	$23,557,306
Construction		$22,179,497	$3,871,778	$26,051,275
Manufacturing		$4,468,447	$6,952,863	$11,421,310
Wholesale Trade		$3,799,730	$15,148,700	$18,948,430
Retail Trade		$4,513,283	$32,832,617	$37,345,901
Transportation and Warehousing		$4,621,556	$9,912,269	$14,533,825
Information		$6,748,938	$14,324,095	$21,073,034
Finance and Insurance		$11,482,702	$45,409,786	$56,892,488
Real Estate and Rental		$23,963,470	$62,389,218	$86,352,688
Professional, Scientific, and Tech Services		$192,614,577	$15,383,356	$207,997,933
Management of Companies		$4,767,719	$4,779,516	$9,547,234
Administrative and Waste Services		$85,867,868	$10,821,040	$96,688,909
Educational Services		$11,884,334	$6,591,083	$18,475,418
Health and Social Services		$30,382	$61,079,080	$61,109,462
Arts, Entertainment, and Recreation		$866,621	$7,120,914	$7,987,535
Accommodation and Food Services		$2,743,961	$18,712,530	$21,456,491
Other Services		$5,592,825	$15,700,583	$21,293,408
Government & non-NAICs	$710,115,840	$1,029,776	$3,170,770	$714,316,386
Total Output	**$710,115,840**	**$404,124,293**	**$342,131,009**	**$1,456,371,142**

Notes: For output impact, the change in final demand or direct impact ($710,115,840) 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 economic impact are shown in 2018 dollars.

The total output impact of NASA Glenn on Northeast Ohio was $1.4 billion in FY 2018. NASA Glenn's $710.1 million worth of expenditures resulted in an output (sales) change of $1.4 billion across all industry sectors (Table 7). For example, Glenn spending affected a $208.0 million increase in sales - direct, indirect, and induced - by the Professional, Scientific, and Technical services industry and an $11.4 million increased in total sales by the Manufacturing industry. Furthermore, if NASA Glenn did not exist in Northeast Ohio, the regional economy would suffer a $96.7 million decrease in output in the Administrative and Waste Services industry. These 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, 48.8% ($710.1 million in 2018 dollars) is accounted for by NASA Glenn's direct spending, which constitutes the direct economic impact to Northeast Ohio. Approximately $404.1 million (27.7%) of the total output impact is a result of indirect spending by NASA Glenn. The remaining output impact of $342.1 million (23.5%) is attributable to the induced components as NASA Glenn spending ripples through the economy.

A detailed analysis of the IMPLAN model's results indicated that the indirect and induced portions (totaled $746.3 million, or 51.2% of total output) can be further divided into three broad categories: NASA Glenn-driven industries, consumer-driven industries, and other industries.

NASA Glenn-driven industries are industries that increases 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 support services; and education. The total increase in output due to indirect and induced economic impacts from the aforementioned industries in FY 2018 was $393.5 million or 52.7% of NASA Glenn's overall indirect and induced impact on Northeast Ohio.

Consumer-driven sectors are those that increased 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: retail; healthcare; real estate; other services (see below); owner-occupied buildings; finance and insurance; and entertainment and food. The increase in output due to indirect and induced economic impacts for these industries in FY 2018 was $276.7 million or 37.1% of the total impact.

Other industries are driven by both NASA Glenn and consumer spending, but their impact is split between NASA Glenn and other area businesses, 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 2018 was $76.0 million or 10.2% of the total impact.

The output distributions for select Glenn- and consumer-driven industries are shown in Figures 5 and 6, respectively. Industries with additional sales of at least $15 million or 4.0% and 9 million or 3.5% were selected to be present in Figure 5 and 6, respectively.

The largest output was generated by scientific research and development services industry, increasing by $111.8 million in FY 2018 due to 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 $111.8 million represented 28% of the $393.5 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 consumer-driven industries of the economy that saw largest increases in sales. The real estate industry saw an increase in sales of $45.8 million in FY 2018. This industry generated the largest output impact (17%) of the $276.7 million increase in output for all industries within the consumer-driven sector. This amount is the summation of the indirect and induced impacts generated primarily by NASA Glenn employees and other workers for rental activities.

Figure 5. Increase in Sales for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2018

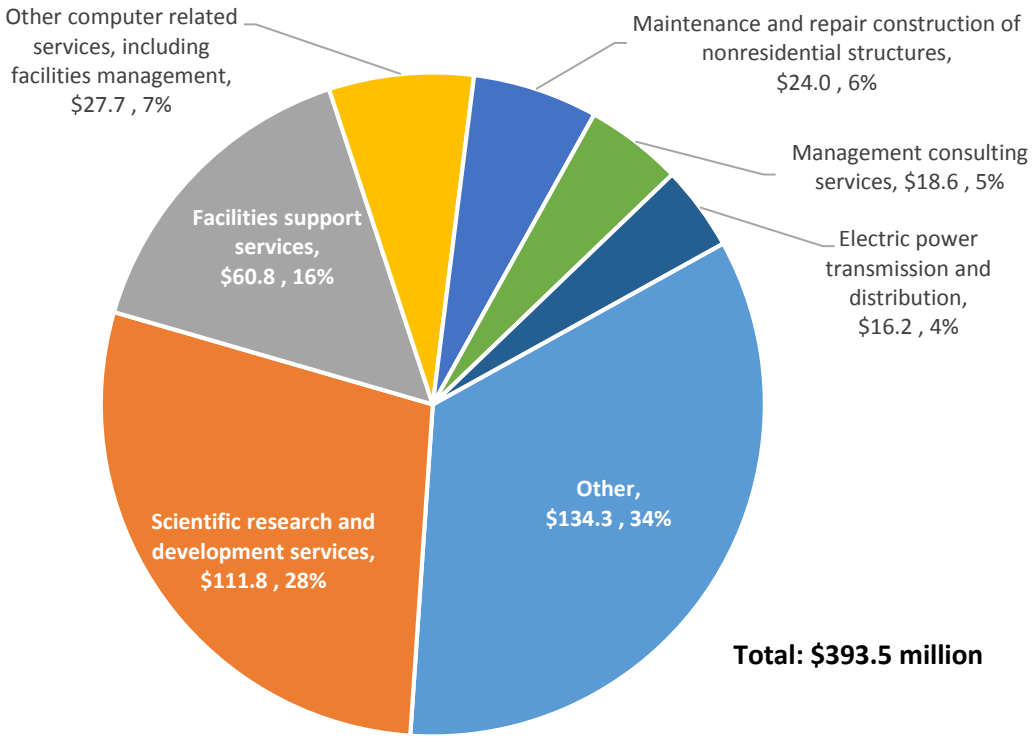
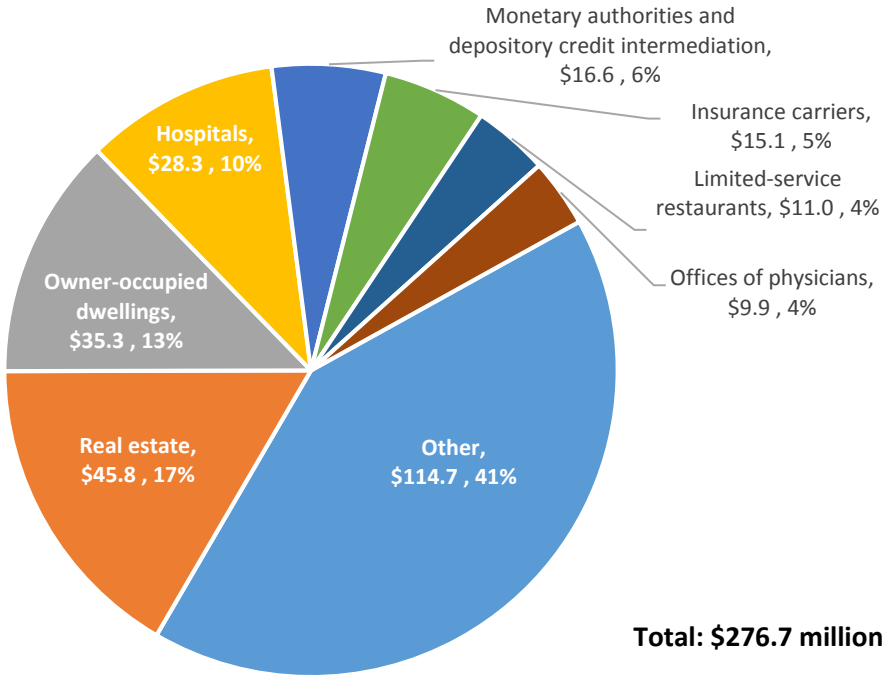


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2018



Total: $276.7 million

D.2.2. Employment Impact on Northeast Ohio, FY 2018

NASA Glenn's presence in Northeast Ohio supported existing jobs and created new full-time and part-time jobs elsewhere, in addition to its own employment (change in final demand or direct impact). NASA Glenn's spending generated increased employment in its supplier industries (indirect impact).

In addition, money spent by employees of NASA Glenn, employees of supply companies created jobs in various other industries that sell products and services to the population (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 industry sector.

Table 8. Employment Impact in Northeast Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		1	4	5
Mining		1	1	1
Utilities		21	6	27
Construction		167	23	190
Manufacturing		15	15	31
Wholesale Trade		16	64	81
Retail Trade		86	365	451
Transportation and Warehousing		36	78	115
Information		17	31	48
Finance and Insurance		35	156	191
Real Estate and Rental		109	129	238
Professional, Scientific, and Tech Services		1,169	110	1,279
Management of Companies		20	20	40
Administrative and Waste Services		828	148	975
Educational Services		476	115	591
Health and Social Services		0	561	562
Arts, Entertainment, and Recreation		16	77	93
Accommodation and Food Services		51	322	372
Other Services		54	234	289
Government & non-NAICs	1,594	3	11	1,608
Total Employment	**1,594**	**3,120**	**2,471**	**7,185**

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

The total employment impact of NASA Glenn on the Northeast Ohio economy in FY 2018 was 7,185. Out of the total employment, 1,594 (22.2%) were directly employed at NASA Glenn research Center in FY 2018. As a result of Glenn's spending on goods and services, an additional 3,120 full-time and part-times jobs (43.4%) were supported and created in the region as indirect economic impact. The rest of the employment impact, 2,471 jobs (34.4%), was 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.

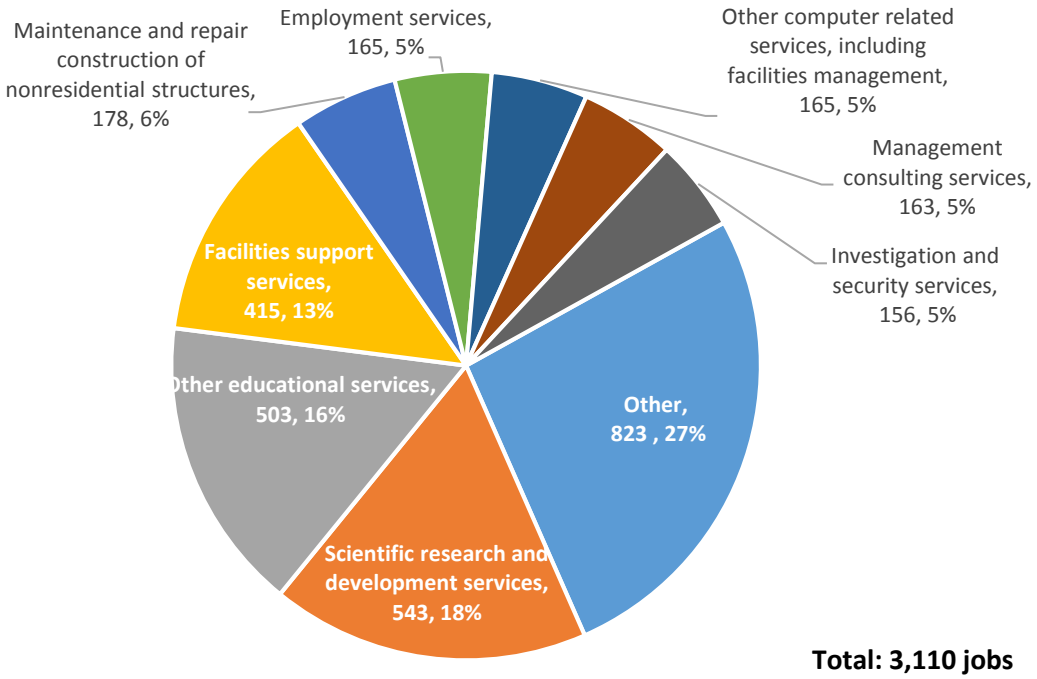
Of the 5,591 jobs created and supported in Northeast Ohio due to the indirect and induced impacts, 3,110 (55.6%) were found in the NASA Glenn-driven industries, 1,975 (35.3%) were in the consumer-driven industries, and 507 (9.1%) fall under the category of other industries.[32] The job distribution for select NASA Glenn and consumer-driven industries are shown in Figure 7 and 8, respectively. The industries displayed in Figures 7 and 8 are the leading industries with the most increased employment (minimum of 150 employees (or over 5.0%) per sector in Figure 7 and 70 (or over 3.5%) in Figure 8).

The scientific research and development service industry generated the largest number of additional jobs. Companies engaged in scientific R&D (professional, scientific, and technical services sector) saw an increase of 543 jobs in FY 2018 due to NASA Glenn's operation in Northeast Ohio (Figure 7). 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 Northeast Ohio's R&D contractors sector. The 523 jobs accounted almost for 18% of the 3,110 jobs that were created in all industries within the NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted similarly.

The real estate industry saw the largest increase among consumer-driven industries; the increase of 220 jobs in FY 2018 was due to NASA Glenn's spending generating labor income in regional supply industries (Figure 8). These jobs are the summation of the indirect and induced employment impacts generated primarily, but not exclusively, by NASA Glenn's spending on real estate in Northeast Ohio. The 220 jobs represent an 11% of the 1,975 jobs created across all consumer-driven industries.

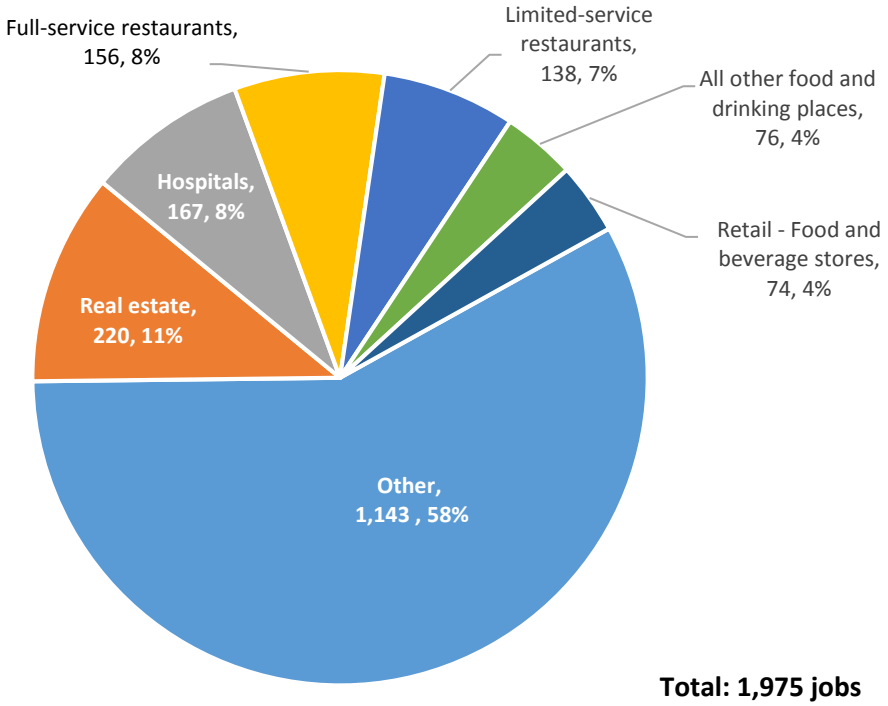
[32] NASA Glenn-driven industries include utilities, construction, information, education, professional and scientific services, and administrative and support services. Consumer-driven industries include retail, healthcare, real estate, other services, owner-occupied buildings, and finance and insurance.

Figure 7. Increase in Jobs for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2018



Total: 3,110 jobs

Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2018



Total: 1,975 jobs

D.2.3. Labor Income Impact on Northeast Ohio, FY 2018

Labor income impact is the estimated total change in labor income paid to employees of local businesses due to spending by NASA Glenn for goods and services purchased in Northeast Ohio and money paid to employees of NASA Glenn. The total wages and benefits paid to all NASA Glenn employees constituted the change in final demand or direct impact of NASA Glenn in Northeast Ohio measured in labor income.

The direct economic impact represents the total compensation NASA Glenn pays its employees within and outside the region. Indirect impact is estimated by summing the money paid to people working for companies that provide products and services purchased by NASA Glenn and inputs to the producers of goods and services ultimately consumed by NASA Glenn.

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 (change in final demand or the direct effect), indirect, and induced impacts. Table 9 displays the earnings impact by industry sector.

Table 9. Labor Income Impact in Northeast Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$27,960	$71,631	$99,591
Mining		$314,923	$184,503	$499,427
Utilities		$2,058,029	$847,061	$2,905,090
Construction		$8,904,769	$1,429,961	$10,334,730
Manufacturing		$1,072,914	$1,099,503	$2,172,417
Wholesale Trade		$1,419,966	$5,654,428	$7,074,394
Retail Trade		$2,071,319	$12,014,754	$14,086,073
Transportation and Warehousing		$2,091,276	$4,280,533	$6,371,809
Information		$1,317,199	$2,308,253	$3,625,452
Finance and Insurance		$2,671,483	$9,892,213	$12,563,696
Real Estate and Rental		$1,745,961	$2,202,683	$3,948,643
Professional, Scientific, and Tech Services		$85,697,848	$8,450,717	$94,148,565
Management of Companies		$2,420,447	$2,426,436	$4,846,884
Administrative and Waste Services		$27,902,329	$5,436,956	$33,339,285
Educational Services		$7,747,006	$4,182,094	$11,929,100
Health and Social Services		$15,413	$33,843,782	$33,859,195
Arts, Entertainment, and Recreation		$324,020	$2,275,185	$2,599,205
Accommodation and Food Services		$1,135,147	$6,963,197	$8,098,343
Other Services		$3,086,575	$8,917,669	$12,004,244
Government & non-NAICs	$235,160,675	$333,495	$1,026,006	$236,520,176
Total Output	**$235,160,675**	**$152,358,078**	**$113,507,565**	**$501,026,318**

Notes: Labor income constitutes economic impact through households of NASA employees and those affected by NASA operations throughout the economy. The direct labor income is adjusted for commuters' compensation. Economic impact is shown in 2018 dollars.

Total labor income increased by $501.0 million in Northeast Ohio as a result of NASA Glenn's operation in FY 2018. Of the $501.0 million of the total labor income, $235.2 million (46.9%) constituted wages and benefits paid directly to NASA Glenn employees (i.e., change in final demand or direct effect measured in 2018 dollars). Of the total impact, $152.4 million (30.4%) represented indirect impact, or the money paid to employees of companies in Northeast Ohio that supply goods and services to NASA Glenn. The remaining earnings constitute an induced impact of $113.5 million (22.7%); occurring as the effects of NASA Glenn's spending rippled through the Northeast Ohio economy via spending derived from labor income.

Of the $265.9 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, $156.2 million (58.8%) was reported in NASA Glenn-driven industries, $82.0 million (30.8%) observed in consumer-driven industries; and $27.7 million (10.4%) was reported in other industries.[33]

The labor income distribution for select NASA Glenn-driven industries is shown in Figure 9. The labor income distribution for select consumer-driven industries is shown in Figure 10. Selected industries, shown in Figure 9 and 10, added over $7.5 million (over 4.0%) and $2.4 million (over 3.0%), respectively.

In the NASA Glenn-driven industries, people who were engaged in scientific research and development services saw their labor income increase by $38.9% million in FY 2018 as shown in Figure 9. These 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 $38.9 million spent on scientific research and development represent at 25% of the $156.2 million increase in labor income reported by all the NASA Glenn-driven industries in FY 2018.

Private hospitals, part of the consumer-driven industries, saw their labor income increased by 13.9 million in FY 2018 (Figure 10). These earnings are the summation of the indirect and induced impacts generated by consumer spending for doctors' services. The $13.9 million accounted for 17% of the $82 million labor income increase that occurred in all consumer-driven industries. Other industries shown in Figure 10 can be interpreted similarly.

[33] 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 2018

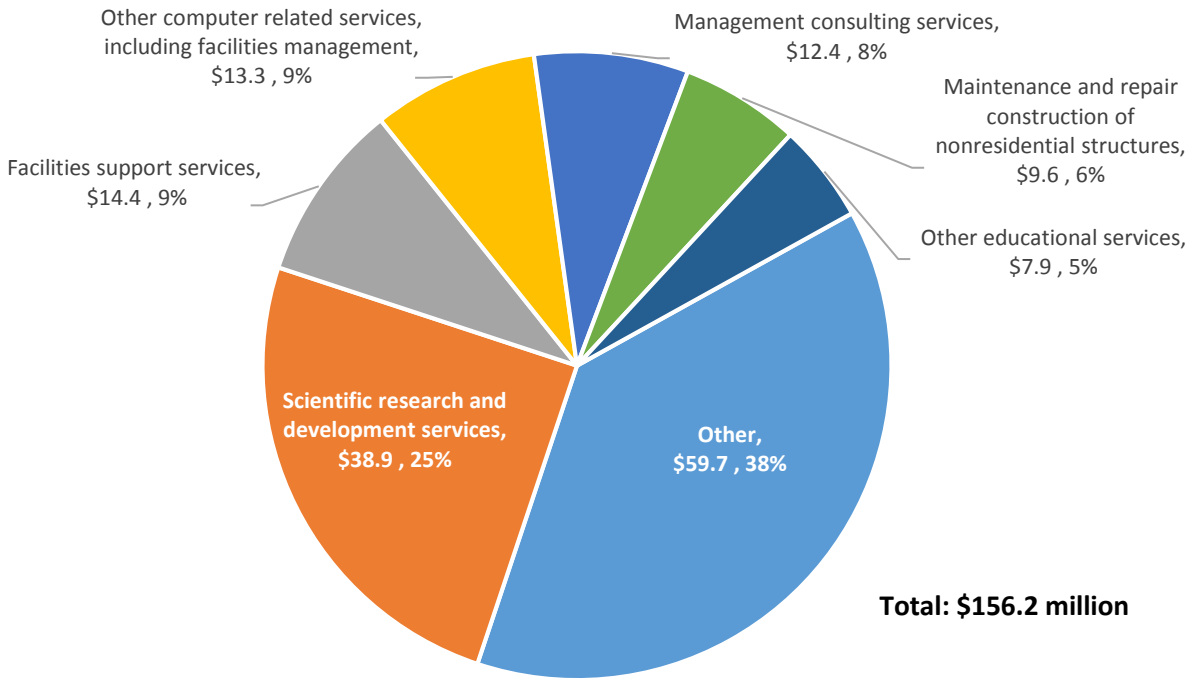
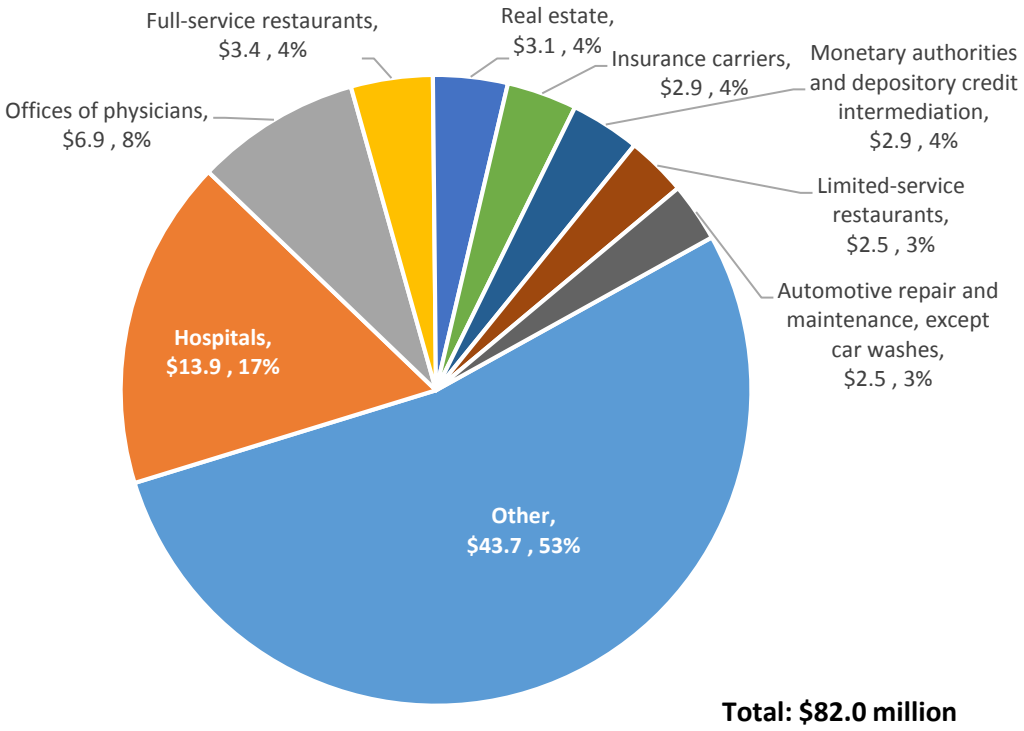


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2018



D.2.4. Value Added Impact on Northeast Ohio, FY 2018

The total value added[34] impact in Northeast Ohio was $758.2 million, which resulted from NASA Glenn's regional spending on goods and services. NASA Glenn spending led to a $758.2 million increase in sale (direct, Indirect, and induced impacts) by all industries, excluding intermediary goods and services. The total output less intermediate expenditures, $333.7 million in FY 2018, constituted the change in final demand (or direct impact) for value added. 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 sales, excluding intermediary goods and services, in all industries that produced products for industries in which income was affected by the demand for products and services created by NASA Glenn. The total value added impact was found by adding the direct, indirect, and induced impacts. Table 10 displays the value added impact by industry sector.

[34] "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 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$33,715	$104,763	$138,478
Mining		$460,046	$438,041	$898,087
Utilities		$8,371,139	$3,475,059	$11,846,199
Construction		$11,403,620	$1,817,905	$13,221,525
Manufacturing		$1,706,034	$2,364,063	$4,070,096
Wholesale Trade		$2,581,253	$10,278,774	$12,860,028
Retail Trade		$2,772,615	$20,335,905	$23,108,520
Transportation and Warehousing		$2,365,365	$4,874,427	$7,239,793
Information		$2,855,962	$6,302,828	$9,158,789
Finance and Insurance		$7,482,664	$24,562,711	$32,045,374
Real Estate and Rental		$17,109,180	$42,655,700	$59,764,881
Professional, Scientific, and Tech Services		$100,861,765	$10,170,503	$111,032,268
Management of Companies		$2,811,310	$2,818,266	$5,629,575
Administrative and Waste Services		$44,391,085	$7,136,914	$51,527,999
Educational Services		$7,733,732	$4,184,068	$11,917,800
Health and Social Services		$17,269	$37,336,927	$37,354,196
Arts, Entertainment, and Recreation		$439,709	$4,157,379	$4,597,089
Accommodation and Food Services		$1,413,337	$9,689,602	$11,102,939
Other Services		$3,998,087	$10,799,263	$14,797,350
Government & non-NAICs	$333,754,445	$531,067	$1,626,521	$335,912,032
Total Output	**$333,754,445**	**$219,338,953**	**$205,129,619**	**$758,223,018**

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 the Northeast Ohio. For an average research institution in Northeast Ohio, the intermediate expenditures accounted for 54% of total output. Economic impact is shown in 2018 dollars.

Total value added in Northeast Ohio increased by $758.2 million in FY 2018 as a result of Glenn's spending on goods and services. Out of this total amount, $333.8 million (44.0%) accounts for the change in final demand or direct impact, calculated as total output less intermediate expenditures, or the large portion of the value added in the wages and salaries paid to NASA Glenn employees. Another $219.3 million (28.9%) represented the value of goods and services, fewer 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 $205.1 million (27.1%). This was the result of the ripple effects NASA Glenn's spending had on Northeast Ohio economy.

Of the $424.5 million increase in value added generated across Northeast Ohio due to the indirect ($219.3 million) and induced impacts ($205.1 million), $208.6 million (49.1%) was observed in Glenn-driven industries, $173.5 million (40.9%) was occurred in consumer-driven industries, and $42.4 million (10.0%) was reported in other industries.[35]

The value added distribution for select NASA Glenn-driven industries is shown in Figure 11. The value added distribution for select consumer-driven industries is shown in Figure 12. Each of the select industries shown in Figures 11 and 12 added at least $7.5 million and $5.5 million each, respectively.

The scientific research and development services industry, the largest NASA Glenn-driven industries, saw a value added increase of 51.8 million in FY 2018 (Figure 11). This amount is the summation of the indirect and induced impacts generated by NASA Glenn's spending. This increase of $51.8 million represented a 25% share of the $208.6 million increase in value added for all NASA Glenn-driven industries. Other industries shown in Figure 11 can be interpreted similarly.

People working in the real estate industry saw their value added grow by $33.6 million in FY 2018 (Figure 12). This increase in value added is a result of the indirect and induced impacts' summation, generated primarily, but not exclusively, by NASA Glenn use of scientific research and development services in Northeast Ohio. The $33.6 million accounted for 19% of the $173.5 million value added increase that occurred in all consumer-driven industries.

[35] 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 2018

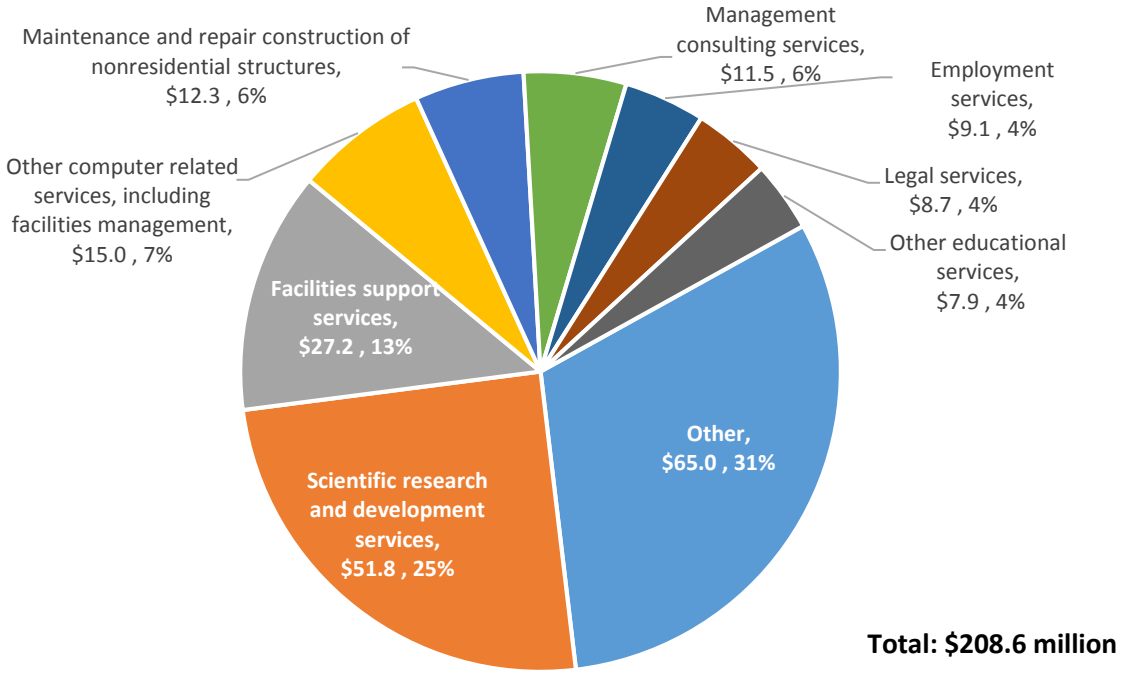
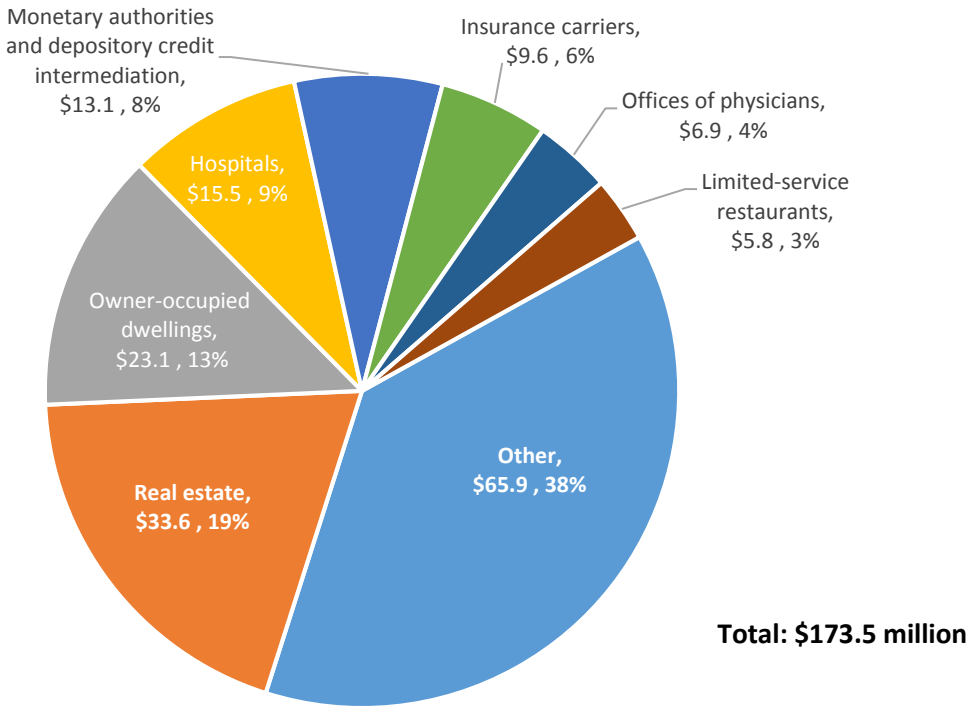


Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2018



D.2.5. Tax Impact on Northeast Ohio, FY 2018

NASA Glenn's operation in Northeast Ohio generated a total of $ 119.2 million in tax revenues in FY 2018. The direct tax impact paid by NASA Glenn's employees in 2018 dollars was $31.8 million, $42.6 million was indirect tax impact, and $44.8 came from induced tax impact.

D.2.6. FY 2018 Northeast Ohio Impact Summary

Economic activity conducted by Glenn Research Center produced the following impact on Northeast Ohio:

- Total Output Impact: $1,456.3M
- Total Employment Impact: 7,185 jobs
- Total Labor Income Impact: $501.0M
- Total Value Added Impact: $758.2M
- Total Tax Impact: $119.2M

The economic impact of NASA Glenn Research Center's activities on Northeast Ohio reflects the benefits of total expenditures of $501.6 million. These expenditures include a total amount of $266.4 million spent on purchases in Northeast Ohio in FY 2018 and expenditures on labor income paid to employees living in or commuting to Northeast Ohio in the amount of $235.2 million.

Excluding expenditures on labor income, 57.3% (almost $153 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 25.4% ($67.5 million) was spent on administrative and support services; and 7.4% ($19.6 million) was spent on construction – the three largest groups of NASA Glenn expenditures in Northeast Ohio.[36] These three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio and, together, represented a 90.0% share ($239.9 million) of all NASA Glenn's FY 2018 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, educational service represented at 4.3% share and utilities at 4.2%. Other sectors' expenditures were less than 1%.

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

[36] Amounts in parentheses detailing percentage numbers are presented in 2017 dollars and correspond to Appendix Table A.3.

D.3. ECONOMIC IMPACT ON THE STATE OF OHIO, FY 2018

This section shows the economic impact that NASA Glenn spending produced for the State of Ohio economy in FY 2018. The methodology used to assess NASA Glenn's economic impact on the state of Ohio was similar to that used for section D.2., Economic Impact on Northeast Ohio, FY 2018. The main difference was that the model accounted for all purchases NASA Glenn made from companies in Ohio as opposed to only companies located in Northeast Ohio.

D.3.1. Output Impact on the State of Ohio, FY 2018

The economic impact assessed with IMPLAN multipliers identifying buy-sell relationship between industries in Ohio. The multipliers applied to spending in Ohio are normally larger than the multipliers applied to expenditures in Northeast Ohio due to a larger geographic area allowing for capturing more purchases within the region. It also enables more purchases from the state economy suppliers and, therefore, less leakage from the economy.

NASA Glenn expenditures were divided into two categories: (1) spending on goods and services purchased from companies and other entities located in the State of Ohio (local) and (2) spending for goods and services from businesses located outside of the State of Ohio. Local spending is then categorized by products made in the local economy, based on an IMPLAN classification system of industries that produced the products. The spending is then assigned to 536 IMPLAN sectors similar to the NAICS code industrial classification. Table A.4. in Appendix A provides a detailed list of NASA Glenn's expenditures by specific industry in the State of Ohio.

Table 11 presents 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). Local expenditures and the contributions of individual industries that provided inputs to the producers of goods and services ultimately consumed by NASA Glenn represented indirect impact. Induced impact was estimated by measuring the spending of workers who were employed at NASA Glenn and supplying industries as a result of Glenn's increased demand for products and services. Total output impact is the sum of direct impact, indirect impact, and induced impact. Table 11 reports output impacts by industry sector, illustrating how NASA Glenn's spending across Ohio affects different sectors of the state economy.

Table 11. Output Impact in the State of Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$125,442	$890,558	$1,015,999
Mining		$1,020,878	$1,253,959	$2,274,837
Utilities		$19,079,355	$8,684,449	$27,763,804
Construction		$22,309,926	$4,308,520	$26,618,446
Manufacturing		$8,485,694	$18,579,602	$27,065,296
Wholesale Trade		$3,647,020	$15,102,891	$18,749,911
Retail Trade		$4,848,427	$35,792,518	$40,640,945
Transportation and Warehousing		$5,312,144	$11,570,452	$16,882,596
Information		$6,930,128	$14,784,946	$21,715,073
Finance and Insurance		$12,179,540	$46,403,984	$58,583,524
Real Estate and Rental		$23,153,340	$63,790,141	$86,943,481
Professional, Scientific, and Tech Services		$212,065,729	$13,814,497	$225,880,226
Management of Companies		$5,110,692	$5,387,135	$10,497,827
Administrative and Waste Services		$88,010,138	$11,365,086	$99,375,224
Educational Services		$12,501,932	$5,975,599	$18,477,532
Health and Social Services		$30,618	$65,508,389	$65,539,007
Arts, Entertainment, and Recreation		$794,404	$6,945,709	$7,740,114
Accommodation and Food Services		$2,890,758	$20,413,505	$23,304,263
Other Services		$5,572,065	$17,437,015	$23,009,080
Government & non-NAICs	$710,115,840	$1,109,628	$3,275,892	$714,501,361
Total Output	**$710,115,840**	**$435,177,859**	**$371,284,848**	**$1,516,578,547**

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 2018 dollars.

The total output impact across the state of Ohio of NASA Glenn's spending on goods and services was $1,516.6 million in FY 2018. NASA Glenn's expenditures of $710.1 million worth of expenditures resulted in an output (sales) change of $1,516.6 million across all industry sectors (Table 11). For example, NASA Glenn's spending affected a $225.9 million increase in total sales (direct, indirect, and induced impacts) by the Professional, Scientific, and Technical services industry, as well as an $86.9 million increase in real estate and rental sector.

Of the total output impact, 46.8% ($710.1 million) is accounted for by the change in final demand or direct impact that occurred because NASA Glenn's activities bring resources from outside of Ohio into the state. Approximately $435.2 million (28.7%) of the total output impact is a result of indirect spending by NASA Glenn on goods and services purchased within the State of Ohio. The remaining output impact of $371.3 million (24.5%) is due to the induced impact of Glenn's spending throughout the state.

The analysis of the IMPLAN model shows that the $806.5 million increase in sales generated by the indirect and induced impacts can be divided into the same broad categories that were identified for Northeast Ohio: NASA Glenn-driven ($419.4 million, 52.0%), consumer-driven ($287.9 million, 35.7%), and other industries ($99.1 million, 12.3%).[37] The output distributions for select Glenn-and consumer-driven industries are shown in Figures 13 and 14, respectively. Selected industries in these figures added over $13 million (or 3.0%) and $12 million (or 3.0%), respectively.

The scientific research and development industry saw the largest output impact; it increased by $133.3 million in FY 2018 due to NASA Glenn's operations (Figure 13). This amount is the summation of the indirect and induced impacts generated primarily, by Glenn's spending on research services. The increase of $133.3 million accounted for 32% of the $419.4 million increase in output for all Glenn-driven industries. Other industries shown in Figure 13 can be interpreted similarly.

In Figure 14, the real estate establishments industry experienced a sales increase a $43.2 million in FY 2018. This amount is the summation of the indirect and induced impact components generated primarily by NASA Glenn employees and other workers. This increase of $43.2 million represented a 15% share of the $287.9 million increase in output for all consumer-driven industries. Other industries shown in Figure 14 can be interpreted similarly.

[37] 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 2018

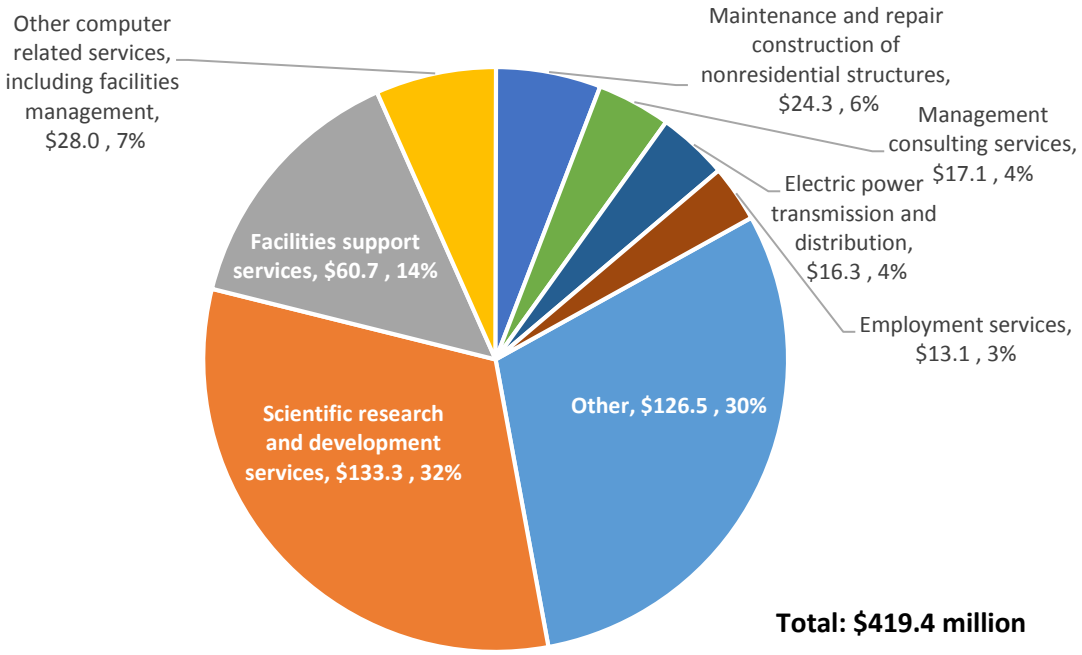
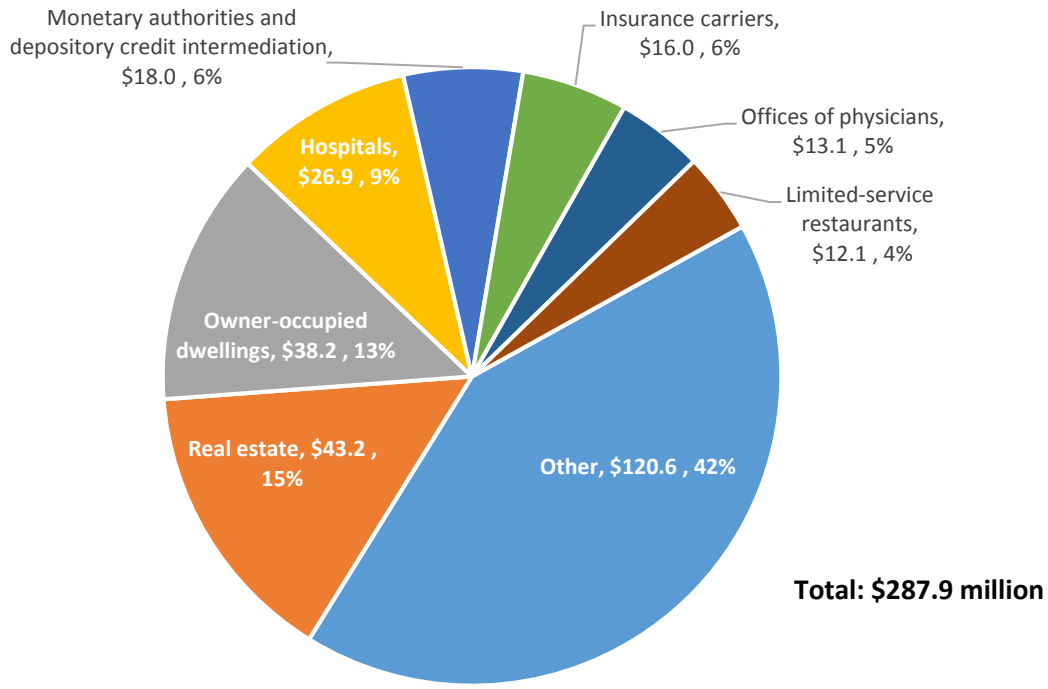


Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2018



D.3.2. Employment Impact on the State of Ohio, FY 2018

Spending for NASA Glenn's activities supported existing employment and the creation of new part- and full-time jobs in addition to their own employment (change in final demand or direct impact). NASA Glenn's spending created employment across the state of Ohio in the supply chain industries from which it purchases goods and services (indirect impact).

In addition, money spent by NASA Glenn employees and employees of supply companies created jobs in various other industries that sell products and services to the population (induced impact). The total employment impact equals the sum of NASA Glenn's employment (direct impact) and the indirect and induced components. Table 12 displays the number of jobs supported and created by industry sector.

Table 12. Employment Impact in the State of Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		2	12	14
Mining		3	3	6
Utilities		22	7	30
Construction		166	25	191
Manufacturing		26	33	60
Wholesale Trade		16	67	84
Retail Trade		98	401	499
Transportation and Warehousing		39	86	125
Information		18	33	51
Finance and Insurance		39	160	199
Real Estate and Rental		112	130	242
Professional, Scientific, and Tech Services		1,299	109	1,408
Management of Companies		21	22	43
Administrative and Waste Services		843	151	994
Educational Services		471	109	580
Health and Social Services		0	612	612
Arts, Entertainment, and Recreation		14	81	95
Accommodation and Food Services		53	345	398
Other Services		52	271	323
Government & non-NAICs	1,594	5	11	1,610
Total Output	**1,594**	**3,299**	**2,670**	**7,563**

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

Employment increased by 7,563 jobs in Ohio in FY 2018 because of NASA Glenn's spending in the state. Out of the total employment, 1,594 people (21.1%) were directly employed at NASA Glenn Research Center. As a result of NASA Glenn's direct spending for goods and services purchased in Ohio through their supply industries, 3,299 full- time and part-time jobs (43.6%) were supported and created in the region as indirect economic impact. The remaining employment, 2,670 jobs (35.3%), was induced impact resulting from spending wages and salaries of NASA Glenn's workers and supply companies' employees through the state economy.

Of the 5,969 jobs created in the State of Ohio due to the indirect and induced effects, 3,254 (54.5%) were found in NASA Glenn-driven sector, 2,116 (35.4%) were in consumer-driven sectors, and 600 (10.1%) were created in other sectors.[38]

The job distribution for select NASA Glenn-driven industries is shown in Figure 15. The job distribution for select consumer-driven industries is shown in Figure 16. Each of the selected industries shown in Figure 15 and Figure 16 supported or added over 150 (4.0%) and 65 jobs (3.0%), respectively.

As shown in Figure 15, the scientific research and development industry generated the highest number of additional jobs. Companies engaged in scientific research and development (professional, scientific, and technical services sector) saw an increase of 649 jobs and accounted for a 20% share of the 3,254 jobs that were created across all NASA Glenn-driven industries in FY 2018. This increase in value added is a result of the indirect and induced impacts' summation, generated primarily, but not exclusively, by NASA Glenn use of scientific research and development services in the State of Ohio.

The real estate industry experienced the largest increase among consumer-driven industries; the increase of 224 jobs in FY 2018 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 jobs accounted for an 11% share of the 2,116 jobs that were created in all consumer- driven industries in the state.

[38] 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 2018

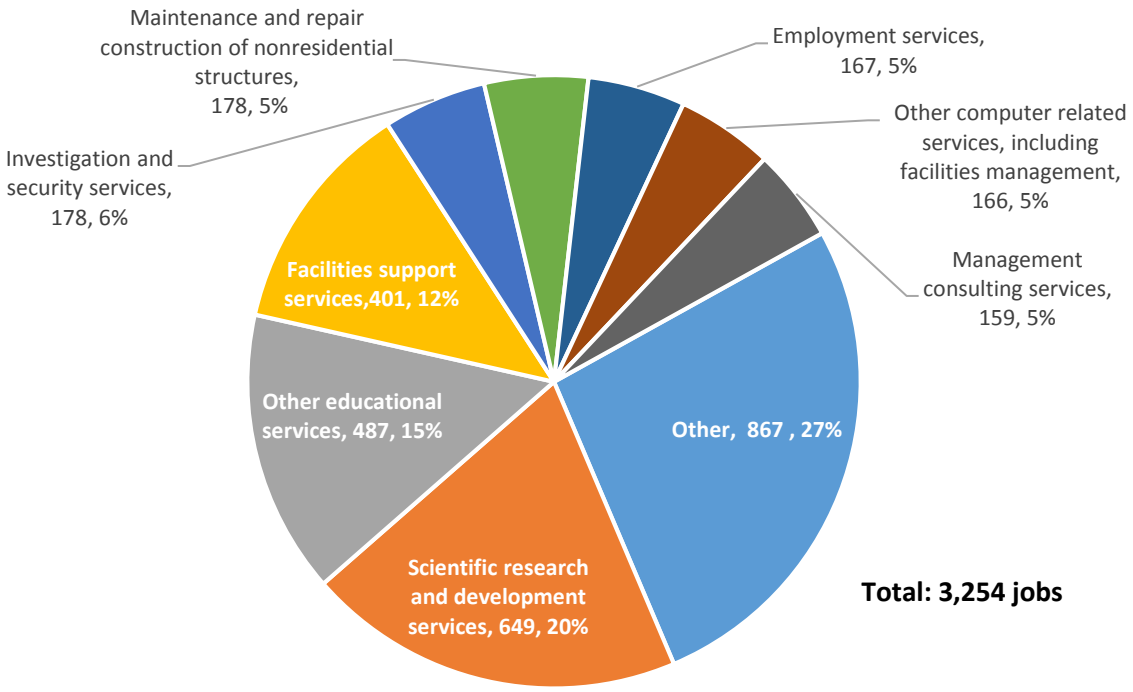
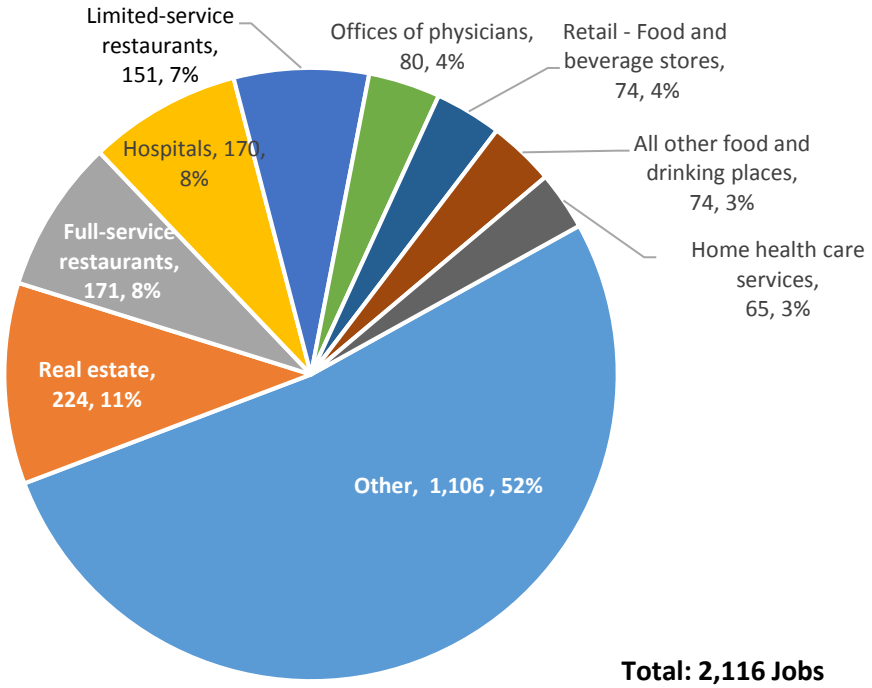


Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2018



D.3.3. Labor Income Impact on the State of Ohio, FY 2018

Labor income is assessed as the estimated change in earnings received by NASA Glenn employees and employees of its supply companies in the state of Ohio due to NASA Glenn's spending on goods and services 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.

The direct economic impact represents the total compensation NASA Glenn pays its employees within and outside the region. Money paid to the employees of both the companies from which NASA Glenn buys its supplies and the suppliers of these companies represented the indirect earnings impact. 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. Adding the direct, indirect, and induced impacts defined the total labor income impact of NASA Glenn. Table 13 displays the labor income impact by industry sector.

Table 13. Labor Income Impact in the State of Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$50,442	$160,906	$211,349
Mining		$230,675	$150,379	$381,054
Utilities		$2,470,143	$1,016,977	$3,487,120
Construction		$9,103,997	$1,617,229	$10,721,227
Manufacturing		$1,817,057	$2,346,167	$4,163,223
Wholesale Trade		$1,314,498	$5,436,311	$6,750,810
Retail Trade		$2,164,098	$12,781,176	$14,945,274
Transportation and Warehousing		$2,682,561	$5,526,725	$8,209,286
Information		$1,417,048	$2,486,867	$3,903,915
Finance and Insurance		$2,763,320	$10,081,640	$12,844,960
Real Estate and Rental		$2,182,553	$2,745,817	$4,928,370
Professional, Scientific, and Tech Services		$90,943,629	$7,315,646	$98,259,275
Management of Companies		$2,616,792	$2,758,336	$5,375,128
Administrative and Waste Services		$30,246,899	$5,806,123	$36,053,022
Educational Services		$8,252,271	$3,649,639	$11,901,910
Health and Social Services		$14,683	$36,153,305	$36,167,988
Arts, Entertainment, and Recreation		$299,932	$2,204,586	$2,504,518
Accommodation and Food Services		$1,185,000	$7,543,431	$8,728,431
Other Services		$3,057,452	$10,472,091	$13,529,542
Government & non-NAICs	$235,760,519	$400,023	$1,029,623	$237,190,165
Total Output	**$235,760,519**	**$163,213,072**	**$121,282,975**	**$520,256,566**

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 adjusted for commuters' compensation and inflation, and it is shown in the table in 2018 dollars.

Total labor income in the state of Ohio increased by $520.3 million as a result of NASA Glenn's spending on goods and services in FY 2018. Of this amount, $235.8 million (45.3%) included wages and benefits paid directly to NASA Glenn employees (change in final demand or direct effect measured is 2018 dollars). Monies paid to employees of companies across the state from which NASA Glenn buys its supplies and suppliers of those companies (indirect impact) represented $163.2 million (31.4%). The remaining earnings impact (induced component), estimated to be $121.3 million (23.3%), 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 $284.5 million increase in labor income attributed to the indirect and induced impacts, $164.3 million (57.7%) was reported in Glenn-driven industries, $87.9 million (30.9%) observed in consumer-driven industries, and $32.3 million (11.4%) was occurred in other industries.[39]

The labor income distribution for select NASA Glenn-driven industries is shown in Figure 17. 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 a 3.5% ($6 million) and 3.0% ($ 2.5 million) share each in Figure 17 and 18, respectively.

Employees in scientific research and development services saw their labor income increase by $46.2 million in FY 2018 in the NASA Glenn-driven industries (Figure 17). These earnings are the summation of the indirect and induced impacts generated by NASA Glenn's purchases of computer-related services. The $46.2 million represented a 28% of the $164.3 million increase in labor income reported by all the NASA Glenn-driven industries.

In consumer-driven industries, employees working for private hospitals had their labor income increase by $12.4 million in FY 2018 (Figure 18). These earnings are the summation of the indirect and induced impacts occurred by consumer spending for doctors' services. The $12.4 million accounted for 14% of the $87.9 million labor income increase that occurred in all consumer-driven industries.

[39] See section D.2.1. Output Impact on Northeast Ohio, FY 2018 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 2018

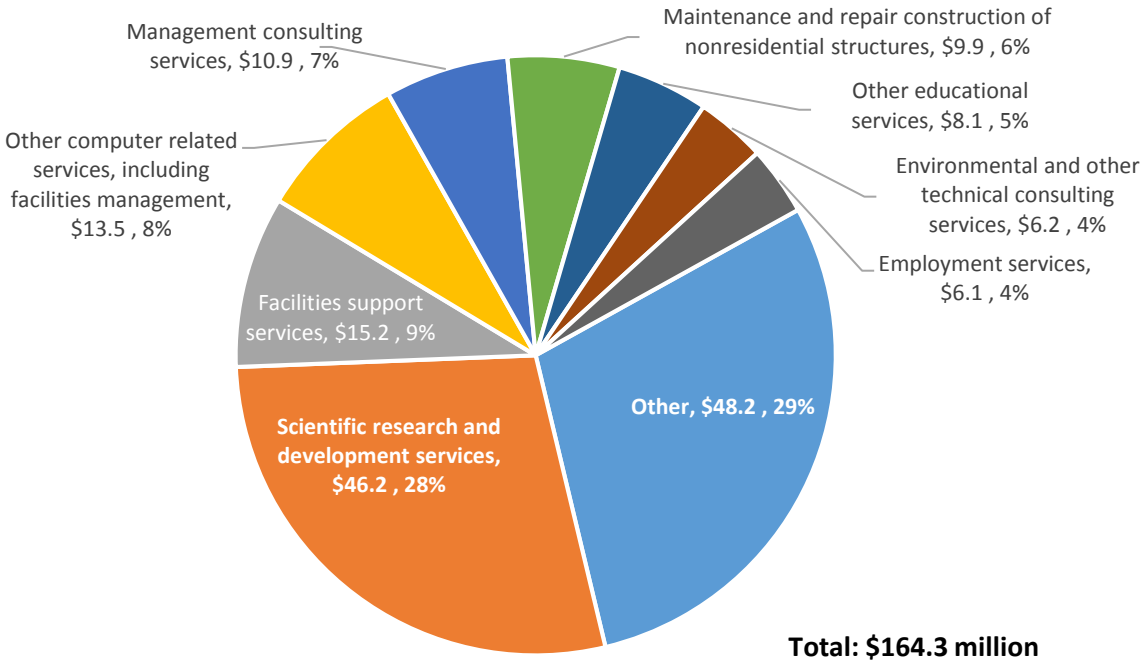
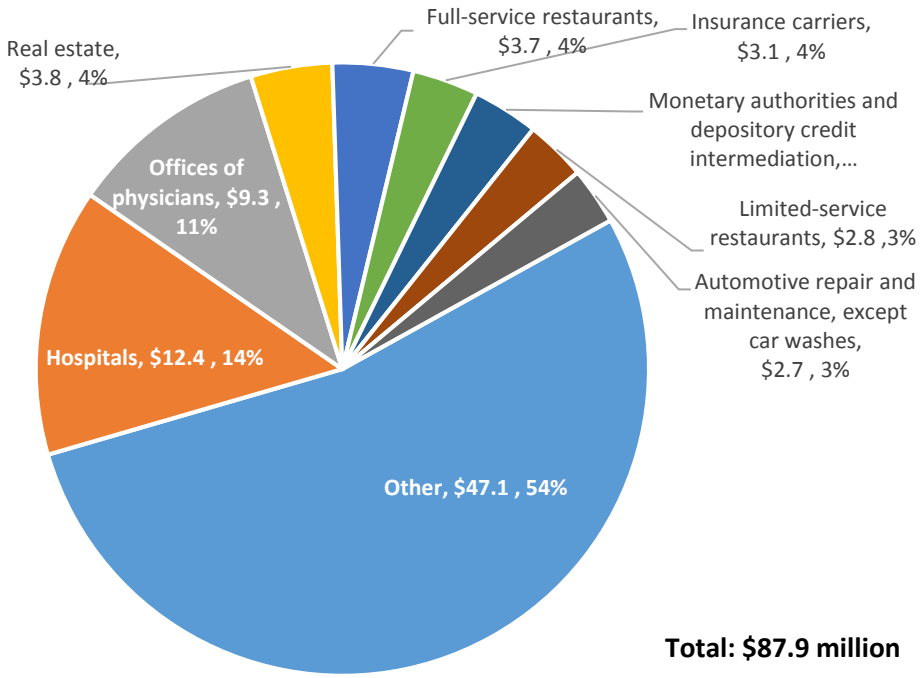


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2018



D.3.4. Value Added Impact on the State of Ohio, FY 2018

NASA Glenn's spending created an increase of $776.6 million in value added for all industries.[40] Of this total amount, $326.7 million (42.1%) was the change in final demand or direct impact calculated as total output less intermediate expenditures. The largest portion of the value added is the wages and salaries paid to NASA Glenn employees. Another $232.8 (30.0%) represented the value of goods and services, less intermediary goods, of companies in Ohio that supply to NASA Glenn (i.e., indirect impact). The remaining value added impact (induced component) was estimated at $217.2 million (28.0%). It occurred as a result of NASA Glenn's spending rippling through the Northeast Ohio economy. The total value added impact is a summation of the direct, indirect, and induced impacts (Table 14).[41]

Table 14. Value Added Impact in the State of Ohio, FY 2018

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$73,026	$359,756	$432,782
Mining		$734,740	$910,509	$1,645,248
Utilities		$9,659,556	$4,145,949	$13,805,505
Construction		$11,617,141	$2,049,447	$13,666,589
Manufacturing		$3,016,775	$5,787,110	$8,803,885
Wholesale Trade		$2,417,679	$9,998,687	$12,416,366
Retail Trade		$2,921,604	$22,027,186	$24,948,790
Transportation and Warehousing		$2,989,930	$6,274,655	$9,264,584
Information		$2,997,007	$6,763,944	$9,760,951
Finance and Insurance		$7,801,741	$25,235,579	$33,037,320
Real Estate and Rental		$16,107,523	$43,014,458	$59,121,982
Professional, Scientific, and Tech Services		$107,935,906	$8,659,652	$116,595,558
Management of Companies		$3,037,529	$3,201,832	$6,239,362
Administrative and Waste Services		$47,084,257	$7,582,061	$54,666,318
Educational Services		$8,255,455	$3,667,659	$11,923,114
Health and Social Services		$16,477	$39,730,683	$39,747,160
Arts, Entertainment, and Recreation		$392,843	$3,885,083	$4,277,926
Accommodation and Food Services		$1,494,832	$10,636,931	$12,131,763
Other Services		$4,018,937	$11,615,887	$15,634,823
Government & non-NAICs	$326,653,287	$201,263	$1,617,572	$328,472,122
Total Output	**$326,653,287**	**$232,774,222**	**$217,164,639**	**$776,592,148**

[40] "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).

[41] 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 54% 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 $776.6 million as a result of NASA Glenn's spending for goods and services in FY 2018. Of this total amount, $326.6 million (42.1%) included the wages and benefits paid directly to NASA Glenn employees (change in final demand or direct impact). Another 232.8 million (30.0%) 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 $217.2 million (28.0%), occurred as the effects of NASA Glenn's spending rippled through the Ohio economy.

Of the $449.9 million increase in value added generated across Ohio due to the indirect and induced impacts, $220.3 million (49.0%) was reported in NASA Glenn-driven industries, $ 178.4 million (39.7%) was generated in consumer-driven industries, and $51.2 million (11.4%) was reported in other industries.

The value added distribution for select NASA Glenn-driven industries is shown in Figure 19. The value added distribution for select consumer-driven industries is shown in Figure
The value added distribution for select NASA Glenn-driven industries is shown in Figure 19. The value added distribution for select consumer-driven industries is shown in Figure 20. Selected industries in Figure 19 and Figure 20 each added at least $6.5 million (3.0%) and $6 million (3.0%), respectively.

Within the NASA Glenn-driven industries, persons engaged in scientific research and development services experienced the largest value added increase of $61.6 million in FY 2018 (Figure 19). This increase in value added is a result of the indirect and induced impacts' summation, generated primarily, but not exclusively, by NASA Glenn's spending on facilities support services. The $61.6 million accounted for 28% of the $220.3 million value added increase that was reported by all NASA Glenn-driven industries.

In the consumer-driven industries, employees working in the real estate industry saw their value added grow by $30.7 million in FY 2018 (Figure 20). This value added increase is a result of the summation of the indirect and induced impacts generated by consumer spending within the industry. The increase of $30.7 million accounted for 17% of the $178.4 million value added increase that occurred in all consumer-driven industries.

Figure 19. Increase in Value Added for NASA Glenn-Driven Industries in Ohio, FY 2018

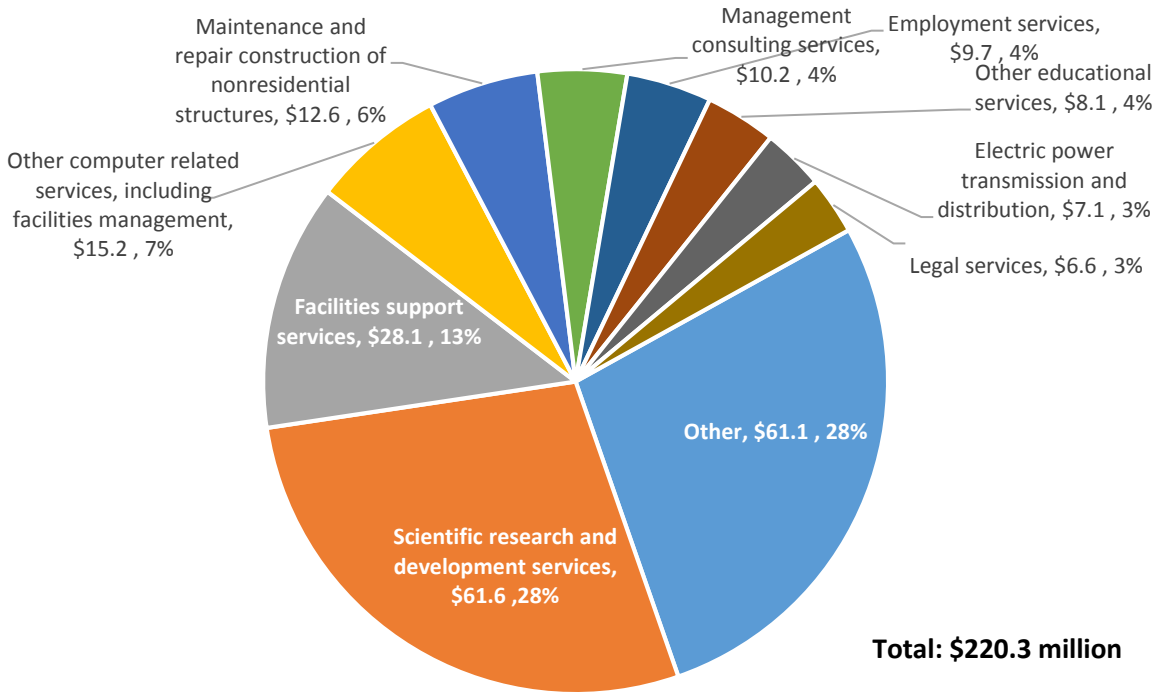
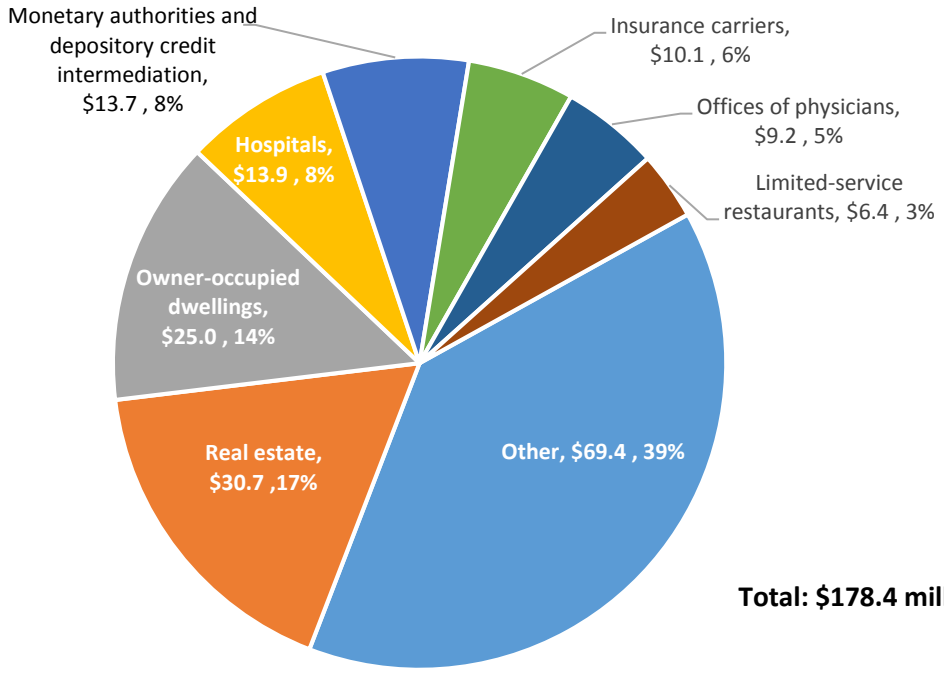


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2018



D.3.5. Tax Impact on the State of Ohio, FY 2018

NASA Glenn's operation and economic impact on the state of Ohio in FY 2018 increased tax revenues by a total of $124.4 million. Of that amount, direct tax impact was $31.8 million in Glenn's employee taxes on wages, $44.8 million indirect tax impact, and $47.8 million – induced tax impact.

D.3.6. FY 2018 Ohio Impact Summary

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

- Total Output Impact: $1,516.6M
- Total Employment Impact: 7,563 jobs
- Total Labor Income Impact: $520.3M
- Total Value Added Impact: $776.6M
- Total Tax Impact: $124.4M

The impact of NASA Glenn's expenditures on the state of Ohio is 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 2018, NASA Glenn's expenditures in the State of Ohio totaled $526.5 million, including labor income (adjusted for commuter spending). The total expenditures in all of Ohio were $24.9 million more than in the total expenditures in Northeast Ohio.

Compared the expenditures made in Northeast Ohio in FY 2018, the largest share of the total payments, excluding labor income, was spent on professional, scientific, and technical services in Ohio (59.7% in Ohio, compared to 57.3% in Northeast Ohio). More than 98.2% of NASA Glenn spending in Ohio ($290.8 million), excluding labor income, went to the following industry sectors: professional, scientific and technical services ($173.5 million); administrative and support services ($68.8 million); construction ($19.6 million); educational services ($12.1 million) and utilities ($11.5 million).[42]

NASA Glenn's statewide expenditure pattern is similar to the expenditures in Northeast Ohio. A large institution employing highly qualified and well paid labor, NASA 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.

[42] Amounts in parentheses detailing percentage numbers are presented in 2018 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2018

Region	Total	Share
Ohio	$290,752,551	61.4%
Washington	$41,157,144	8.7%
Maryland	$26,796,311	5.7%
Alabama	$18,366,930	3.9%
California	$15,857,268	3.3%
Texas	$11,373,214	2.4%
Connecticut	$7,232,181	1.5%
Virginia	$6,928,962	1.5%
Indiana	$6,734,384	1.4%
Missouri	$5,027,430	1.1%
Massachusetts	$4,780,372	1.0%
Pennsylvania	$3,937,917	0.8%
New Jersey	$3,513,234	0.7%
Colorado	$3,411,712	0.7%
Illinois	$3,245,585	0.7%
New York	$3,147,902	0.7%
Kansas	$3,023,728	0.6%
New Hampshire	$2,391,196	0.5%
Arizona	$2,193,591	0.5%
Michigan	$2,149,201	0.5%
Florida	$1,556,092	0.3%
New Mexico	$1,508,318	0.3%
Iowa	$1,147,374	0.2%
Oregon	$910,193	0.2%
Georgia	$806,314	0.2%
North Carolina	$769,611	0.2%
Minnesota	$736,530	0.2%
Oklahoma	$639,042	0.1%
Rhode Island	$444,180	0.1%
Delaware	$414,090	0.1%
Tennessee	$403,889	0.1%
South Carolina	$286,962	0.1%

Region	Total	Share
Wisconsin	$284,315	0.1%
District of Columbia	$260,672	0.1%
Utah	$247,420	0.1%
Montana	$242,211	0.1%
South Dakota	$233,707	0.0%
Kentucky	$181,888	0.0%
Louisiana	$170,259	0.0%
Mississippi	$84,376	0.0%
Wyoming	$79,747	0.0%
Nevada	$70,071	0.0%
Arkansas	$57,791	0.0%
Vermont	$34,448	0.0%
Idaho	$17,516	0.0%
Nebraska	$2,224	0.0%
Alaska	$561	0.0%
West Virginia	$0	0.0%
U.S. Total (No ND)	**$473,610,617**	**99.8%**
Canada	$271,301	0.1%
Great Britain	$160,471	0.0%
France	$139,500	0.0%
Switzerland	$73,833	0.0%
Germany	$55,542	0.0%
Israel	$32,033	0.0%
Taiwan	$5,900	0.0%
Spain	$3,600	0.0%
Australia	$1,615	0.0%
Netherlands	$910	0.0%
Foreign Total	**$744,705**	**0.2%**
Grand Total	**$474,355,322**	**100.0%**

Table A.2. NASA Glenn Grants Allocated to Academic Institutions by State, FY 2018

State	College / University	Share
Maryland	$1,836,744	15.4%
Ohio	$1,450,381	12.2%
California	$1,331,951	11.2%
Texas	$882,106	7.4%
Illinois	$733,377	6.2%
Massachusetts	$720,728	6.1%
Arizona	$628,390	5.3%
Georgia	$462,312	3.9%
Pennsylvania	$451,917	3.8%
Colorado	$432,084	3.6%
New Jersey	$422,723	3.6%
New York	$374,729	3.1%
Connecticut	$335,083	2.8%
Michigan	$325,668	2.7%
South Carolina	$188,916	1.6%
Indiana	$172,416	1.4%
Kentucky	$139,834	1.2%
Oregon	$119,486	1.0%
Iowa	$117,992	1.0%
North Carolina	$116,460	1.0%
Kansas	$91,576	0.8%
Tennessee	$88,543	0.7%
Mississippi	$84,376	0.7%
Virginia	$62,006	0.5%
Utah	$57,954	0.5%
Florida	$51,674	0.4%
Missouri	$47,982	0.4%
Delaware	$47,106	0.4%
Washington	$40,729	0.3%
Minnesota	$38,261	0.3%
Montana	$14,592	0.1%
Wisconsin	$11,268	0.1%
South Dakota	$8,585	0.1%
New Mexico	$0	0.0%
Outside US	$13,252	0.1%
Great Britain Total	$13,252	0.1%
Grand Total	**$11,901,201**	**100.0%**

Note: Sixteen states did not have Academic Institutions that received NASA Glenn grants in 2018.

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2018

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$11,280,130**
	Electric power transmission and distribution	49	$9,104,642
	Natural gas distribution	50	$417,928
	Water, sewage and other systems	51	$1,757,561
Construction			**$19,606,442**
	Maintenance and repair construction of nonresidential structures	62	$19,606,442
Manufacturing			**$796,422**
	Printing	154	$5,815
	Support activities for printing	155	$58,672
	Industrial gas manufacturing	162	$22,466
	Other rubber product manufacturing	198	$690
	Iron, steel pipe and tube manufacturing from purchased steel	218	$44,030
	Sheet metal work manufacturing	241	$152,344
	Machine shops	249	$322,646
	Valve and fittings, other than plumbing, manufacturing	254	$61,653
	Industrial process furnace and oven manufacturing	297	$9,400
	Fluid power cylinder and actuator manufacturing	298	$41,321
	Fluid power pump and motor manufacturing	299	$4,160
	Scales, balances, and miscellaneous general purpose machinery manufacturing	300	$12,460
	Computer terminals and other computer peripheral equipment manufacturing	303	$15,681
	Industrial process variable instruments manufacturing	317	$6,621
	Electricity and signal testing instruments manufacturing	319	$24,890
	Watch, clock, and other measuring and controlling device manufacturing	322	$6,080
	Sign manufacturing	388	$7,494
Wholesale Trade & Retail Trade			**$2,633,550**
	Wholesale trade	395	$178,390
	Retail - Motor vehicle and parts dealers	396	$19,935
	Retail - Miscellaneous store retailers	406	$2,435,225
Transportation and Warehousing			**$44,651**
	Truck transportation	411	$1,187
	Transit and ground passenger transportation	412	$43,464
Information			**$45,036**
	Software publishers	422	$45,036
Real Estate and Rental and Leasing			**$48,657**
	Commercial and industrial machinery and equipment rental and leasing	445	$48,657

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Professional, Scientific, and Technical Services			**$152,749,968**
	Legal services	447	$105,000
	Accounting, tax preparation, bookkeeping, and payroll services	448	$4,014,969
	Architectural, engineering, and related services	449	$1,885,521
	Specialized design services	450	$11,890
	Custom computer programming services	451	$12,415
	Other computer related services, including facilities management	453	$26,203,860
	Management consulting services	454	$6,997,570
	Environmental and other technical consulting services	455	$6,993,147
	Scientific research and development services	456	$106,309,359
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	$216,236
Administrative and Support and Waste Management and Remediation Services			**$67,548,687**
	Facilities support services	463	$59,704,283
	Investigation and security services	467	$5,656,048
	Services to buildings	468	$1,960,361
	Waste management and remediation services	471	$227,995
Educational Services			**$11,530,028**
	Junior colleges, colleges, universities, and professional schools	473	$835,708
	Other educational services	474	$10,694,319
Health Care and Social Assistance			**$28,917**
	Hospitals	482	$28,917
Arts, Entertainment, and Recreation			**$113,565**
	Museums, historical sites, zoos, and parks	493	$113,565
Other Services (except Public Administration)			**$10,802**
	Commercial and industrial machinery and equipment repair and maintenance	507	$10,802
Labor Income			**$235,160,675**
	Employee Compensation (c)		$235,160,675
TOTAL EXPENDITURES IN NEO			**$501,597,531**

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 2018. 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 2018

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$11,503,160**
	Electric power transmission and distribution	49	$9,104,642
	Natural gas distribution	50	$513,567
	Water, sewage and other systems	51	$1,884,952
Construction			**$19,606,442**
	Maintenance and repair construction of nonresidential structures	62	$19,606,442
Manufacturing			**$1,826,608**
	Printing	154	$5,815
	Support activities for printing	155	$58,672
	Industrial gas manufacturing	162	$22,466
	Other rubber product manufacturing	198	$690
	Iron, steel pipe and tube manufacturing from purchased steel	218	$44,030
	Nonferrous metal, except copper and aluminum, shaping	227	$43,990
	Sheet metal work manufacturing	241	$152,344
	Machine shops	249	$462,862
	Metal heat treating	251	$5,290
	Valve and fittings, other than plumbing, manufacturing	254	$403,310
	Other fabricated metal manufacturing	261	$292,904
	All other industrial machinery manufacturing	271	$7,468
	Pump and pumping equipment manufacturing	287	$17,068
	Overhead cranes, hoists, and monorail systems manufacturing	292	$682
	Industrial process furnace and oven manufacturing	297	$26,764
	Fluid power cylinder and actuator manufacturing	298	$41,321
	Fluid power pump and motor manufacturing	299	$4,160
	Scales, balances, and miscellaneous general purpose machinery manufacturing	300	$34,202
	Computer terminals and other computer peripheral equipment manufacturing	303	$15,681
	Industrial process variable instruments manufacturing	317	$18,308
	Electricity and signal testing instruments manufacturing	319	$35,040
	Analytical laboratory instrument manufacturing	320	$49,914
	Watch, clock, and other measuring and controlling device manufacturing	322	$52,366
	Other aircraft parts and auxiliary equipment manufacturing	359	$16,387
	Jewelry and silverware manufacturing	384	$7,382
	Sign manufacturing	388	$7,494

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Wholesale Trade & Retail Trade			**$2,956,397**
	Wholesale trade	395	$191,040
	Retail - Motor vehicle and parts dealers	396	$19,935
	Retail - Miscellaneous store retailers	406	$2,745,422
Transportation and Warehousing			**$50,725**
	Truck transportation	411	$7,261
	Transit and ground passenger transportation	412	$43,464
Information			**$45,036**
	Software publishers	422	$45,036
Real Estate and Rental and Leasing			**$53,732**
	Real estate	440	$5,075
	Commercial and industrial machinery and equipment rental and leasing	445	$48,657
Professional, Scientific, and Technical Services			**$173,509,811**
	Legal services	447	$105,000
	Accounting, tax preparation, bookkeeping, and payroll services	448	$4,014,969
	Architectural, engineering, and related services	449	$2,334,983
	Specialized design services	450	$11,890
	Custom computer programming services	451	$36,415
	Other computer related services, including facilities management	453	$26,203,860
	Management consulting services	454	$6,997,570
	Environmental and other technical consulting services	455	$6,993,147
	Scientific research and development services	456	$126,546,134
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	$265,843
Administrative and Support and Waste Management and Remediation Services			**$68,832,969**
	Facilities support services	463	$59,711,393
	Investigation and security services	467	$6,933,220
	Services to buildings	468	$1,960,361
	Waste management and remediation services	471	$227,995
Educational Services			**$12,144,701**
	Junior colleges, colleges, universities, and professional schools	473	$1,450,381
	Other educational services	474	$10,694,319
Health Care and Social Assistance			**$28,917**
	Hospitals	482	$28,917
Arts, Entertainment, and Recreation			**$113,565**
	Museums, historical sites, zoos, and parks	493	$113,565

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Other Services (except Public Administration)			**$15,397**
	Commercial and industrial machinery and equipment repair and maintenance	507	$15,397
Government Enterprise			**$65,091**
	Other federal government enterprises	520	$65,091
Labor Income			**$235,760,519**
	Employee Compensation (c)		$235,760,519
TOTAL EXPENDITURES IN OHIO			**$526,513,070**

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 2018. 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.