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The NASA Glenn Research Center: An Economic Impact Study Fiscal Year 2017

Iryna Lendel
Cleveland State University, i.lendel@csuohio.edu

Jinhee Yun

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Maxine Goodman Levin
College of Urban Affairs

Prepared for:
NASA GLENN RESEARCH CENTER

Prepared by:
Iryna V. Lendel, Ph.D.
Jinhee Yun

The NASA Glenn Research Center:

An Economic Impact Study Fiscal Year 2017

June 2018

CENTER FOR ECONOMIC DEVELOPMENT

2121 Euclid Avenue | Cleveland, Ohio 44115
http://urban.csuohio.edu/economicdevelopment

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College of Urban Affairs

THE NASA GLENN RESEARCH CENTER: AN ECONOMIC IMPACT STUDY FISCAL YEAR 2017

Prepared for:
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IRYNA LENDEL, PH.D.
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Table of Contents

List of Tables

List of Figures

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 campus includes more than 150 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 campus. The estimated replacement cost is approximately $3.57 billion. The Lewis Field site 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: Human Exploration and Operations in Space, Space Science, Space Technology, and Aeronautics Research. Within the **Human Exploration & Operations** mission portfolio, NASA Glenn provided technical management and integration, research and development engineering and testing to support development of the Orion Multi-Purpose Crew Vehicle and Space Launch System; led microgravity combustion science and fluid physics research on the International Space Station; led aspects of the Human Research Program, which performs research in support of astronaut health; developed next-generation systems that support humans reaching farther into space, and initiated projects within the Advanced Exploration Systems (AES) program, which is contributing technological advancements for future robotic and human spaceflight missions beyond low Earth orbit. NASA Glenn is leading AES projects in spacecraft fire safety, advanced modular power systems, and power, avionics, software, and communication technologies for extra-vehicular activity applications. In addition, NASA Glenn provided vital 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 technologies; managing the Dynamic Radioisotope Power Systems project; managing the development of the NASA's Evolutionary Xenon Thruster – Commercial (NEXT-C), gridded-Ion electric propulsion system that will enhance future Discovery space missions; supporting the Long-Life In-Situ Solar System Explore Probe development with complex environmental testing; developing new scientific instruments and mission concepts for planetary surfaces (e.g. Venus, Mars) and Earth science (e.g. fresh water); and supporting NASA Headquarters with assessments and panel membership for Planetary Science which includes technology/tools coordination and science advisory groups.

- In support of the **Space Technology** mission, NASA Glenn led technology demonstration projects to advance Hall Thruster solar electric propulsion capability as well as cryogenic fluid management technologies to enable future missions. NASA Glenn also led game-changing technology projects related to advanced space power systems, nuclear systems, and other technologies. 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. 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 2016. 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 is an analytical approach used to estimate the benefits generated by 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 analytical tool 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. For FY 2017 study, the Center used a 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 direct NASA Glenn spending across diverse economic sectors and illustrate what impact it makes on the regional economics of Northeast Ohio and Ohio. The table below summarizes NASA Glenn's economic impact on Northeast Ohio and the State of Ohio during FY 2017.

Economic Impact	Northeast Ohio	State of Ohio
Output	$1,422.0 million	$1,480.4 million
Value Added	$741.7 million	$775.6 million
Employment	7,271 jobs	7,603 jobs
Labor Income	$485.1 million	$510.8 million
Taxes	$123.7 million	$128.8 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 activities in Northeast Ohio in FY 2017, stimulated by $655.9 million in direct spending originating primarily from outside of the region, generated an increased demand in output (sales) valued at $1,422 million for goods and services produced in the region. The value added output increased by $741.7 million as a result of NASA Glenn's activities. In addition, 7,271 jobs were created and supported in the region, and labor income in Northeast Ohio increased by $485.1 million. NASA Glenn's activities in Northeast Ohio also generated $123.7 million in local, state, and federal taxes.
- NASA Glenn's $655.9 million worth of expenditures originating primarily from outside of the region resulted in an output (sales) change of $1,480 million across all industry sectors in Ohio in FY 2017. Ohio value added increased by $775.6 million as a result of NASA Glenn's activities in the state. In addition, 7,603 jobs were created and supported in Ohio, and labor income across the state increased by $510.8 million. NASA Glenn operations in Ohio also generated $128.8 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, construction, and educational 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, full-service restaurants, limited-service restaurants, hospitals, retail-food and beverage stores, offices of physicians, and all other food and drinking places.

NASA GLENN RESEARCH CENTER: AN OVERVIEW

- In FY 2017, NASA Glenn civil service employment totaled 1,508. During the past five years, Glenn civil service employment had a peak of 1,664 employees in 2013. Overall, during the past five fiscal years, NASA Glenn's civil service employment has decreased by 9.4%.
- NASA Glenn employs highly educated and highly skilled civil service workers. In FY 2017, 87% of NASA Glenn's employees held at least a bachelor's degree. Looking at all NASA Glenn employees, 19% held doctoral degrees, and 38% held master's degrees.[2]
- The largest occupational category was scientist and engineers with 71% of FY 2017 employment. Even though the total number of NASA Glenn's employees had decreased during the past five years, the share of scientist and engineers in NASA Glenn has continually increased from 68% in FY 2013 to 71% in FY 2017.
- The total number of NASA Glenn employees, including both civil service employees and local contractors, was 3,134 in FY 2017. This showed a decrease of 63 employees from FY 2016 to FY 2017. From FY 2013 to FY 2017, the highest total combined employment was 3,307 in FY 2013 and the lowest was 3,125 in FY 2015.
- The total compensation NASA Glenn civil service employees received in FY 2017 reached $232.3 million. In this report, total compensation included both payroll that accounted for $177.7 million, and employee benefits, that accounted for another $54.6 million. Total compensation increased by $4.0 million in nominal dollars, or 1.8% between FY 2016 and FY 2017. Compared to FY 2016, NASA Glenn nominal payroll has increased by $2.1 million (or 1.2%). During the past five fiscal years, total compensation increased by $8.2 million (3.7%) and the payroll also slightly increased by $1.5 million (0.8%).
- Total revenue in FY 2017 reached $691.1 million, with a 4.1% increase from FY 2016 and a 5.5% increase from FY 2013, without adjustment for inflation. Over the five-year period, NASA Glenn revenues ranged from $655.1 million in FY 2013 to $691.1 million in FY 2017, which has grown steadily since 2013.
- In FY 2017, NASA Glenn allocated its spending of $441.9 million to vendors in 46 states, Washington, D.C., Puerto Rico, and eight foreign countries. Compared to its total expenditure of $407.0 million in FY 2016, NASA Glenn increased its expenditure by 8.6% or $34.9 million (in nominal dollars) in FY 2017. When adjusted for inflation to 2017 dollars, the changes in expenditures are larger. Between FY 2016 and FY 2017, expenditures increased by 10.9%, representing a reduction of $43.4 million in constant 2017 dollars.
- The largest portion of NASA Glenn expenditures, $295.3 million, are spent in Ohio, accounting for 66.8% of NASA Glenn's total expenditures; Ohio expenditures are reflecting a $10.7 million increase in nominal dollars. However, compared to FY 2016, the share of NASA Glenn's expenditures in Ohio decreased from 69.9% in FY 2016 to 66.8% in FY 2017.
- Northeast Ohio received $272.6 million, which accounted for 92.3% of NASA Glenn's Ohio spending in FY 2017. Northeast Ohio also represents 61.7% of NASA Glenn's total spending in FY 2017. Additionally, Cuyahoga County, represented 91.1% of spending in Ohio as well as 60.9% of total NASA Glenn spending in FY 2017.
- Other than Ohio, two states (Washington and Maryland) each received over $24 million or at least 5.6% of NASA Glenn's total expenditures during FY 2017. Washington received $30.4 million, which is the largest amount of NASA Glenn spending in FY 2017 outside of Ohio. Compared to FY 2016, Washington saw a huge nominal increase in spending from $7.0 million to $30.4 million (335%). Washington was ranked

[2] These counts do not include Student Trainees

the number five (excluding Ohio) with the share of 1.7% in NASA Glenn spending in FY 2016. However, in FY 2017, this state had the largest share of spending (excluding Ohio) with almost 7% of NASA Glenn's total expenditure. Maryland received $24.7 million (5.59%), and California received $12.9 million (2.9%), making them the second and third- largest beneficiaries of NASA Glenn spending in FY 2017 outside of Ohio.

- NASA Glenn decreased its expenditures in foreign countries by 22% compared to FY 2016. Foreign countries received $0.7 million, accounting for 0.2% of NASA Glenn's total spending in FY 2017. 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 awarded $18.1 million to colleges and universities in 31 states and Great Britain in FY 2017. Grants accounted for $13.9 million of this total. This constitutes a $1.8 million increase in grants (15.3%) from FY 2016, in nominal dollars. NASA Glenn also awarded $4.2 million in contracts to Ohio academic institutions in FY 2017 through on-site contracts. The total academic funding awarded in the top five states – Ohio, California, Maryland, Illinois, and Texas – in FY 2017 collectively accounted for 63.2% of the total awards, compared to the FY 2016's top five states spending in California, Maryland, Illinois, Ohio, and Pennsylvania, accounting for 64.3% of the total funding awarded to academic institutions.
- Academic institutions in Ohio received $5.7 million of NASA Glenn's academic awards in FY 2017, or 31.6% of total funding, placing the state in first after including the contract dollars. Ohio colleges and universities received $489,228 more in grants in FY 2017 than in FY 2016 in nominal dollars. Colleges and universities in California received $1.93 million, which accounted for the second largest share (10.7%) of NASA Glenn's academic awards in FY 2017. Maryland and Illinois are ranked third and fourth, receiving $1.47 million and $1.21 million, respectively, in funding to academic institutions, or 8.2% and 6.7% of total awards.
- Within the State of Ohio, academic institutions in Northeast Ohio received $3.2 million in FY 2017. This accounted for both 17.6% of NASA Glenn's total academic awards and 55.6% of all academic awards received by Ohio colleges and universities. In comparison to FY 2016, NASA Glenn increased its grants to the universities and colleges in Northeast Ohio by 32.4% ($200,353) in nominal dollars.
- 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 generates wealth in the region and advances the nation.

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) 2017.[3] It uses an input/output model that reflects the buy-sell relationships among industries in the corresponding regions. The model estimates the effect of NASA Glenn spending on the studied economies. This model assesses economic impact in terms of growth in total output (sales), value added (output less intermediary goods),[4] labor income, the number of new jobs, and taxes.

The report also describes some of NASA Glenn's research and development (R&D) activities and provides an overview of NASA Glenn. It looks at change in the structure of NASA Glenn's employees through their occupations, place of residence, and payroll. The report provides information on NASA Glenn's expenditures and revenues, awards to academic institutions, and taxes contributed by employees.

The analysis was conducted by the Center for Economic Development at Cleveland State University's Maxine Goodman Levin College of Urban Affairs. This FY 2017 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2017.[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 campus includes more than 150 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 campus. The estimated current replacement value of Lewis Field and Plum Brook Station is over $3.57 billion.

Glenn's main campus, Lewis Field, is situated on 350 acres of land and contains more than 150 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 6,400 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.

Human Exploration & Operations (Human Spaceflight to the International Space Station (ISS), Moon and Beyond).

- Managing the European Service Module (ESM) development by the European Space Agency (ESA) and its integration within the Orion MPCV Program and vehicle. The ESM provides power, propulsion, consumable water and gasses, and communications for Orion's Crew Module (CM).
- Managing and developing next-generation Solar Electric Propulsion systems that support 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 Multi-Purpose Crew Vehicle.
- Conducting space-qualification environmental testing of the integrated Orion spacecraft at Plum Brook Station.
- Leading development of experiments and research apparatus in the fields of combustion science and fluid physics and transport phenomena in microgravity, which is performed on the International Space Station.
- Contributing to the Human Research Program, which performs research and technology related to human health and medical devices.
- Leading the operation and utilization of new, advanced communications technology, including the SCaN Testbed - a demonstration already located and in service on the International Space Station for software-defined radios.
- Developing next-generation systems that support humans in space via specific projects within NASA's Advanced Exploration Systems (AES) program. NASA Glenn is leading AES projects to make advancements in spacecraft fire safety, including developing and launching payloads to test and observe flames in a microgravity environment, advanced modular power systems, and power, avionics, software, and communication technologies for extra-vehicular activity applications.
- Managing several research and advanced technology development projects on the ISS and on Earth, in support of human exploration.
- Managing and overseeing the development of system upgrades for and supporting safe and reliable operation of the International Space Station's electrical power system.

Space Technology

- Leading the development of Solar Electric Propulsion Hall Thruster technology that can enable future space-based exploration and scientific missions of the future.
- Leading development of technologies for cryogenic fluids transfer and storage, for both application to the Space Launch System and future transportation systems.
- Providing propulsion system analysis and testing of "green" fuels for satellite missions.
- Managing and developing kilowatt class nuclear power systems for in-space and surface power.

- Testing small satellite infusion of propulsion and power generation technologies using micro-sats and Cube-sats.
- 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, 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

- 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. The Advanced Stirling Converter (ASC) and Stirling Radioisotope Generators (SRGs) are examples of these technologies.
- 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 with industry ion-grid solar electric propulsion thrusters and power processing units to be provided as NASA equipment to future Space Science Missions.
- Supporting the Long-Life In-Situ Solar System Explore Probe development with complex environmental testing with 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).
- 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 and partnerships, and 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, and more efficient, higher performing combustion and turbine systems.
- Managing and performing research and 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 and 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 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 and 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, and 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 contains an economic overview of the NASA Glenn Research Center during FY 2017. This analysis offers information on the payroll, revenues, expenditures, awards to academic institutions, occupational distribution, number of employees, employee residence locations, and income taxes paid by NASA Glenn employees and how these economic factors have changed between FY 2013 and FY 2017.

C.1. EMPLOYMENT AND OCCUPATIONS

The labor force at NASA Glenn Research Center consists of two components: civil service employees and local contractors. This is common in federal laboratories to hire contracted employees, since they allow for more flexibility in performance and labor costs. While hiring civil servants is more complex and lengthy, the contractors can be easily adjusted to align with the varying amount and nature of Glenn's scope of work and new projects. The civil service employment has been relatively constant in order to retain workers with long-term core expertise. These workers are essential for efficient and effective execution of aerospace projects that often last many years.

Table 1 presents the total number of civil service employment and the shares of the four main occupational categories between FY 2013 and FY 2017. The civil service employment was at 1,508 in FY 2017, which is 64 people less than in FY 2016. During the past five years, civil service employment peaked in FY 2013 with 1,664, decreasing slightly each year with the exception of a slight increase in FY 2016. Overall, civil service employment declined by 9.4% over the last five years.

Civil service employment distribution at NASA Glenn is categorized into four occupations: administrative professionals, clerical staff, scientists and engineers, and technicians. The occupational structure of NASA Glenn's employment has seen only slight changes during the analyzed period.

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2013-FY 2017

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
2013	1,664	21%	3%	68%	8%
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%

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

The largest occupational employment was scientist and engineers with 71% of all workers in FY 2017. Even though the total number of NASA Glenn's employees had decreased during the past five years, the share of scientists and engineers at NASA Glenn has continually increased since FY 2013 from the share of 68% in 2013 to 71% in FY 2017.

In FY 2017, the administrative professional group was the second-largest occupational category, representing 22% of NASA Glenn civil service employees. This category experienced a slight decrease from 23% in FY 2015, but has consistently accounted for about 20% of the total civil service employees, ranging from 21% to 23%.

Over the past five years, the number of technicians employed by NASA Glenn has decreased by 3%, from 8 % in FY 2013 to 5% in FY 2017. Looking back further, this downward trend continues over the long-term with technicians accounting for 22% of the workforce in FY 2001.

The smallest civil service employment category at NASA Glenn is the clerical employees, which accounted for 3% of the total civil service employees in FY 2013 and FY 2014, and fell an additional percentage point to 2% between 2015 and 2017.

The civil service employees at NASA Glenn are highly educated and skilled; 87% of NASA Glenn's employees held a bachelor's degree or higher in FY 2017.[8] Specifically, 19% held a doctoral degree and 38% had a master's degree. Although NASA Glenn lost some of its employees, it retained highly skilled professionals and slightly increased the percentage of employment with bachelor's degrees or higher.

Table 2 shows NASA Glenn's on or near-site contractor employment from FY 2013 to FY 2017. NASA Glenn has maintained a relatively steady number of contractors over the five-year study period, ranging from 1,562 to 1,673. Although the civil sector employment fell between FY 2016 and FY 2017 (by 64 employees), the local contractor employment increased by 1 during the same period of time.

The total number of NASA Glenn employees, including both civil service employees and local contractors, was 3,134 in FY 2017. This showed a decrease of 63 from FY 2016 to FY 2017. From FY 2013 to FY 2017, the highest total combined employment was 3,307 in FY 2013 and the lowest was 3,125 in FY 2015.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2013-FY 2017

Fiscal Year	Employment of On- or Near-Site Contractors
2013	1,643
2014	1,673
2015	1,562
2016	1,625
2017	1,626

[8] These counts do not include Student Trainees.

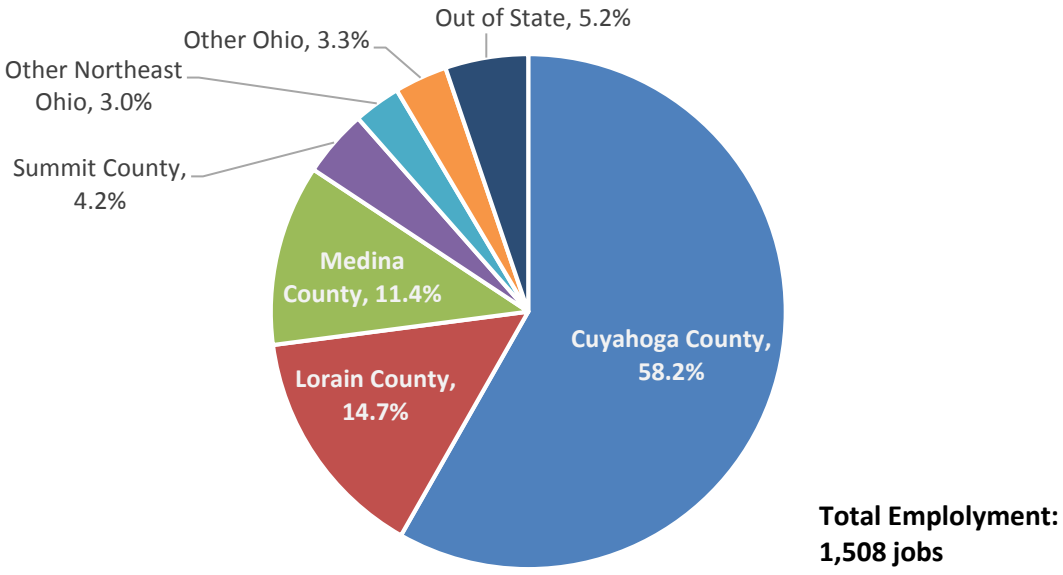
C.2. Place of Residence for Glenn Employees

NASA Glenn Lewis Field is located near Cleveland Hopkins International Airport in Cuyahoga County, Northeast Ohio. NASA Glenn also includes Plum Brook Station near Sandusky, Ohio, west of Northeast Ohio. Most civil service employees working at NASA Glenn live in Cuyahoga County or the other surrounding counties that comprise Northeast Ohio.[9]

Figure 1 presents the breakdown of employees' postal addresses by geographic region. The vast majority of civil employees (91.5%; 1,379 employees) live in Northeast Ohio in FY 2017. Specially, 878 employees (58.2%) of the 1,508 civil servants lived in Cuyahoga County, the same county as NASA Glenn Lewis Field. A significant number of NASA Glenn employees live in Lorain County (14.7%; 222 employees), Medina County (11.4%; 171 employees), and Summit County (4.2%; 63 employees). The other Northeast Ohio counties are home to 45 NASA Glenn employees (3.0%). Another 50 employees (3.3%) lived in Ohio counties outside of Northeast Ohio. Only 79 employees (5.2%) had postal addresses located outside Ohio.

Compared to FY 2016, the percentage of NASA Glenn employees who reside in Cuyahoga County has decreased by 1.4%, while those classified as living out of state increased by 1.6%. However, the distribution of NASA Glenn employment across regions within and outside of areas of study, Northeast Ohio and Ohio, structurally changed very little between FY 2016 and FY 2017.

Figure 1. NASA Glenn Civil Service Employees by Place of Residence, FY 2017



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

The places of residence of NASA Glenn civil service employees are shown by their occupations in Table 3. In FY 2017, over 91% of the employees in all four occupational categories resided in Northeast Ohio. Cuyahoga County accounts for the highest share of employees in each occupational category within Northeast Ohio. More than 58% of NASA Glenn's scientists and engineers, Administrative Professionals, and Clerical employees lived in Cuyahoga County in FY 2017. Technicians and clerical employees were the most likely to reside in Northeast Ohio, at 97.7% and 96.0% respectively. Approximately 9% of NASA Glenn's scientists and engineers and administrative professionals have postal addresses outside of Northeast Ohio.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2017

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	91.8%	96.0%	91.0%	97.7%	91.5%
Cuyahoga County	58.2%	64.0%	58.5%	55.1%	58.2%
Lorain County	15.6%	28.0%	13.9%	18.4%	14.7%
Medina County	10.3%	4.0%	11.4%	18.4%	11.4%
Summit County	5.0%	0.0%	4.2%	2.3%	4.2%
Lake County	1.2%	0.0%	1.1%	1.2%	1.1%
Geauga County	0.3%	0.0%	1.2%	1.2%	1.0%
Portage County	1.2%	0.0%	0.8%	0.0%	0.8%
Ashtabula County	0.0%	0.0%	0.0%	1.2%	0.1%
Other Ohio	5.6%	4.0%	2.4%	2.3%	3.3%
Out of State	2.7%	0.0%	6.5%	0.0%	5.2%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

The total compensation NASA Glenn civil service employees received in FY 2017 reached $232.3 million. In this report, total compensation included both payroll that accounted for $177.7 million and employee benefits that accounted for another $54.6 million.

Total compensation increased by $4.0 million in nominal dollars, or 1.8% between FY 2016 and FY 2017.[10] Compared to FY 2016, NASA Glenn's nominal payroll has increased by $2.1 million (or 1.2%).[11] During the past five fiscal years, total compensation increased by $8.2 million (3.7%)[12] and the payroll also slightly increased by $1.5 million (0.8%).[13]

During FY 2017, the cost of benefits increased at a greater rate than salary.[14] Percent of benefits in relation to total compensation has been increasing year over year since FY 2013. Benefits were 21.3% of total compensation in FY 13 ($28.7k), and 23.5% ($36.2k) of total compensation in FY 17.

Despite the fact that the wage component in total compensation is declining, the average wage per civil service employee increased from $111,726 in FY 2016 to $117,861 in FY 2017, a 5.5% growth. Between FY 2013 and FY 2017, there was an average wage increase of 11.3% (or $11,934).[15]

[10] Total compensation increased by $1.2 million, or 0.5% between FY 2016 and FY 2017, after adjusting for inflation.

[11] In real dollars adjusted for inflation, total payroll has decreased by $84,818 (or -0.05%) between FY 2016 and FY 2017.

[12] Total real compensation increased by $1.9 million (or 0.8%) between FY 2013 to FY 2017.

[13] The payroll decreased by $3.5 million, after adjusting for inflation, or 1.9% over last five years.

[14] Total real benefits increased by $1.3 million, or 2.3%, between FY 2016 and FY 2017, and $5.4 million, or 11.0%, from FY 2013 to FY2017.

[15] The average wage per employee in real terms increased 8.2%, or $8,947, between FY 2013 and FY 2017.

C.4. NASA GLENN EXPENDITURES, FY 2017

In FY 2017, NASA Glenn allocated its spending of $441.9 million to vendors in 47 states, Washington, D.C., Puerto Rico, and eight foreign countries. Compared to its total expenditure of $407.0 million in FY 2016, NASA Glenn increased its expenditure by 8.6% or $34.9 million (in nominal dollars) in FY 2017. When adjusted for inflation to 2017 dollars, the changes in expenditures are larger.[16] Between FY 2016 and FY 2017, expenditures increased by 10.9%, representing a reduction of $43.4 million in constant 2017 dollars.[17]

Figure 2 shows the geographic distribution of NASA Glenn's spending during FY 2017, of which Ohio is the largest beneficiary. In FY 2017, largest portion of NASA Glenn expenditures, $295.3 million, were made in Ohio accounting for 66.8% of NASA Glenn's total expenditures and reflecting a $10.7 million increase in nominal dollars.[18] However, compared to FY 2016, the share of NASA Glenn's expenditures in Ohio decreased from 69.9% in FY 2016 to 66.8% in FY 2017.

Of Ohio's total expenditures, Northeast Ohio received $272.6 million, which accounted for 92.3% of NASA Glenn's Ohio spending in FY 2017. Northeast Ohio also represents 61.7% of NASA Glenn's total spending in FY 2017. Additionally, Cuyahoga County represented 91.1% of spending in Ohio as well as 60.9% of total NASA Glenn spending in FY 2017.

Other than Ohio, two states (Washington and Maryland) each received over $24 million or at least 5.6% of NASA Glenn's total expenditures during FY 2017. Washington received $30.4 million, which was the largest amount of NASA Glenn spending in FY 2017 outside of Ohio. Compared to FY 2016, Washington saw a huge nominal increase in spending from $7.0 million to $30.4 million (335%). Washington was the fifth state (besides Ohio) with the largest share (1.7%) of NASA Glenn spending in FY 2016. However, in FY 2017, this state had the largest share of spending (except Ohio) with almost 7% of NASA Glenn's total expenditures. Maryland received $24.7 million (5.6%), and California received $12.9 million (2.9%), making them the second and third- largest beneficiaries of NASA Glenn spending in FY 2017 outside of Ohio.

Aside from Ohio and the three states listed above, Missouri saw the largest nominal dollar increase in expenditures at $3.7 million, and Tennessee experienced the largest nominal dollar decline at $4.5 million. In addition to Missouri, Illinois, Indiana, Colorado, Michigan, Arizona, Massachusetts, Oklahoma and Minnesota all saw an increase in NASA Glenn spending totaling more than $1 million between FY 2016 and FY 2017. (See Appendix Table A.1 for more information on NASA Glenn spending by state.)

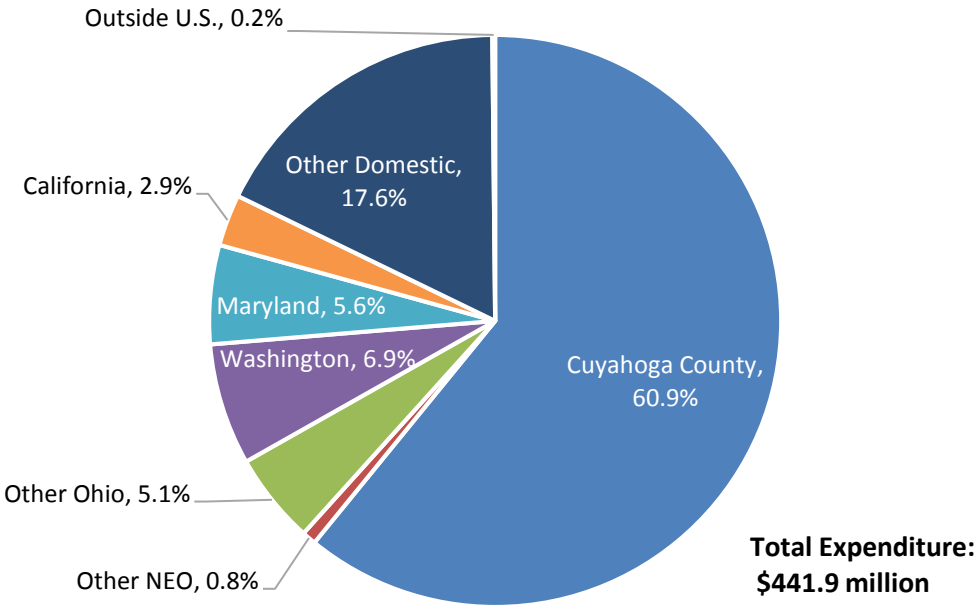
In FY 2017, NASA Glenn decreased its expenditures in foreign countries by 22% compared to FY 2016. Foreign countries received $0.7 million, accounting for 0.2% of NASA Glenn's total spending in FY 2017. Among foreign countries, the largest beneficiary was Canada (See Appendix Table A.1 for more information on NASA Glenn out of country expenditures).

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

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

[18] Total expenditures increased by $4.7 million in real dollars adjusted for inflation between FY 2016 and FY 2017.

Figure 2. NASA Glenn Spending in Selected Regions, FY 2017



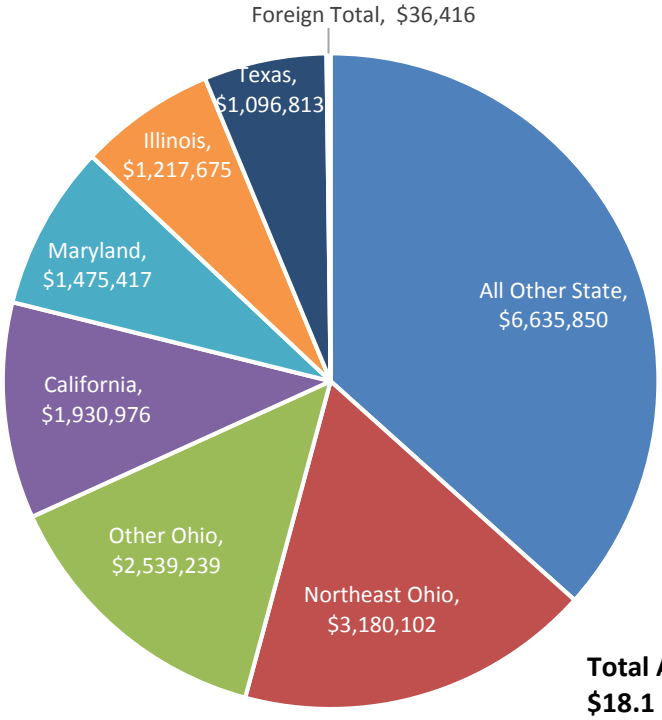
C.5. NASA Glenn Awards to Academic Institutions

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

NASA Glenn awarded $18.1 million to colleges and universities in 31 states and Great Britain in FY 2017. Grants accounted for $13.9 million of this total. This constitutes a $1.8 million increase in grants (15.3%) from FY 2016, in nominal dollars. NASA Glenn also awarded $4.2 million in contracts to Ohio academic institutions in FY 2017 through on-site contracts.

Figure 3 shows the distribution of financial awards to colleges and universities with emphasis on select states that received a large share of the funding. The total academic funding awarded in the top five states – Ohio, California, Maryland, Illinois, and Texas – in FY 2017 collectively accounted for 63.2% of the total awards, compared to the FY 2016's top five states spending in California, Maryland, Illinois, Ohio, and Pennsylvania, accounting for 64.3% of the total funding awarded to academic institutions. Texas saw a huge nominal increase in awards from $0.52 million in FY 2016 to $ 1.1 million in FY 2017 (91.8%), while Pennsylvania experienced a nominal decline in awards, from $0.69 million in FY 2016 to $0.51 million in FY 2017 (-26.1%) (See Appendix Table A.2. for more information).

Figure 3. NASA Glenn Academic Awards to Colleges and Universities, FY 2017



Total Academic Awards: $18.1 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 $5.7 million of NASA Glenn's academic grants in FY 2017, or 31.6% of total funding, placing the state in first after including the contract dollars. Ohio colleges and universities received $489,228 more in grants in FY 2017 than in FY 2016 in nominal dollars. Colleges and universities in California received $1.93 million, which accounted for the second largest share (10.7%) of NASA Glenn's academic awards in FY 2017. Maryland and Illinois are ranked third and fourth, receiving $1.47 million and $1.21 million, respectively, in funding to academic institutions, or 8.2% and 6.7% of total awards.

Within the State of Ohio, academic institutions in Northeast Ohio received $3.2 million in FY 2017. This accounted for both 17.6% of NASA Glenn's total academic awards and 55.6% of all academic awards received by Ohio colleges and universities. In comparison to FY 2016, NASA Glenn increased its grants to the universities and colleges in Northeast Ohio by 32.4% ($200,353) in nominal dollars.

Table 4 shows the distribution of NASA Glenn awards to academic institutions in the State of Ohio from FY 2013 to FY 2017 (inflated to 2017 dollars).[19] Total academic funding awarded in Ohio increased by 28.3%, from $4.5 million in FY 2013 to $5.7 million in FY 2017, after adjusting for inflation.[20] 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 each received more than $1.8 million from NASA Glenn in FY 2017. Combined, the two universities accounted for 73.5% of NASA Glenn awards to Ohio academic institutions in FY 2017. CWRU received $2.3 million, representing the highest amount of funding in FY 2017. Compared to FY 2016, the funding for Case Western Reserve University was increased by 31.5% ($557,700). Between FY 2013 and FY 2017, NASA Glenn increased its academic funding to CWRU by 645% or $2.0 million (adjusted to 2017 dollars).[21]

In FY 2017, the University of Akron received $439,979 and Ohio State University received $321,017. The University of Cincinnati did not receive funding between FY 2014 and FY 2016, but received $230,167 in FY 2017. The remainder of the FY 2017 awards from NASA Glenn to Ohio academic institutions went to Cleveland State University ($170,955), Cuyahoga Community College ($133,615), Ohio University ($128,063), and Kent State University ($91,633). Compared FY 2016, Cleveland State University was awarded considerably less in FY 2017 (a 48.2% decrease), and Ohio University and Kent State University experienced a funding growth of 61.8% and 126.8%, respectively.

[19] For FY 2017 report, the methodology of collecting data for Table 4 has changed. In the current report 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.

[20] NASA Glenn increased its total academic funding in Ohio by 32.7%, from $4.3 million in FY 2013 to 5.7 million in FY 2017 in nominal dollars.

[21] Academic funding awarded to CWRU increased by 676% or $$2.0 million between FY 2013 and FY 2017 (in nominal dollar)

Table 4. NASA Glenn Total Awards in Ohio by Academic Institution, FY 2013-FY 2017

Ohio Colleges and Universities	FY2013	FY2014	FY2015	FY2016	FY2017	FY2017 Share
Case Western Reserve University	$312,564	$1,984,599	$1,829,012	$1,786,220	$2,343,920	41.0%
University of Toledo	$1,650,598	$2,581,670	$2,548,101	-	$1,859,992	32.5%
The University of Akron	$1,904,294	$1,194,757	$799,546	$555,199	$439,979	7.7%
Ohio State University	$58,723	$18,356	$275,098	$360,406	$321,017	5.6%
University of Cincinnati	$43,157	-	-	-	$230,167	4.0%
Cleveland State University	$389,635	$117,866	$737,035	$330,070	$170,955	3.0%
Cuyahoga Community College	-	-	-	$160,641	$133,615	2.3%
Ohio University	$94,512	$70,362	$60,842	$79,153	$128,063	2.2%
Kent State University	$5,820	-	$20,689	$40,410	$91,633	1.6%
TOTAL	$4,459,303	$5,967,609	$6,270,324	$3,312,099	$5,719,341	100.0%

Notes:
Table is sorted by FY 2017 column.
Data inflated to 2017 dollars (Inflation 229.9 based on CPI-U for the Midwest region).

C.6. NASA Glenn Revenues

Total revenue in FY 2017 reached $691.1 million, which 4.1% increased from FY 2016 and a 5.5% increased from FY 2013 without adjustment for inflation. Over the five-year period, NASA Glenn revenues ranged from $655.1 million in FY 2013 to $691.1 million in FY 2017, which has grown steadily since 2013.

NASA Glenn's revenue consists of two sources: NASA direct authority and reimbursable commitments. Table 5 shows NASA Glenn's revenues between FY 2013 and FY 2017. The share of revenue from NASA's direct authority declined between FY 2013 to FY 2014, dropping from 92.9% to 91.3%, but steadily increased thereafter. In FY 2017, NASA Glenn received $655.9 million of revenue directly from NASA and an additional $46.5 million from reimbursable commitments.

Over the five-year study period, reimbursable funding has changed, reflecting the fluctuation of non-NASA customers doing business with NASA Glenn in recent years. Within the past year, Glenn's revenues from reimbursable commitments has decreased by 13.5% ($5.5 million in nominal dollars) from FY 2016 to FY 2017.

From FY 2016 to FY 2017, reimbursable commitments from the Department of Defense showed a 19.1% increase, driven largely by the U.S. Air Force, which had a $2.7 million (13.3%) increase. In FY 2017, the Department of Defense accounted for the largest share of total reimbursable commitment (69.6%) and other federal agency had the second-largest share of the total reimbursable commitment (18.5%).

Table 5. NASA Glenn Revenues, FY 2013-FY 2017 (in millions of nominal dollars)

Description	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
NASA Direct Authority	$608.6	$618.8	$624.6	$623.4	$655.9
Total Reimbursable Commitments	$46.5	$59.1	$46.9	$40.7	$35.2
Total FY Authority	$655.1	$677.9	$671.5	$664.1	$691.1
NASA Budget %	92.9%	91.3%	93.0%	93.9%	94.9%

C.7. Taxes Paid by NASA Glenn Employees

State and local taxes paid directly to state and local entities by NASA Glenn employees are important to the regional economies of Northeast Ohio and Ohio. NASA Glenn's total employment and payroll of employees whose workplaces are located on the NASA Glenn campus determine the amount of taxes paid by NASA Glenn. Most NASA Glenn employees are located in the Cities of Brook Park, Cleveland, and Fairview Park, which affects the distribution of their tax dollars.

Table 6 displays income taxes paid by NASA Glenn employees, broken down into the amounts received by federal, state, and local governments. The distribution of these taxes exclude those paid by Glenn employees to local governments based on their place of residence. Total income tax paid by NASA Glenn employees in FY 2017 amounted to $33.4 million, a slight increase of 1.6% from the FY 2016 total (in a nominal dollar comparison).

The State of Ohio and the City of Brook Park were the two largest beneficiaries of the income taxes paid by NASA Glenn's employees. Together, they accounted for 99.6% of the total state and local income taxes paid in FY 2017. The State of Ohio's share of income tax in FY 2017 was 62.5% ($5.6 million). Over the last 5 years, NASA Glenn employees paid approximately $28.6 million to the State of Ohio.

The City of Brook Park received $3.3 million in income tax from NASA Glenn employees in FY 2017, a slight increase (0.6%) compared to FY 2016. NASA Glenn employees paid $24,514 in income tax to the City of Fairview Park in FY 2017. This represented a 12.6% decrease in income tax paid by NASA Glenn workers to the City of Fairview Park between FY 2013 and FY 2017. At the same time, income tax paid to the City of Cleveland remained very low, peaking in FY 2013 at $13,492. In FY 2017, NASA Glenn employees paid $10,106 in income taxes to the City of Cleveland, a decrease of almost 25.1% when compared to FY 2013.

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
2013	$3,317,434	$13,492	$28,048	$6,091,867	-	**$9,450,841**
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**
5-Year Total	**$16,607,165**	**$50,420**	**$131,974**	**$28,581,856**	**$96,570,833**	**$141,942,247**

Note: Data in nominal dollars. Federal taxes in FY 2013 were not reported.

D. ECONOMIC IMPACT OF NASA GLENN

This section focuses on the methodology and results of research on the economic impact NASA Glenn had on Northeast Ohio and the State of Ohio in FY 2017.[22] 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 is estimated as the sum of three types of impact: direct, indirect, and induced.[23] 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 are based on the assumption that NASA Glenn established its operations in the region at the beginning of FY 2017 and generated a demand by purchasing goods and services for its organization across a number of different supply industries.

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.[24] The increase in demand from 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. Additionally, economic impact is assessed from the wages NASA Glenn employees use to buy goods and services for themselves and their households. Assessment of intermediate goods purchasing is represented in the indirect portion of the economic impact, while the spending patterns of both NASA Glenn employees and employees of NASA Glenn's suppliers are reflected in the induced effects portion of the assessment.

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. 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, NASA Glenn is treated as a research and development institution, which assumes that NASA Glenn's intermediate expenditure pattern conforms 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 (NEO) or Ohio). These relationships determine how the economy responds to changes in buying and selling patterns among firms and industries. Input-output (I-O) models estimate inter-industry relationships at the county, regional, state, or

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

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

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

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.[25]

This study utilizes regional I-O multipliers from the IMPLAN Professional model.[26] Specifically, SAM multipliers are used to estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.[27] 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 affect total payroll accounting, 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. 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. 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. 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 federal sources (from outside of the study area), no further adjustments were required.

[25] 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.

[26] 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.

[27] 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.

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.[28]
- 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.

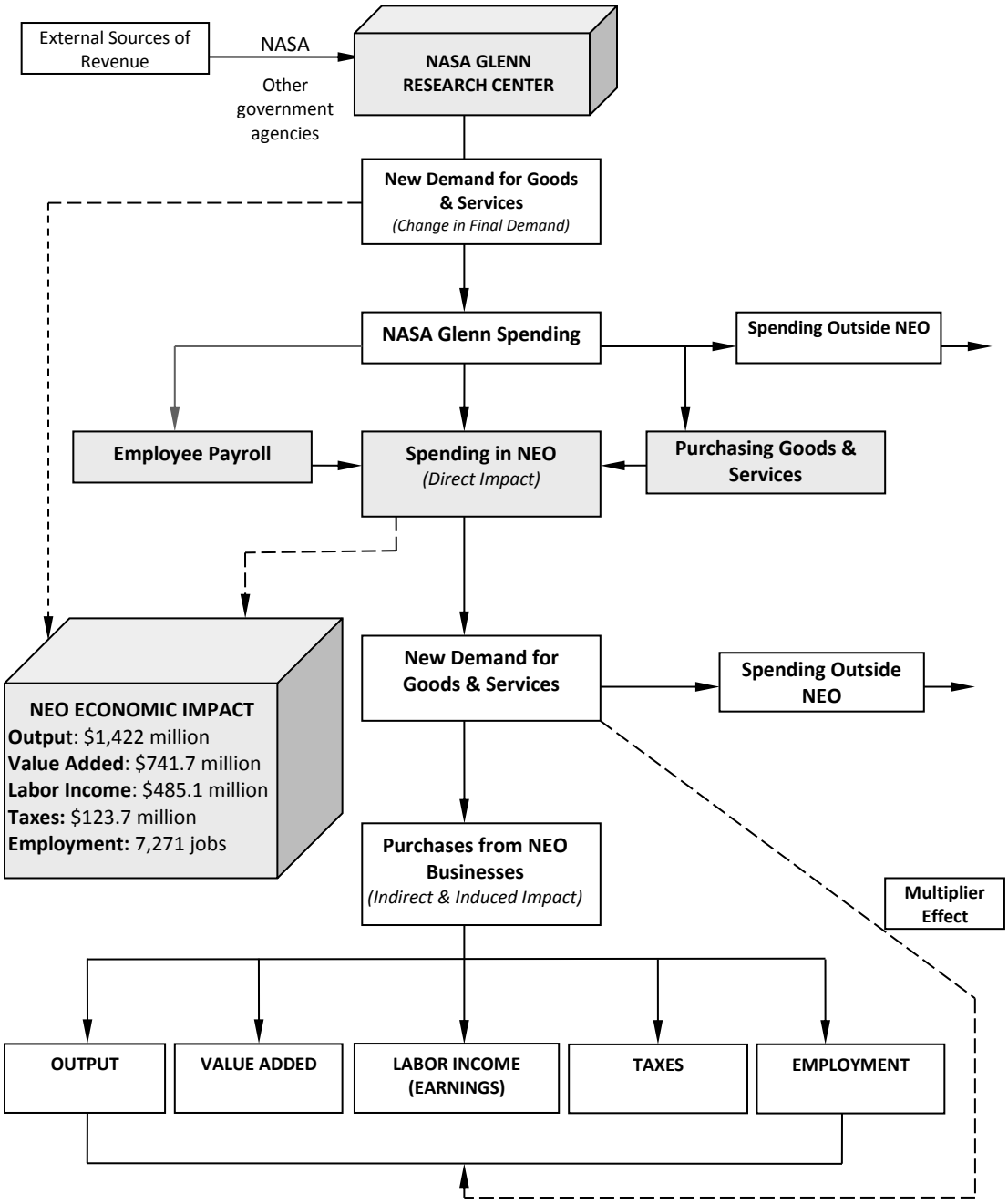
The employment, labor income, value added impact, and output impact are each a summation of three components: direct impact, indirect impact, and induced impact.[29] Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio's economy through its spending in the region in FY 2016.

Through its attraction of federal dollars, 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.

[28] 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.

[29] 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 2017



D.2. Economic Impact on Northeast Ohio, FY 2017

This section presents the economic impact that NASA Glenn spending produced for the Northeast Ohio economy in FY 2017. The analysis includes a detailed overview of 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 2017

NASA Glenn's expenditures were divided into two groups 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. The second group is considered as a leakage from this region; therefore, these expenditures are not included in the impact calculations for Northeast Ohio. Local spending is then categorized by products purchased from different industries in the regional economy, based on an IMPLAN industry classification system that differentiates spending across 536 sectors.[30] 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. Table A.3., found in appendix A, provides detailed NASA Glenn expenditures in Northeast Ohio by industry.

Over 45% of NASA Glenn spending in Northeast Ohio was for employee compensation. NASA Glenn makes its largest expenditures on the professional, scientific and technical services industry (29.3%), including about 19.6% of total expenditures on the scientific research and development industry. The spending in Northeast Ohio results in a significant regional economic impact.

Table 7 displays the total output impact of NASA Glenn on the economy of Northeast Ohio, comprised of direct impacts, indirect impacts, and induced impacts. Local Glenn expenditures represent direct output impact for Northeast Ohio. This impact includes the regional margin of purchases from the retail industry. Indirect impact is estimated by summing the contributions of individual industries that provide inputs to the producers of the goods and services ultimately consumed by Glenn. Induced impact is derived from measuring the spending of employees as a result of the demand for products and services created by Glenn. Lastly, total output impact is the sum of change in final demand, direct impact, indirect impact, and induced impact. Table 7 reports output impacts by industry sector and presents how Glenn spending across Northeast Ohio affects all sectors of the economy.

[30] In 2014, the IMPLAN data sectors were expanded from 440 to 536 sectors to better describe the type of expenditures and therefore better measure the economic impact. The main changes of sector representation occurred in energy-related industries, construction and some manufacturing.

Table 7. Output Impact in Northeast Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$51,935	$196,969	$248,904
Mining		$704,464	$478,453	$1,182,916
Utilities		$22,301,083	$6,853,998	$29,155,080
Construction		$37,640,397	$3,793,588	$41,433,984
Manufacturing		$5,653,734	$7,557,777	$13,211,511
Wholesale Trade		$4,692,217	$16,257,060	$20,949,277
Retail Trade		$5,116,225	$32,436,576	$37,552,800
Transportation and Warehousing		$5,108,535	$10,345,159	$15,453,693
Information		$6,368,592	$15,008,913	$21,377,505
Finance and Insurance		$10,642,273	$42,731,718	$53,373,991
Real Estate and Rental		$22,894,633	$69,172,728	$92,067,361
Professional, Scientific, and Tech Services		$183,025,985	$15,279,873	$198,305,858
Management of Companies		$4,516,651	$4,585,023	$9,101,675
Administrative and Waste Services		$76,000,788	$10,683,119	$86,683,907
Educational Services		$12,376,594	$6,041,649	$18,418,243
Health and Social Services		$63,700	$55,204,132	$55,267,831
Arts, Entertainment, and Recreation		$1,388,202	$6,953,834	$8,342,035
Accommodation and Food Services		$2,436,298	$18,061,766	$20,498,063
Other Services		$5,176,414	$15,130,413	$20,306,827
Government & non-NAICs	$674,249,080	$1,085,830	$3,728,168	$679,063,078
Total Output	**$674,249,080**	**$407,244,548**	**$340,500,914**	**$1,421,994,542**

Notes: For output impact, the change in final demand or direct impact ($674,249,080) 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 across Northeast Ohio as a result of Glenn Research Center FY 2017 activities was $1.4 billion.

Glenn's expenditures of $674.2 million in Northeast Ohio resulted in a change in output (sales) of $1.4 billion across all industry sectors (Table 7). For example, Glenn spending affected a $198.3 million increase in sales (direct, indirect, and induced impacts) by the Professional, Scientific, and Technical services industry and a $13.2 million increased in total sales by the Manufacturing industry. Furthermore, if NASA Glenn did not exist in Northeast Ohio, the regional economy would suffer an $86.7 million decrease in output in the Administrative and Waste Services industry. Thus, the impact of NASA Glenn's presence in the area is represented 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, 47.4% ($674.2 million in 2017 dollars) is accounted for by NASA Glenn's direct spending, which constitutes the direct economic impact to Northeast Ohio. Approximately $407.2 million (28.6%) of the total output impact is a result of indirect spending by NASA Glenn. The remaining output impact of $340.5 million (23.9%) 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 $747.7 million (52.6%) change in output (sales) due to indirect and induced economic impacts can be 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. Among these industries are utilities, construction, information, professional and scientific services, administrative and support services, and education. The total increase in output for these six industries in FY 2017 was $395.4 million or 52.9% of NASA Glenn's overall indirect and induced impact on Northeast Ohio.

Consumer-driven sectors are those industry groups whose increased sales, employment, and earnings are attributed primarily to spending by Glenn employees and other workers who produce goods and services for Glenn and their suppliers. They 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 2017 was $395.4 million or 52.9% of the total impact.

Other industries are those that are driven by both NASA Glenn and consumer spending, but their impact is split between NASA Glenn and other businesses in the region and cannot 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 2017 was $80.2 million or 10.7% of the total impact.

The output distribution for select industries within the NASA Glenn-driven sectors is shown in Figure 5 and the output distribution for select industries within the consumer-driven sectors is presented in Figure 6. Industries with additional sales of at least $11 million and $9 million were selected to be present in Figure 5 and 6, respectively (or 3% of each total sales for Glenn-Driven industries or Consumer-driven industries).

The scientific research and development services industry generates the largest impact of output; it increased by $102.7 million 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 $102.7 million represented 26% of the $395.4 million increase in output for all NASA Glenn-driven industries. Other industries shown in Figure 5 can be interpreted in a similar manner.

In Figure 6, the real estate industry saw an increase in sale of $46.4 million in FY 2017. This industry generated the largest output impact (17%) of the $272.1 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 2017

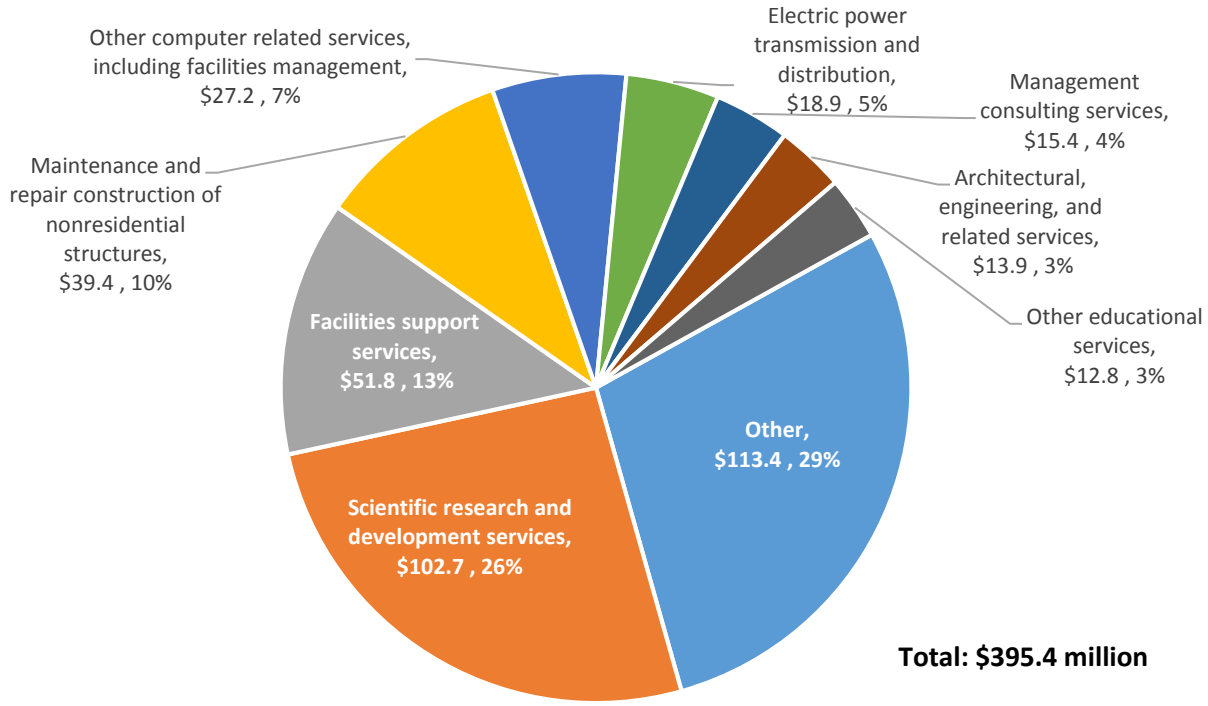
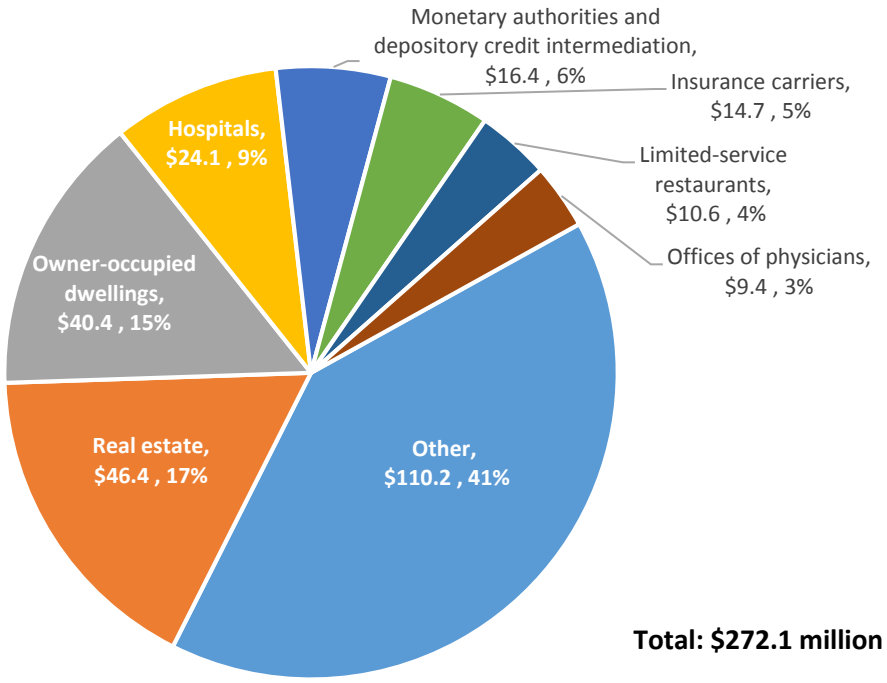


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2017



Total: $272.1 million

D.2.2. Employment Impact on Northeast Ohio, FY 2017

NASA Glenn's operation in Northeast Ohio supported existing jobs and created new full-time and part-time jobs in addition to its own employment (change in final demand or direct impact). Glenn spending triggers increased employment in industries from which it purchases goods and services (direct impact) and employment in industries that provided inputs into the production of those goods (indirect impact).

In addition, money spent by employees of NASA Glenn employees and those companies with which Glenn does business create jobs in variety of other industries (induced impact). The total employment impact equals the sum of NASA Glenn's full-time equivalent (FTE) employment, direct impact, indirect impact, and induced impact. Table 8 displays the number of new and supported jobs by industry sector.

Table 8. Employment Impact in Northeast Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		1	4	6
Mining		2	2	4
Utilities		33	6	39
Construction		309	25	334
Manufacturing		19	17	36
Wholesale Trade		20	69	89
Retail Trade		99	389	488
Transportation and Warehousing		37	77	114
Information		17	34	51
Finance and Insurance		34	152	186
Real Estate and Rental		101	135	236
Professional, Scientific, and Tech Services		1,159	111	1,270
Management of Companies		18	19	37
Administrative and Waste Services		818	157	975
Educational Services		488	108	595
Health and Social Services		0	531	531
Arts, Entertainment, and Recreation		25	76	101
Accommodation and Food Services		47	320	367
Other Services		51	238	289
Government & non-NAICs	1,508	3	11	1,523
Total Employment	**1,508**	**3,282**	**2,481**	**7,271**

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

Employment increased by 7,271 in Northeast Ohio in FY 2017 due to NASA Glenn's spending. Of these 7,271 jobs, 1,508 (20.7%) were directly employed at NASA Glenn in FY 2017. As a result of Glenn's direct spending for goods and services purchased in the region, 3,282 full-time and part-time jobs (45.1%) were created as indirect economic impact. The remaining employment impact, 2,481 jobs (34.1%), is in the form of induced impacts as NASA Glenn spending ripples through the economy. These industries produce products that are typically within a consumer purchasing pattern of the region.

Of the 5,763 jobs created and supported in Northeast Ohio due to the indirect and induced impacts, 3,265 (56.6%) were found in the NASA Glenn-driven industries, 1,969 (34.2%) were in the consumer-driven industries, and 529 (9.2%) fall under the category of other industries.[31] The job distribution for select industries within the NASA Glenn-driven industries is shown in Figure 7. The job distribution for select industries within the consumer-driven ones is shown in Figure 8. The industries presented in Figures 7 and 8 are the leading industries with the most increased employment (minimum of 130 employees (or over 4%) per sector in Figure 7 and 60 (or over 3%) in Figure 8).

NASA Glenn's scientific research and development service industry saw the largest increase among consumer-driven industries; the increase of 523 jobs in FY 2017 was due to NASA Glenn's spending that generates labor income in regional supply industries (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 16% of the 3,265 jobs that were created in all industries within the NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted the same manner.

The real estate industry generated the highest number of additional jobs among consumer-driven industries; the increase of 218 jobs in FY 2017 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 218 jobs accounted for 11% of the 1,969 jobs created across all consumer-driven industries.

[31] 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 2017

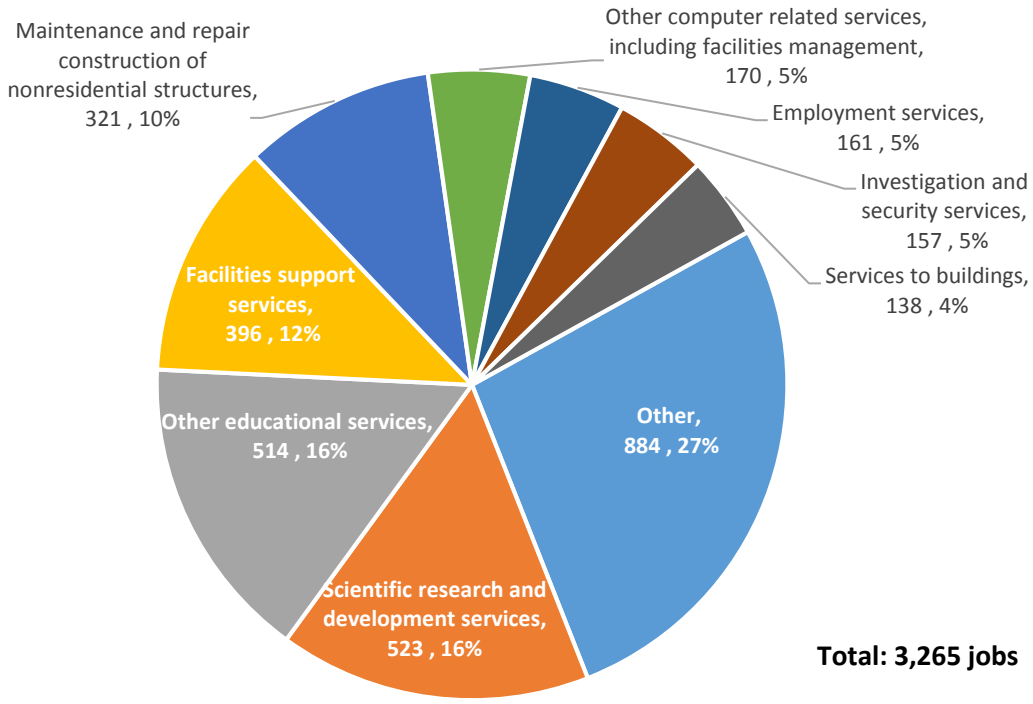
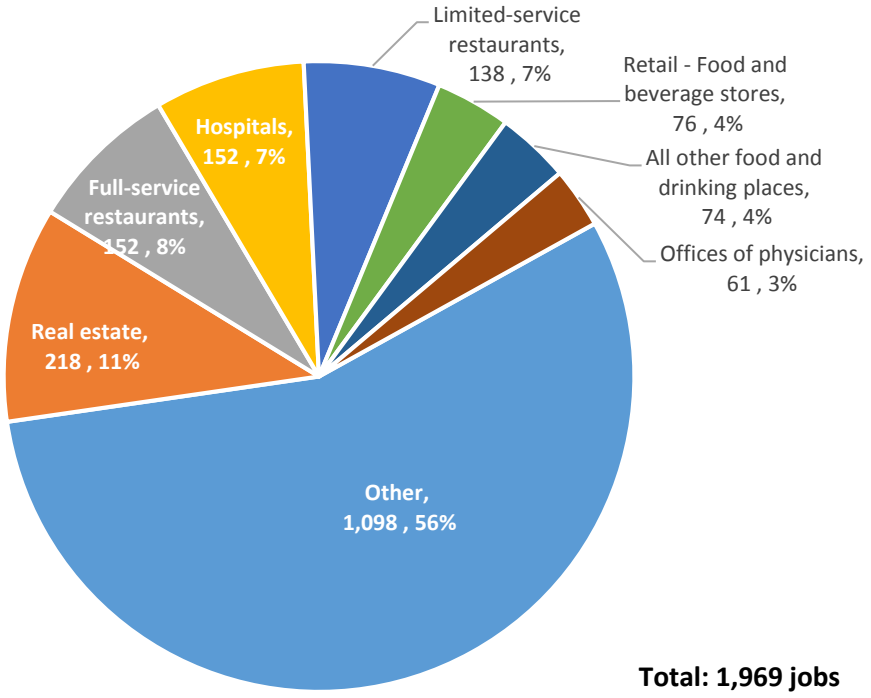


Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2017



D.2.3. Labor Income Impact on Northeast Ohio, FY 2017

Labor income is assessed as the estimated earnings received by NASA Glenn employees and the change in the earnings of employees of its supply companies in Northeast Ohio due to NASA Glenn's spending on goods and services in Northeast Ohio. Money paid to employees of companies and other suppliers of goods and services to NASA Glenn represent the direct earnings impact. Indirect impact is estimated by summing the monies paid to persons who work for companies that provide inputs to the producers of the goods and services ultimately consumed by Glenn.

Induced impact represents money paid to workers in all industries who are employed as a result of purchases by people whose income is affected by the 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 Induced impact represents monies paid to workers in all industries who are employed as a result of purchases by households whose income is affected by the demand for products and services created by Glenn. Adding the direct, indirect, and induced impacts to the disposable income and healthcare benefits received by NASA Glenn employees (final demand change) results in total earnings impact. Table 9 shows the earnings impact by industry sector.

Table 9. Labor Income Impact in Northeast Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$29,439	$74,832	$104,271
Mining		$397,103	$228,435	$625,538
Utilities		$2,747,224	$726,699	$3,473,923
Construction		$15,030,062	$1,389,585	$16,419,647
Manufacturing		$1,279,760	$1,115,828	$2,395,588
Wholesale Trade		$1,697,392	$5,870,938	$7,568,330
Retail Trade		$2,269,448	$11,998,442	$14,267,889
Transportation and Warehousing		$2,084,203	$4,129,166	$6,213,368
Information		$1,219,330	$2,337,654	$3,556,984
Finance and Insurance		$2,490,693	$9,579,967	$12,070,661
Real Estate and Rental		$1,683,171	$2,233,248	$3,916,419
Professional, Scientific, and Tech Services		$83,208,517	$8,069,974	$91,278,490
Management of Companies		$2,226,100	$2,259,798	$4,485,897
Administrative and Waste Services		$23,328,417	$5,241,999	$28,570,416
Educational Services		$7,699,074	$3,766,723	$11,465,797
Health and Social Services		$32,617	$30,547,235	$30,579,852
Arts, Entertainment, and Recreation		$473,163	$2,039,680	$2,512,843
Accommodation and Food Services		$994,045	$6,564,753	$7,558,798
Other Services		$2,723,339	$8,619,922	$11,343,261
Government & non-NAICs	$225,301,372	$310,940	$1,068,746	$226,681,058
Total Output	**$225,301,372**	**$151,924,036**	**$107,863,622**	**$485,089,030**

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 in Northeast Ohio increased by $485.1 million as a result of NASA Glenn's spending in FY 2017 for goods and services. Out of this total amount, $225.3 million (46.4%) represents money paid for wages and benefits paid directly to NASA Glenn employees, i.e., direct impact. Of the total impact, $151.9 million (31.3%) represented indirect impact, or the money paid to employees of companies in Northeast Ohio that supply goods and services to NASA Glenn. The rest of the total impact, $107.9 million (22.2%), was created as induced impact due to spending of NASA Glenn and suppliers' employees made through industries in the regional economy. These industries produce products that are typically within a consumer purchasing pattern of the region.

Of the $259.8 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, $154.8 million (59.6%) was reported in NASA Glenn-driven industries, $77.3 million (29.8%) was generated in consumer-driven industries; and $27.2 million (10.7%) was reported in other industries.[32]

The labor income distribution for select NASA Glenn-driven and consumer-driven industries are shown in Figure 9 and 10, respectively.

Selected industries, shown in Figure 9 and 10, added over $6.5 million (over 4%) and $2.3 million (over 3%), respectively.

As shown in Figure 9, the scientific research and development services, part of the NASA Glenn-driven industries, saw their labor income increase by $37.9 million in FY 2017. These earnings are the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn using scientific research and development services in Northeast Ohio. The $37.9 million spent on scientific research and development accounted for 24% of the $157.8 million increase in labor income reported by all the NASA Glenn-driven industries.

In the consumer-driven industries, people working in private hospitals saw their household earnings increase by $12.1 million in FY 2017 (Figure 10). These earnings are the summation of the direct, indirect, and induced impacts generated by consumer spending at private hospitals. The $12.1 million represent 16% of the $77.3 million labor income increase that occurred in all industries within the consumer-driven ones. Other industries shown in Figure 10 can be interpreted similarly.

[32] 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 2017

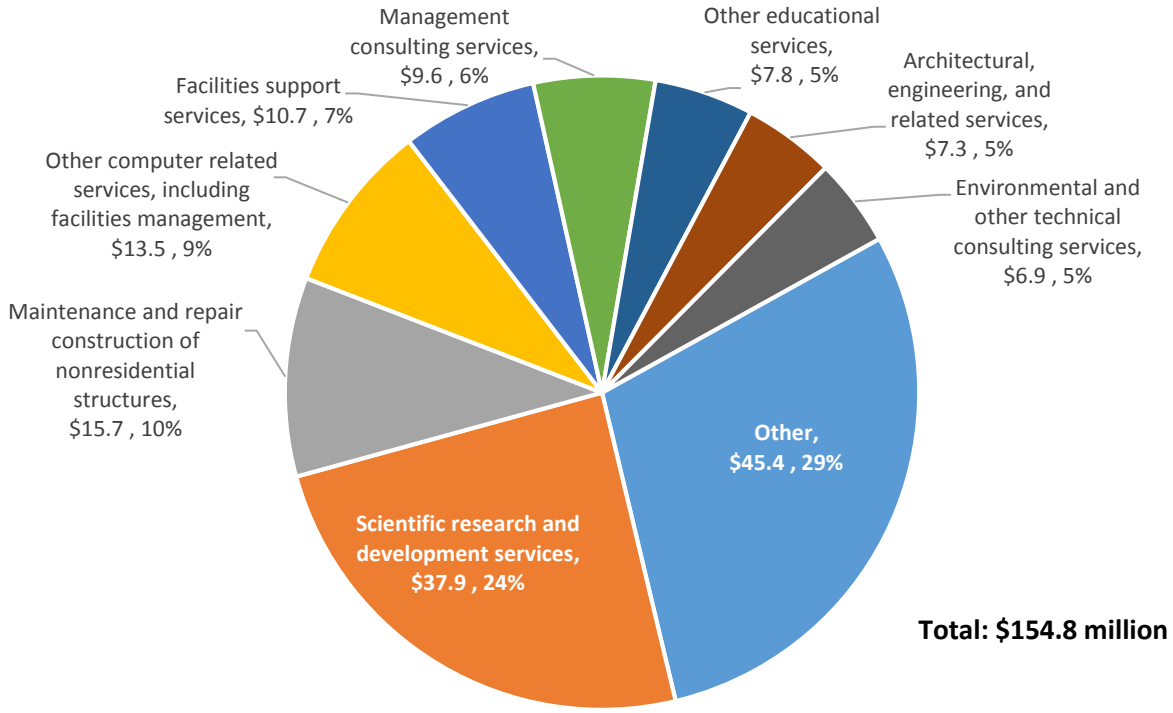
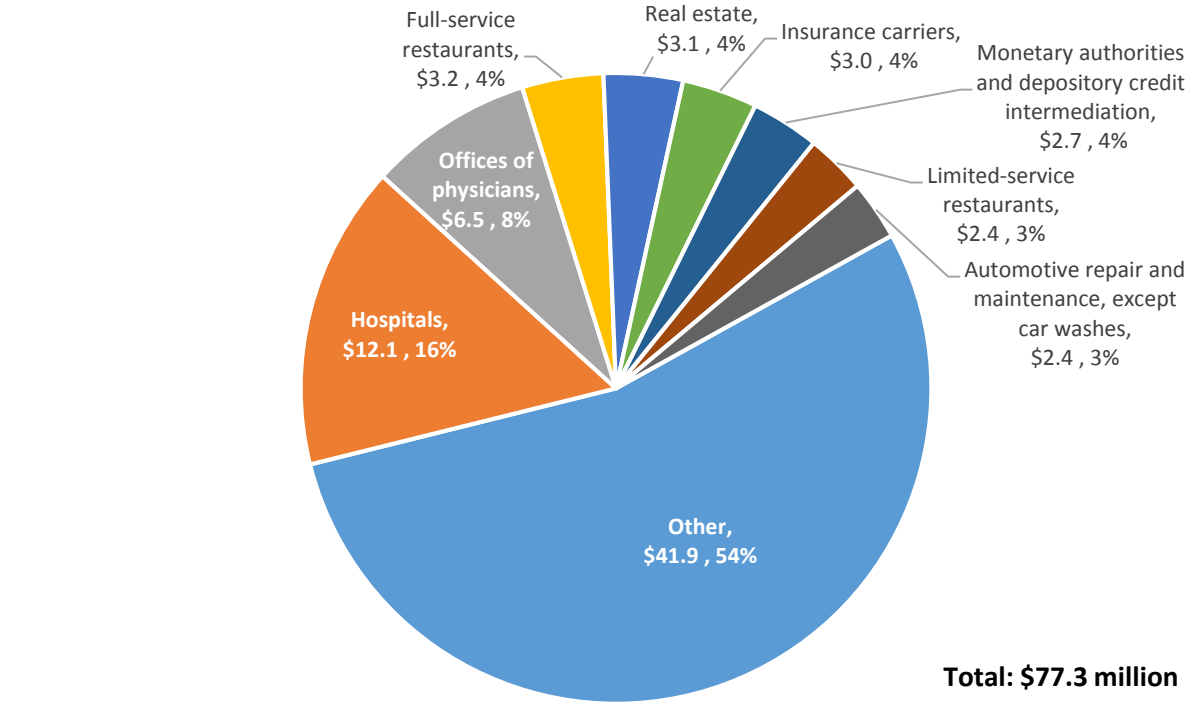


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2017



D.2.4. Value Added Impact on Northeast Ohio, FY 2017

NASA Glenn's spending created an increase of $741.7 million in value added for all industries in Northeast Ohio. Glenn's spending affected a $741.7 million increase in sales (direct, indirect, and induced impacts) by all industries, excluding intermediary goods and services. The total output less intermediate expenditures constituted the change in final demand (or direct impact) for value added—$316.9 million. The sales from companies and other suppliers of goods and services to NASA Glenn, excluding the value of intermediary goods and services, represented the indirect value added impact.

Indirect impact was estimated by summing the sales of companies that provide inputs to the producers of goods and services ultimately consumed by NASA Glenn, excluding the value of intermediary goods and services. Induced impact represents sales excluding intermediary goods and services in all industries that produce products for households whose income is affected by the demand for products and services created by Glenn. The total value added impact was found by adding the direct, indirect, and induced impacts. The value added impact by industry sector is shown in Table 10.

Table 10. Value Added Impact in Northeast Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$33,267	$85,461	$118,728
Mining		$502,477	$323,915	$826,393
Utilities		$11,849,389	$3,261,787	$15,111,176
Construction		$19,199,392	$1,761,186	$20,960,578
Manufacturing		$2,122,811	$2,517,394	$4,640,205
Wholesale Trade		$3,092,087	$10,694,911	$13,786,999
Retail Trade		$3,143,471	$20,877,027	$24,020,498
Transportation and Warehousing		$2,464,562	$4,815,133	$7,279,695
Information		$2,554,805	$6,343,200	$8,898,005
Finance and Insurance		$6,934,962	$23,857,245	$30,792,208
Real Estate and Rental		$16,012,358	$46,698,458	$62,710,816
Professional, Scientific, and Tech Services		$98,823,894	$10,274,723	$109,098,617
Management of Companies		$2,783,402	$2,825,537	$5,608,939
Administrative and Waste Services		$36,912,166	$6,933,249	$43,845,416
Educational Services		$7,785,522	$3,784,142	$11,569,665
Health and Social Services		$37,506	$34,334,592	$34,372,098
Arts, Entertainment, and Recreation		$604,366	$4,160,025	$4,764,391
Accommodation and Food Services		$1,237,186	$9,247,506	$10,484,693
Other Services		$3,559,849	$10,309,329	$13,869,178
Government & non-NAICs	$316,897,068	$453,166	$1,549,915	$318,900,148
Total Output	**$316,897,068**	**$220,106,641**	**$204,654,737**	**$741,658,445**

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 $741.7 million as a result of NASA operation in FY 2017. Out of this total amount, $316.9 million (42.7%) represented 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 $220.1 million (29.7%) accounts for 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 $204.7 million (27.6%). It occurred as a result of NASA Glenn's spending rippling through the Northeast Ohio economy.

Of the $424.8 million increase in value added attributed to the indirect ($220.1 million) and induced impacts ($204.7 million), $209.5 million (49.3%) was observed in Glenn-driven industries, $171.6 million (40.4%) was occurred in consumer-driven industries, and $43.7 million (10.3%) was reported in other industries.[33]

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 $8 million and $5.5 million each, respectively.

The scientific research and development services industry in Northeast Ohio saw the largest value added increase $50.1 million in FY 2017 (Figure 11). This amount is the summation of the indirect and induced impacts generated by NASA Glenn's spending. This increase of $50.1 million represented a 24% share of the $209.5 million increase in value added for all NASA Glenn-driven industries. Other industries shown in Figure 11 can be interpreted similarly.

In the consumer-driven industries, people engaged in the scientific research and development services industry saw the sector's value added increase by 37.9 million in FY 2017 (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 $37.9 million accounted for 24% of the $171.6 million value added increase that occurred in all consumer-driven industries.

[33] 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 2017

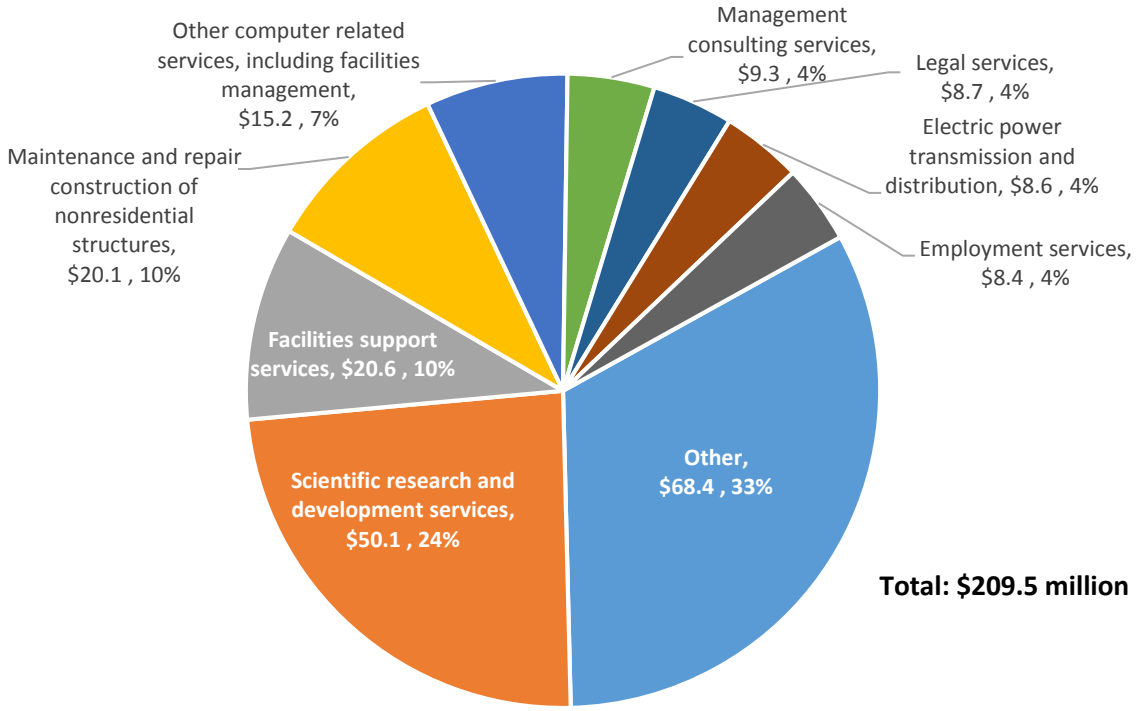
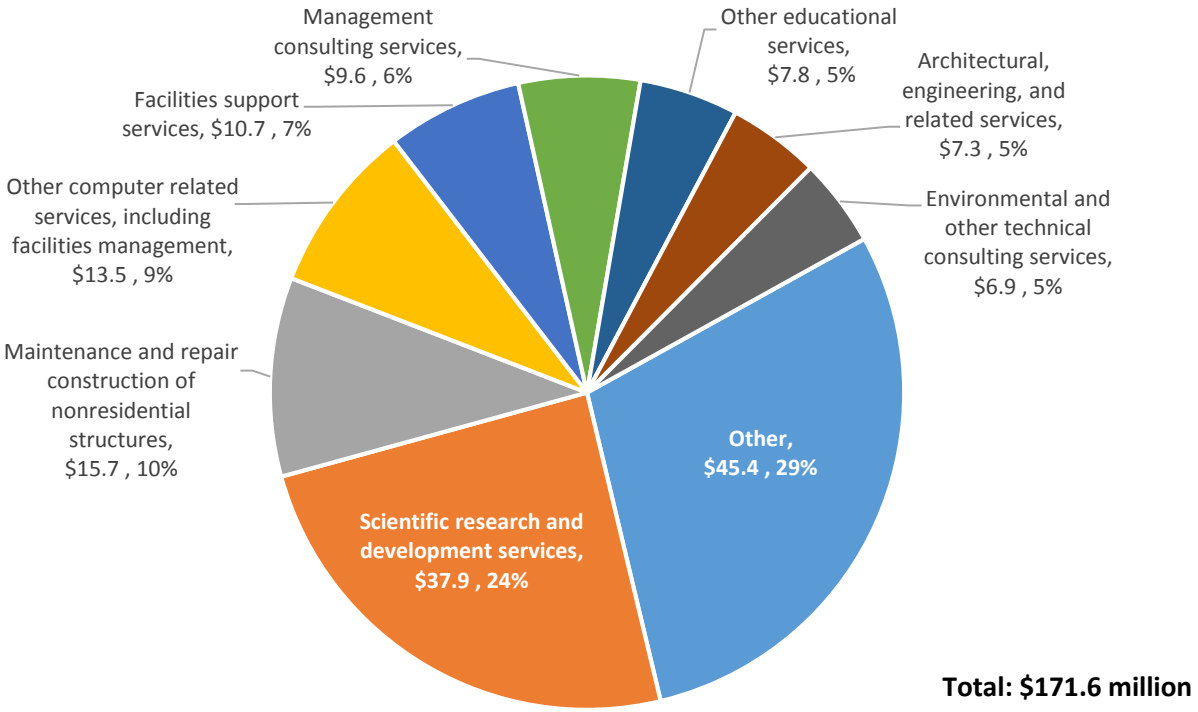


Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2017



D.2.5. Tax Impact on Northeast Ohio, FY 2017

NASA Glenn's operation and economic impact on Northeast Ohio in FY 2017 increased tax revenues by a total of $123.7 million. Of that, direct tax impact paid by NASA Glenn's employees in 2017 dollars was $33.4 million, $44.3 million was indirect tax impact, and $45.9 came from induced tax impact.

D.2.6. FY 2017 Northeast Ohio Impact Summary

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

- Total Output Impact: $1,422.0 M
- Total Employment Impact: 7,271 jobs
- Total Labor Income Impact: $485.1 M
- Total Value Added Impact: $741.7 M
- Total Tax Impact: $123.7 M

The impact of NASA Glenn's expenditure on Northeast Ohio reflects the benefits of total expenditures of $497.9 million. These expenditures include a total amount of $272.6 million spent on purchases in Northeast Ohio in FY 2017 and expenditures on labor income paid to employees living in or commuting to Northeast Ohio in the amount of $225.3 million.

Excluding expenditures on labor income, 53.5% (almost $146 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 21.7% ($59.1 million) was spent on administrative and support services; and 13.0% ($35.5 million) was spent on construction – the three largest groups of NASA Glenn expenditures in Northeast Ohio.[34] These three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio and, together, represented an 88.2% share ($240.4 million) of all NASA Glenn's FY 2017 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, utilities accounted for 5.8% and educational service 4.5%. Other sectors' expenditures were less than 1%.

Businesses benefited the most from spending by NASA Glenn personnel and other workers whose earnings are due in part to NASA Glenn expenditures follow typical consumer spending patterns. These include food service, real estate companies, hospitals and healthcare services, motor vehicle dealers, counting services, commercial banks, and miscellaneous retailers.

[34] 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 2017

Assessment of the economic impact of NASA Glenn operations on Ohio's economy in FY 2017 followed a methodology similar to the calculation of economic impact of NASA Glenn on Northeast Ohio. For the State of Ohio, we account for all purchases NASA Glenn made from companies located in Ohio. The economic impact is assessed through a detailed analysis of the change in output (sales), employment, labor income, value added, and taxes due to NASA Glenn's activities in Ohio. This section follows the structure of Section D.2., Economic impact on Northeast Ohio, FY 2017.

D.3.1. Output Impact on the State of Ohio, FY 2017

The economic impact analysis uses multipliers to estimate the ripple effect that initial expenditures have on the economy. These multipliers measure the effect of NASA Glenn Research Center spending on output (sales) across the State of Ohio. The multipliers applied to spending in Ohio are generally larger than those applied to expenditures in Northeast Ohio. A larger geographic area allows for the capture of more purchases within the region, which, in turn, enables less leakage from the economy. Stated another way, as the analyzed geographic area increases in size, the amount of goods and services purchased from outside that area decreases.

NASA Glenn expenditures were divided into (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 and services made in and provided by the local economy, based on an IMPLAN classification system of industries that produced the products and services. The spending is then assigned to 536 IMPLAN sectors similar to the NAICS code industrial classification. Table A.4. in Appendix A lists detailed NASA Glenn expenditures by specific industry in the State of Ohio.

Table 11 shows 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). Indirect impact is estimated by summing the contributions of individual industries that provide inputs to the producers of the goods and services ultimately consumed by NASA Glenn. 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 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$143,076	$879,690	$1,022,766
Mining		$1,225,639	$897,419	$2,123,058
Utilities		$25,144,527	$8,921,905	$34,066,431
Construction		$37,667,140	$4,298,543	$41,965,683
Manufacturing		$9,532,966	$19,302,016	$28,834,982
Wholesale Trade		$4,391,170	$15,894,227	$20,285,397
Retail Trade		$5,374,126	$36,514,255	$41,888,380
Transportation and Warehousing		$5,661,885	$12,146,792	$17,808,676
Information		$6,665,254	$16,192,880	$22,858,134
Finance and Insurance		$10,922,121	$44,464,696	$55,386,817
Real Estate and Rental		$21,088,937	$70,385,633	$91,474,570
Professional, Scientific, and Tech Services		$200,603,027	$13,749,410	$214,352,437
Management of Companies		$4,743,207	$5,282,391	$10,025,598
Administrative and Waste Services		$77,558,698	$11,309,006	$88,867,704
Educational Services		$13,086,108	$5,732,479	$18,818,588
Health and Social Services		$63,896	$58,668,968	$58,732,864
Arts, Entertainment, and Recreation		$1,303,429	$6,953,166	$8,256,596
Accommodation and Food Services		$2,561,328	$20,711,559	$23,272,887
Other Services		$4,824,820	$16,426,314	$21,251,134
Government & non-NAICs	$674,249,080	$1,066,089	$3,806,828	$679,121,997
Total Output	**$674,249,080**	**$433,627,442**	**$372,538,178**	**$1,480,414,700**

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 of NASA Glenn on the State of Ohio was $1,480.4 million in FY 2017. NASA Glenn's $674.2 million worth of expenditures resulted in an output (sales) change of $1,480.4 million across all industry sectors (Table 11). For example, NASA Glenn's spending caused a $214.4 million increase in total sales by the Professional, Scientific, and Technical services industry. If Glenn did not exist in the State of Ohio, the regional output in the Real Estate and Rental industry would drop by $91.5 million. These examples illustrate the idea that the regional impact of 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 the State of Ohio.

Of the total output impact, 45.5% ($674.2 million) is accounted for by Glenn's direct spending, which constitutes the direct economic impact to the State of Ohio. $433.6 million (29.2%) 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 $372.5 million (25.2%) is due to the induced impact of Glenn's spending throughout the state.

A detailed analysis of the IMPLAN model's results indicates that the $806.2 million change in output (sales) due to indirect and induced economic impacts can be divided into three broad categories: NASA Glenn-driven ($420.5 million, 52.2%), consumer-driven ($281.8 million, 35.0%), and other industries ($103.9 million, 12.9%).[35]

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 $12.5 million (or 3.0%) and $11.5 million (or 4.0%), respectively.

The scientific research and development industry generated the largest output impact; it increased by $122.7 million in FY 2017 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 $122.7 million accounted for 29% of the $420.5 million increase in output for all Glenn-driven industries. Other industries shown in Figure 13 can be interpreted similarly.

In consumer-driven industries (Figure 14), the owner-occupied dwellings industry generated the largest output impact; it increased by $43.9 million in FY 2017 due to NASA Glenn's operations in the State of Ohio.[36] This amount is the summation of the indirect and induced impact components generated primarily by NASA Glenn employees and other workers. This increase of $43.9 million represented a 16% share of the $281.8 million increase in output for all consumer-driven industries. Other industries shown in Figure 14 can be interpreted similarly.

[35] 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.

[36] An owner-occupied dwelling is a special industry sector developed by the Bureau of Economic Analysis. It estimates what owner/occupants would pay in rent if they rented rather than owned their homes. This sector creates an industry out of owning a home. Its sole product (or output) is ownership, purchased entirely by personal consumption expenditures. Owner-occupied dwellings capture the expenses of home ownership such as repair and maintenance construction, various closing cost, and other expenditures related to the upkeep of the space in the same way expenses are captured for rental properties.

Figure 13. Increase in Sales for Select NASA Glenn-Driven Industries in Ohio, FY 2017

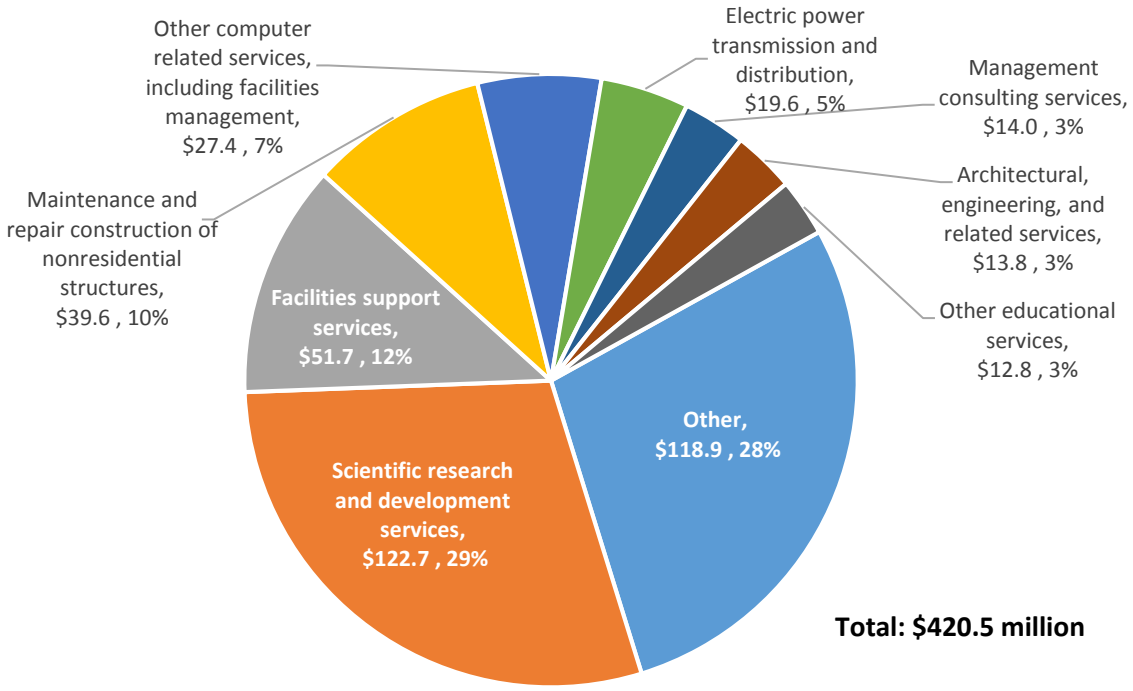
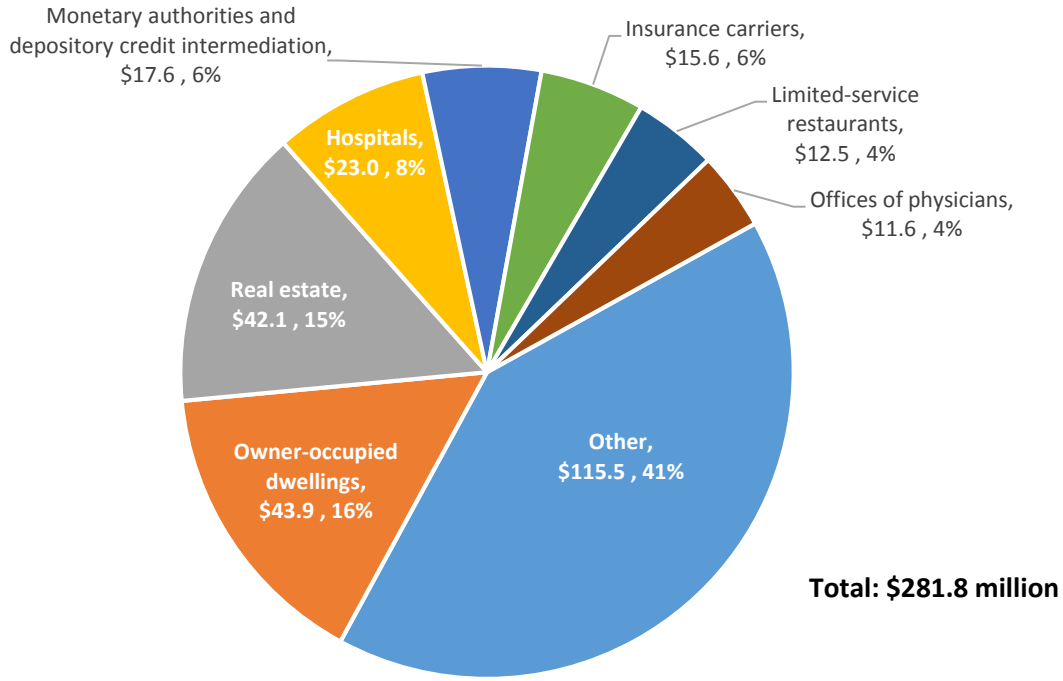


Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2017



D.3.2. Employment Impact on the State of Ohio, FY 2017

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

In addition, money spent by employees of NASA Glenn 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 shows the number of jobs supported and created by industry sector.

Table 12. Employment Impact in the State of Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		2	12	14
Mining		5	4	9
Utilities		32	8	39
Construction		311	28	339
Manufacturing		28	35	63
Wholesale Trade		20	71	90
Retail Trade		107	439	546
Transportation and Warehousing		39	87	125
Information		17	37	54
Finance and Insurance		37	160	197
Real Estate and Rental		99	132	231
Professional, Scientific, and Tech Services		1,270	110	1,380
Management of Companies		19	22	41
Administrative and Waste Services		793	160	953
Educational Services		487	107	595
Health and Social Services		1	576	577
Arts, Entertainment, and Recreation		22	80	102
Accommodation and Food Services		48	357	405
Other Services		47	271	319
Government & non-NAICs	1,508	4	12	1,524
Total Output	**1,508**	**3,387**	**2,708**	**7,603**

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

The total employment impact of NASA Glenn on the State of Ohio economy in FY 2017 was 7,603 jobs. Out of the total employment, 1,508 (19.8%) were directly employed at NASA Glenn Research Center. As a result of NASA Glenn's spending on goods and services, an additional 3,387 full- time and part-time jobs (44.5%) were supported and created in the region as indirect economic impact. The remaining 2,708 jobs (35.6%) were created as induced impact due to purchases made by NASA Glenn and suppliers' employees. These industries produce products that are typically within a consumer purchasing pattern of the region.

Of the 6,095 jobs created in the State of Ohio due to the indirect and induced effects, 3,358 (55.1%) were in NASA Glenn-driven sectors, 2,104 (34.5%) were in consumer-driven sectors, and 633 (10.4%) were created in other sectors.[37] The job distribution for select NASA Glenn-driven and consumer-driven industries are shown in Figure 15 and 16, respectively. Each of the selected industries shown in Figures 15 and 16 supported or added over 160 (or 4.5%) and 70 (or 3.0%) jobs, respectively.

The scientific research and development industry generated the highest number of additional jobs (Figure 15). Companies engaged in scientific research and development (professional, scientific, and technical services sector) saw an increase of 622 jobs and accounted for an 18% share of the 3,358 jobs that were created across all NASA Glenn-driven industries in FY 2017. 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 saw the largest increase among consumer-driven industries; the increase of 213 jobs in FY 2017 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. The 213 jobs represent a 10% share of the 2,104 jobs created across all consumer-driven industries.

[37] 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 2017

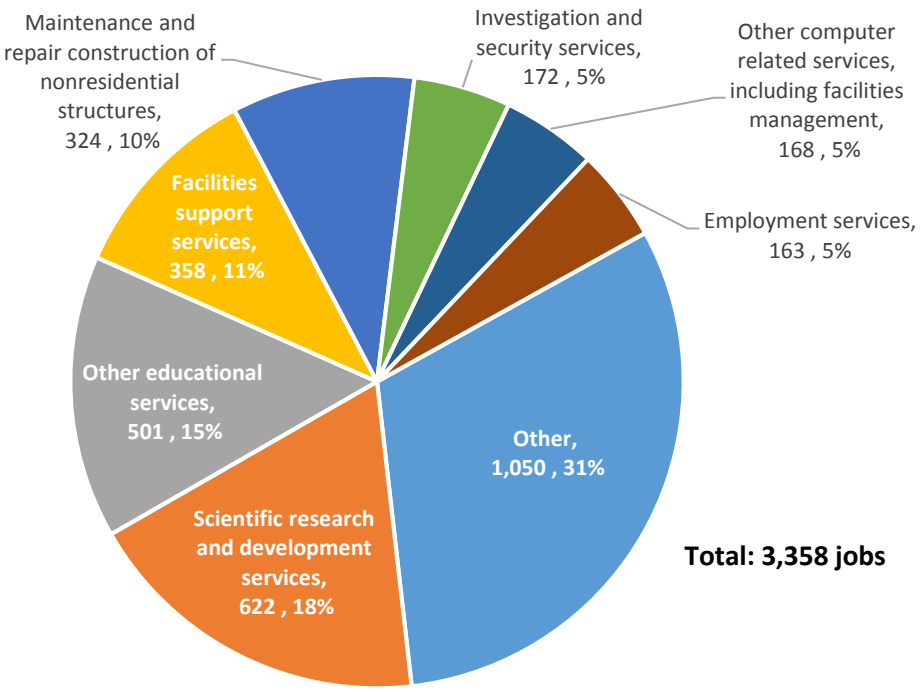
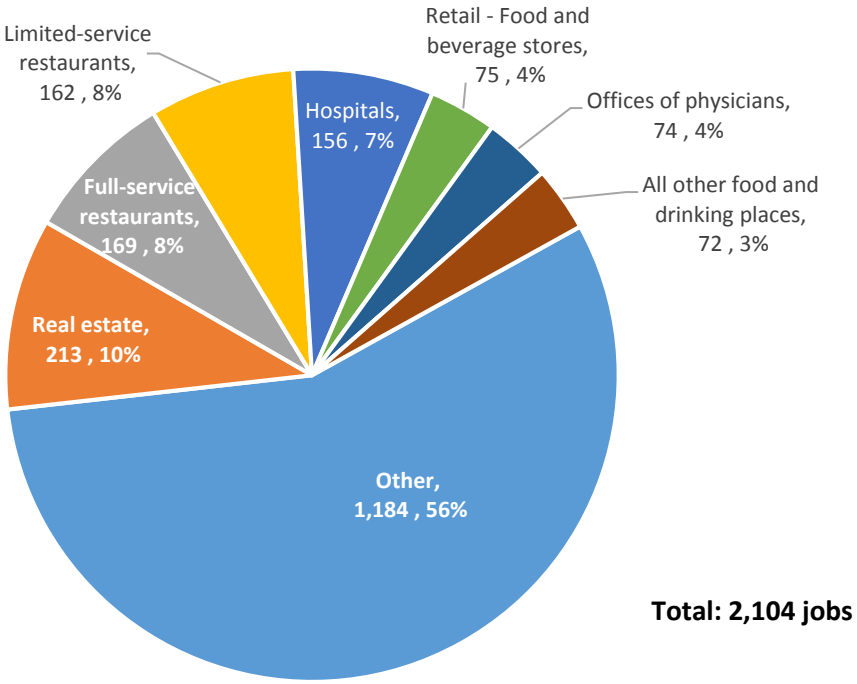


Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2017



D.3.3 Labor Income Impact on the State of Ohio, FY 2017

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 the State of Ohio and the 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 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. The labor income impact by industry is showed in Table 13.

Table 13. Labor Income Impact in the State of Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$68,839	$222,812	$291,651
Mining		$272,484	$158,913	$431,397
Utilities		$3,344,316	$971,535	$4,315,851
Construction		$14,992,741	$1,568,066	$16,560,807
Manufacturing		$1,882,357	$2,344,991	$4,227,348
Wholesale Trade		$1,534,835	$5,536,055	$7,070,890
Retail Trade		$2,332,098	$13,170,163	$15,502,261
Transportation and Warehousing		$2,482,438	$5,227,123	$7,709,561
Information		$1,361,289	$2,703,379	$4,064,667
Finance and Insurance		$2,481,837	$9,883,323	$12,365,160
Real Estate and Rental		$1,908,270	$2,595,711	$4,503,980
Professional, Scientific, and Tech Services		$88,744,917	$7,033,389	$95,778,306
Management of Companies		$2,316,933	$2,580,310	$4,897,243
Administrative and Waste Services		$26,460,755	$5,683,800	$32,144,554
Educational Services		$8,256,294	$3,466,746	$11,723,040
Health and Social Services		$31,061	$32,137,040	$32,168,101
Arts, Entertainment, and Recreation		$513,528	$2,142,843	$2,656,371
Accommodation and Food Services		$1,025,548	$7,386,772	$8,412,320
Other Services		$2,475,411	$9,765,367	$12,240,778
Government & non-NAICs	$232,336,321	$338,210	$1,073,500	$233,748,032
Total Output	**$232,336,321**	**$162,824,160**	**$115,651,839**	**$510,812,320**

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 increased by $510.8 million in the State of Ohio as a result of NASA Glenn's spending on goods and services in FY 2017. Of this amount, $232.3 million (45.5%) constituted wages and benefits paid directly to NASA Glenn employees (i.e., change in final demand or direct effect measured is 2017 dollars). Of the $510.8 million of the total labor income, $162.8 million (31.9%) represented indirect impact, or the money paid to employees of companies in the State of Ohio that supply goods and services to NASA Glenn. The remaining induced earnings were $115.7 million (22.6%); they occurred as the effects of NASA Glenn's spending rippled through the State of Ohio economy via labor income spending.

Of the $278.5 million increase in labor income generated across the State of Ohio due to the indirect and induced impacts, $164.5 million (59.1%) was reported in Glenn-driven industries, $82 million (29.4%) observed in consumer-driven industries, and $32.0 million (11.5%) was occurred in other industries.[38]

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 4% ($6.5 million) and 3% ($ 2.3 million) share each in Figure 17 and 18, respectively.

In the NASA Glenn-driven industries, people who were engaged in scientific research and development services saw their labor income increase by $45.4 million in FY 2017 (Figure 17). These earnings are the summation of the indirect and induced impacts generated by NASA Glenn's purchases of computer-related services. The $45.4 million accounted for 28% of the $164.5 million increase in labor income reported by all the NASA Glenn-driven industries.

Private hospitals, part of the consumer-driven industries, saw their labor income increase by $10.9 million in FY 2017 (Figure 18). These earnings are the summation of the indirect and induced impacts occurred by consumer spending for doctors' services. The $10.9 million accounted for 13% of the $82.0 million labor income increase that occurred in all consumer-driven industries.

[38] See section D.2.1. Output Impact on Northeast Ohio, FY 2016 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 2017

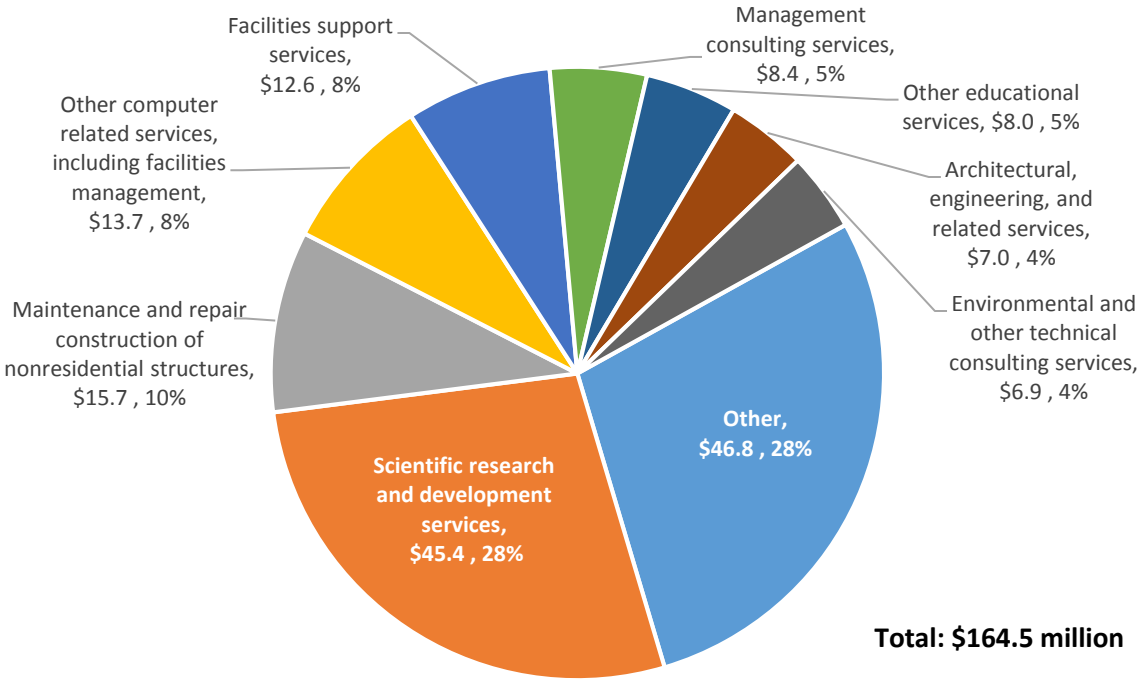
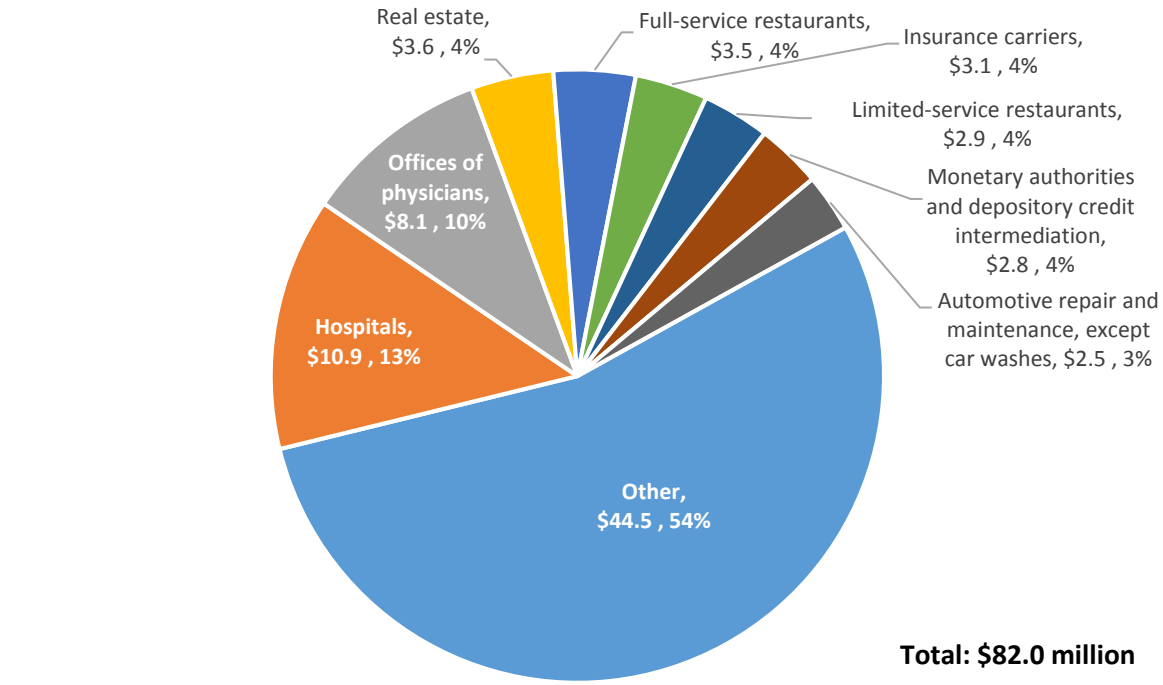


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2017



D.3.4. Value Added Impact on the State of Ohio, FY 2017

The total value added impact was $775.6 million, which resulted from NASA Glenn's regional spending on goods and services in the State of Ohio.[39] NASA Glenn's spending led to a $775.6 million increase in sales (direct, indirect, and induced impacts) by all industries, excluding intermediary goods and services. The total output less intermediate expenditures, $323.6 million in FY 2017, constituted the change in final demand (or direct impact) for value added. Indirect impact was estimated by summing the sales of companies that provide inputs to the producers of goods and services ultimately consumed by NASA Glenn (excluding the value of intermediary goods and services). Induced impact represented sales, excluding intermediary goods and services, in all industries that produced products for households whose income is affected by the demand for products and services created by NASA Glenn. The total value added impact is a summation of the direct, indirect, and induced impacts and the wages and benefits received by NASA Glenn employees (change in final demand) (Table 14).[40]

Table 14. Value Added Impact in the State of Ohio, FY 2017

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$78,025	$334,233	$412,258
Mining		$795,757	$601,139	$1,396,896
Utilities		$13,045,880	$4,159,343	$17,205,223
Construction		$19,145,422	$1,986,457	$21,131,879
Manufacturing		$3,412,746	$6,133,656	$9,546,402
Wholesale Trade		$2,826,550	$10,195,187	$13,021,737
Retail Trade		$3,264,701	$23,350,467	$26,615,168
Transportation and Warehousing		$2,978,062	$6,198,374	$9,176,436
Information		$2,817,226	$7,405,452	$10,222,678
Finance and Insurance		$7,006,969	$24,862,384	$31,869,353
Real Estate and Rental		$14,398,803	$46,855,222	$61,254,025
Professional, Scientific, and Tech Services		$106,205,749	$8,779,001	$114,984,751
Management of Companies		$2,899,751	$3,229,381	$6,129,132
Administrative and Waste Services		$41,126,885	$7,455,795	$48,582,681
Educational Services		$8,344,583	$3,495,977	$11,840,560
Health and Social Services		$35,723	$36,026,891	$36,062,613
Arts, Entertainment, and Recreation		$617,551	$4,042,774	$4,660,324
Accommodation and Food Services		$1,308,773	$10,702,081	$12,010,854
Other Services		$3,308,806	$10,867,660	$14,176,466
Government & non-NAICs	$323,639,558	$162,291	$1,515,409	$325,317,258
Total Output	**$323,639,558**	**$233,780,253**	**$218,196,882**	**$775,616,693**

[39] "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).

[40] 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 $775.6 million as a result of NASA Glenn's spending for goods and services in FY 2017. Out of this total amount, $323.6 million (41.7%) represents 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 $233.8 million (30.1%) accounted for the value of goods and services and fewer intermediary goods of companies in Northeast Ohio that supply NASA Glenn (i.e., indirect impact). The remaining value added impact (induced component) was estimated at $218.2 million (28.1%). It occurred as a result of NASA Glenn's spending rippling through the State of Ohio economy.

Of the $452.0 million increase in value added observed across the State of Ohio due to the induced and indirect impacts, $223.8 million (49.5%) was reported in NASA Glenn-driven industries, $175.3 (38.8%) was generated in consumer-driven industries, and $52.8 million (11.7%) 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 20. Selected industries in Figure 19 and Figure 20 each added at least $6.5 million (3%) and $6 million (3.5%), respectively.

The scientific research and development services industry, the largest NASA Glenn-driven industries, saw a value added increase of $60.2 million in FY 2017 (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 $60.2 million accounted for 27% of the $223.8 million value added increase that was reported by all NASA Glenn-driven industries.

People working in the real estate industry saw their value added grow by $29.7 million in FY 2017 (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 $29.7 million accounted for 17% of the $175.3 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 2017

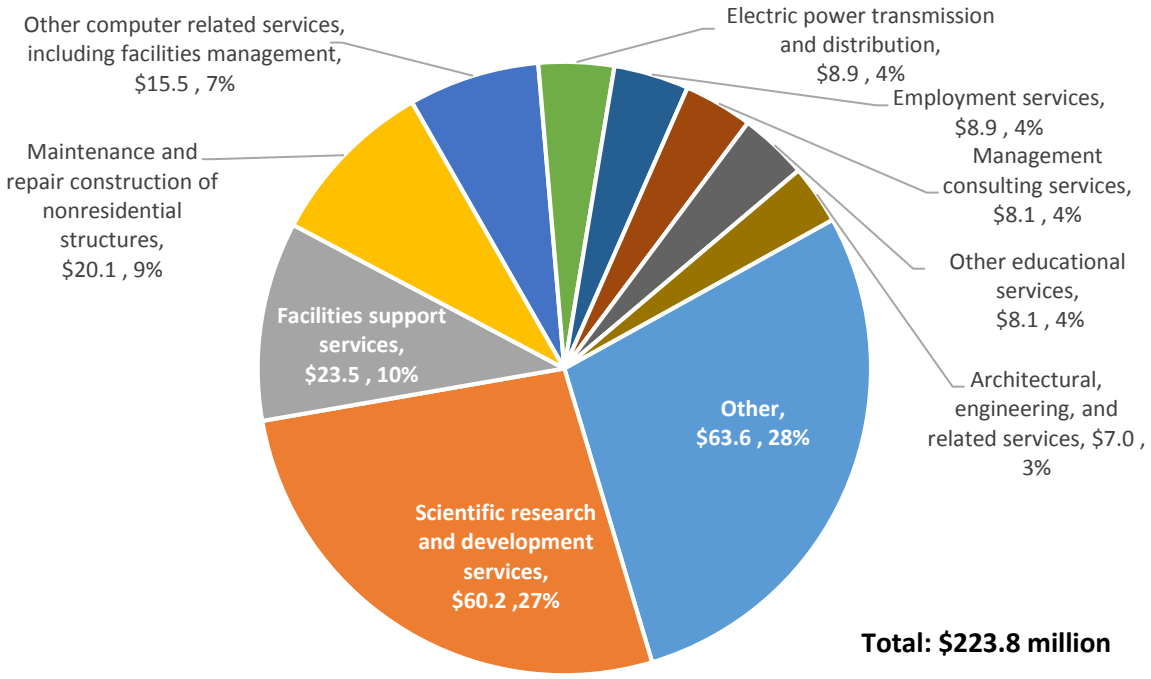
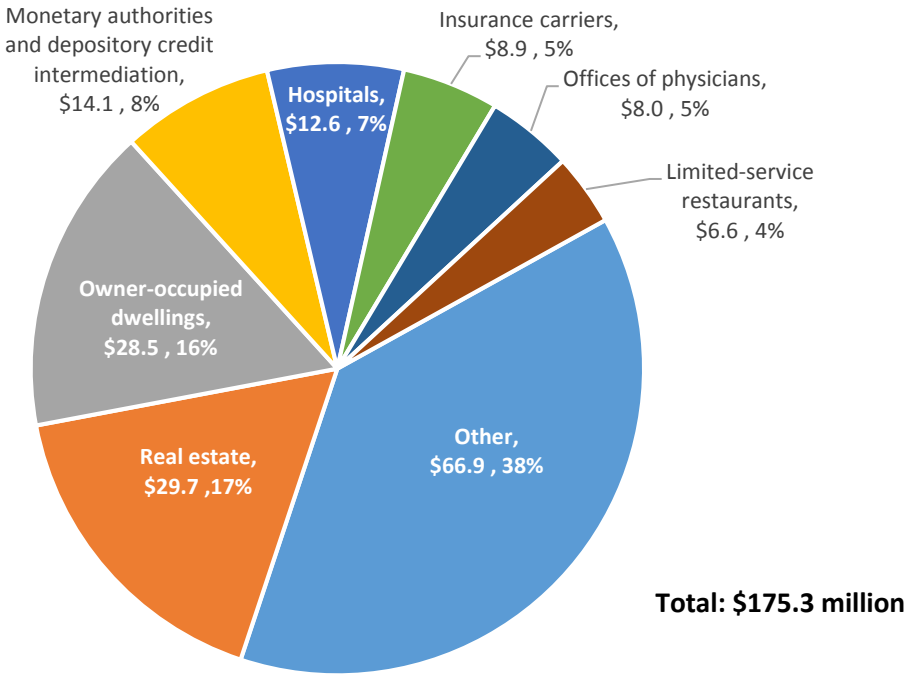


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2017



D.3.5. Tax Impact on the State of Ohio, FY 2017

NASA Glenn's operation in the State of Ohio increased tax revenues by a total of $128.8 million in FY 2017. Of that amount, direct tax impact was $33.4 million in Glenn's employee taxes on wages, $46.2 million indirect tax impact, and $49.2 million induced tax impact.

D.3.6. FY 2017 Ohio Impact Summary

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

- Total Output Impact: $1,480.4 M
- Total Employment Impact: 7,603 jobs
- Total Labor Income Impact: $510.8 M
- Total Value Added Impact: $775.6 M
- Total Tax Impact: $128.8 M

NASA Glenn's expenditures on the State of Ohio is only slightly higher than the economic impact on Northeast Ohio due to the models capture more buy-sell relationships in the larger geographic area. However, the majority of NASA Glenn's spending in Ohio were spent in Northeast Ohio.

In FY 2016, NASA Glenn's expenditures in the State of Ohio totaled $527.6 million. These expenditures include a total amount of $295.3 million spent on purchases in the State of Ohio in FY 2017 and expenditures on labor income paid to employees living in or commuting to the State of Ohio in the amount of $232.3 million. The total expenditures in all of Ohio were $29.7 million more than in the total expenditures in Northeast Ohio.

Compared the expenditures made in Northeast Ohio in FY 2017, the largest share of the total payments, excluding labor income, was spent on professional, scientific, and technical services in Ohio (56.0% in Ohio, compared to 53.5% in Northeast Ohio). More than 98.3% of NASA Glenn spending in Ohio ($295.3 million), excluding labor income, went to the following industry sectors: professional, scientific and technical services ($165.2 million); administrative and support services ($60.3 million); construction ($35.5 million); and utilities ($16.1 million).[41]

NASA Glenn's statewide expenditure pattern is similar to the expenditures in Northeast Ohio. Being a large institution employing highly qualified and highly paid labor, NASA Glenn is accountable for a large part of the economic impact through the spending of its employees. Businesses deriving the most benefit from spending by NASA Glenn personnel and other workers whose earnings are due in part to NASA Glenn's expenditures followed typical consumer spending patterns. These businesses include the following industries: food services, accounting services, commercial banks, miscellaneous retailers, real estate companies, motor vehicle dealers, educational institutions and hospitals and other healthcare services.

[41] Amounts in parentheses detailing percentage numbers are presented in 2017 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2017

State	Spending	Share
Ohio	$295,272,203	66.8%
Washington	$30,372,015	6.9%
Maryland	$24,714,352	5.6%
California	$12,874,950	2.9%
Connecticut	$8,467,703	1.9%
Virginia	$6,588,527	1.5%
Texas	$6,478,556	1.5%
Missouri	$6,456,997	1.5%
Indiana	$5,703,957	1.3%
Illinois	$5,143,227	1.2%
Pennsylvania	$5,129,100	1.2%
Michigan	$3,741,890	0.8%
Massachusetts	$3,731,755	0.8%
Arizona	$3,411,327	0.8%
Colorado	$3,160,395	0.7%
New Jersey	$2,756,288	0.6%
New York	$2,285,495	0.5%
New Mexico	$2,148,574	0.5%
Georgia	$1,766,605	0.4%
Minnesota	$1,762,163	0.4%
Florida	$1,452,167	0.3%
Oklahoma	$1,332,666	0.3%
New Hampshire	$1,279,623	0.3%
Alabama	$1,071,364	0.2%
North Carolina	$831,283	0.2%
Iowa	$710,714	0.2%
Tennessee	$676,301	0.2%
South Carolina	$470,974	0.1%
Oregon	$385,936	0.1%
District of Columbia	$224,858	0.1%
Rhode Island	$142,284	0.0%
Wisconsin	$128,295	0.0%

State	Spending	Share
South Dakota	$108,837	0.0%
Nebraska	$107,389	0.0%
Mississippi	$71,990	0.0%
Delaware	$71,649	0.0%
Utah	$62,908	0.0%
Vermont	$61,405	0.0%
Nevada	$50,337	0.0%
Montana	$47,882	0.0%
West Virginia	$32,519	0.0%
Kansas	$26,918	0.0%
Idaho	$12,887	0.0%
Hawaii	$10,849	0.0%
Maine	$733	0.0%
Puerto Rico	$709	0.0%
Alaska	$428	0.0%
Kentucky[42]	-$129,556	0.0%
U.S. Total	**$441,210,429**	**99.8%**
Canada	$144,162	0.0%
France	$20,560	0.0%
Germany	$385,222	0.1%
Great Britain	$146,476	0.0%
Netherlands	$779	0.0%
Portugal	$2,595	0.0%
Singapore	$46	0.0%
Switzerland	$2,490	0.0%
Foreign Total	**$702,330**	**0.2%**
Grand Total	**$441,912,759**	**100.0%**

[42] Negative cost for FY17 due to returned funds on a closed Space Act Agreement.

Table A.2. NASA Glenn Grants Allocated to Academic Institutions by State, FY 2017

State	Amount	Share
California	$1,930,976	13.9%
Ohio	$1,540,326	11.1%
Maryland	$1,475,417	10.6%
Illinois	$1,217,675	8.7%
Texas	$1,096,813	7.9%
Arizona	$824,486	5.9%
Massachusetts	$642,818	4.6%
Connecticut	$631,693	4.5%
Michigan	$622,604	4.5%
Pennsylvania	$510,972	3.7%
New Jersey	$506,545	3.6%
Georgia	$384,000	2.8%
South Carolina	$356,360	2.6%
Colorado	$320,211	2.3%
New York	$298,965	2.1%
Tennessee	$283,163	2.0%
North Carolina	$260,419	1.9%
Indiana	$229,046	1.6%
Washington	$117,350	0.8%
South Dakota	$108,837	0.8%
Virginia	$89,278	0.6%
Iowa	$87,430	0.6%
Missouri	$73,877	0.5%
Mississippi	$71,990	0.5%
Kentucky	$59,491	0.4%
Delaware	$57,718	0.4%
Minnesota	$39,482	0.3%
Florida	$27,137	0.2%
Oregon	$17,252	0.1%
Hawaii	$10,849	0.1%
Alabama	$3,878	0.0%
Outside US	$36,416	0.3%
Great Britain Total	$36,416	0.3%
Grand Total	**$13,933,472**	**100.0%**

Note: Nineteen states did not have Academic Institutions that received NASA Glenn grants in 2017.

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2017

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$15,888,768**
	Electric power transmission and distribution	49	$12,729,657
	Natural gas distribution	50	$454,388
	Water, sewage and other systems	51	$2,704,723
Construction			**$35,546,609**
	Maintenance and repair construction of nonresidential structures	62	$35,546,609
Manufacturing			**$1,021,521**
	Printing	154	$7,623
	Support activities for printing	155	$34,815
	Industrial gas manufacturing	162	$1,489
	Iron and steel mills and ferroalloy manufacturing	217	$5,892
	Nonferrous metal, except copper and aluminum, shaping	227	$14,424
	Sheet metal work manufacturing	241	$20,305
	Metal tank (heavy gauge) manufacturing	244	$57,611
	Machine shops	249	$293,217
	Turned product and screw, nut, and bolt manufacturing	250	$49,028
	Metal heat treating	251	$9,940
	Valve and fittings, other than plumbing, manufacturing	254	$17,040
	Other fabricated metal manufacturing	261	$100
	All other industrial machinery manufacturing	271	$21,452
	Air purification and ventilation equipment manufacturing	275	$7,157
	Heating equipment (except warm air furnaces) manufacturing	276	$13,311
	Industrial mold manufacturing	278	$8,200
	Pump and pumping equipment manufacturing	287	$162,491
	Industrial process furnace and oven manufacturing	297	$6,400
	Industrial process variable instruments manufacturing	317	$101,743
	Totalizing fluid meter and counting device manufacturing	318	$36,248
	Electricity and signal testing instruments manufacturing	319	$17,412

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
	Watch, clock, and other measuring and controlling device manufacturing	322	$120,272
	Office supplies (except paper) manufacturing	387	$15,350
Wholesale Trade & Retail Trade			**$2,366,403**
	Wholesale trade	395	$175,115
	Retail – Miscellaneous store retailers	406	$2,186,288
	Retail – Non-store retailers	407	$5,000
Transportation and Warehousing			**$13,045**
	Truck transportation	411	$2,210
	Transit and ground passenger transportation	412	$10,835
Information			**$1,175**
	Book publishers	419	$1,175
Real Estate and Rental and Leasing			**$35,363**
	Commercial and industrial machinery and equipment rental and leasing	445	$35,363
Professional, Scientific, and Technical Services			**$145,733,881**
	Legal services	447	$109,400
	Accounting, tax preparation, bookkeeping, and payroll services	448	$4,011,389
	Architectural, engineering, and related services	449	$5,120,870
	Custom computer programming services	451	$15,905
	Computer systems design services	452	$8,212
	Other computer related services, including facilities management	453	$25,773,660
	Management consulting services	454	$4,390,050
	Environmental and other technical consulting services	455	$8,378,039
	Scientific research and development services	456	$97,794,081
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	$132,276
Administrative and Support and Waste Management and Remediation Services			**$59,091,124**
	Facilities support services	463	$51,282,708
	Business support services	465	$136,032
	Investigation and security services	467	$5,462,777
	Services to buildings	468	$2,052,077
	Other support services	470	$5,890
	Waste management and remediation services	471	$151,641
Educational Services			**$12,203,357**

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
	Junior colleges, colleges, universities, and professional schools	473	$819,079
	Other educational services	474	$11,384,277
Health Care and Social Assistance			**$62,083**
	Hospitals	482	$62,083
Arts, Entertainment, and Recreation			**$624,275**
	Museums, historical sites, zoos, and parks	493	$624,275
Other Services (except Public Administration)			**$3,750**
	Business and professional associations	515	$3,750
Labor Income			**$225,301,372**
	Employee Compensation (c)		$225,301,372
TOTAL EXPENDITURES IN NEO			**$497,892,724**

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 2017. 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.

All expenditures in this table are presented in 2017 dollars.

Table A.4. NASA Glenn Detailed Expenditures in the State of Ohio, FY 2017

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
Utilities			**$16,125,081**
	Electric power transmission and distribution	49	$12,729,657
	Natural gas distribution	50	$594,078
	Water, sewage and other systems	51	$2,801,346
Construction			**$35,546,609**
	Maintenance and repair construction of nonresidential structures	62	$35,546,609
Manufacturing			**$1,594,078**
	Printing	154	$7,623
	Support activities for printing	155	$34,815
	Industrial gas manufacturing	162	$1,489
	Polystyrene foam product manufacturing	192	$8,877
	Iron and steel mills and ferroalloy manufacturing	217	$5,892
	Nonferrous metal, except copper and aluminum, shaping	227	$48,430
	Ferrous metal foundries	229	$61,500
	Sheet metal work manufacturing	241	$20,305
	Metal tank (heavy gauge) manufacturing	244	$95,263
	Machine shops	249	$345,952
	Turned product and screw, nut, and bolt manufacturing	250	$49,028
	Metal heat treating	251	$11,371
	Valve and fittings, other than plumbing, manufacturing	254	$17,040
	Fabricated pipe and pipe fitting manufacturing	260	$25,880
	Other fabricated metal manufacturing	261	$100
	All other industrial machinery manufacturing	271	$21,452
	Air purification and ventilation equipment manufacturing	275	$7,157
	Heating equipment (except warm air furnaces) manufacturing	276	$13,311
	Industrial mold manufacturing	278	$8,200
	Pump and pumping equipment manufacturing	287	$217,699
	Industrial process furnace and oven manufacturing	297	$40,155
	Scales, balances, and miscellaneous general purpose machinery manufacturing	300	$23,351
	Industrial process variable instruments manufacturing	317	$129,866
	Totalizing fluid meter and counting device manufacturing	318	$36,248
	Electricity and signal testing instruments manufacturing	319	$106,562
	Analytical laboratory instrument manufacturing	320	$44,223

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
	Watch, clock, and other measuring and controlling device manufacturing	322	$120,272
	Aircraft engine and engine parts manufacturing	358	$76,911
	Office supplies (except paper) manufacturing	387	$15,105
Wholesale Trade & Retail Trade			**$2,718,665**
	Wholesale trade	395	$339,775
	Retail - Miscellaneous store retailers	406	$2,373,890
	Retail - Nonstore retailers	407	$5,000
Transportation and Warehousing			**$14,040**
	Truck transportation	411	$3,205
	Transit and ground passenger transportation	412	$10,835
Information			**$1,175**
	Book publishers	419	$1,175
Real Estate and Rental and Leasing			**$41,960**
	Commercial and industrial machinery and equipment rental and leasing	445	$41,960
Professional, Scientific, and Technical Services			**$165,248,155**
	Legal services	447	$119,564
	Accounting, tax preparation, bookkeeping, and payroll services	448	$4,011,389
	Architectural, engineering, and related services	449	$5,500,316
	Custom computer programming services	451	$72,905
	Computer systems design services	452	$8,212
	Other computer related services, including facilities management	453	$25,773,660
	Management consulting services	454	$4,390,050
	Environmental and other technical consulting services	455	$8,378,039
	Scientific research and development services	456	$116,787,111
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	$206,910
Administrative and Support and Waste Management and Remediation Services			**$60,324,483**
	Facilities support services	463	$51,299,567
	Business support services	465	$136,032
	Investigation and security services	467	$6,679,277
	Services to buildings	468	$2,052,077
	Other support services	470	$5,890
	Waste management and remediation services	471	$151,641
Educational Services			**$12,924,604**

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure
	Junior colleges, colleges, universities, and professional schools	473	$1,540,326
	Other educational services	474	$11,384,277
Health Care and Social Assistance			**$62,083**
	Hospitals	482	$62,083
Arts, Entertainment, and Recreation			**$624,275**
	Museums, historical sites, zoos, and parks	493	$624,275
Other Services (except Public Administration)			**$8,955**
	Commercial and industrial machinery and equipment repair and maintenance	507	$4,780
	Grantmaking, giving, and social advocacy organizations	514	$425
	Business and professional associations	515	$3,750
Government Enterprise			**$38,240**
	Other federal government enterprises	520	$38,240
Labor Income			**$232,336,321**
	Employee Compensation (c)		$232,336,321
TOTAL EXPENDITURES IN OHIO			**$527,608,724**

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 2017. 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.

All expenditures in this table are presented in 2017 dollars.