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Prepared for:
NASA GLENN RESEARCH CENTER

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June 2016

**The NASA Glenn
Research
Center:**

**An Economic
Impact Study
Fiscal Year 2015**

**CENTER FOR
ECONOMIC
DEVELOPMENT**

Acknowledgements

The authors would like to thank Therese Griebel, Robert Sefcik and Christopher Blake, employees of the NASA Glenn Research Center, and James Kubera from Wichita Tribal Enterprises LLC, for their contributions to this project. They helped to coordinate the data gathering for the study and provided feedback on the report's content. This project is a result of collaboration between NASA Glenn, Wichita Tribal Enterprises company and Cleveland State University's Center for Economic Development.

The authors of this report also want to recognize the assistance of researchers within the Levin College and appreciate the feedback and technical support of Candi Clouse, Economic Development Center's program manager and Bryan Townley, Economic Development Center's graduate assistant. They offered data management, methodological suggestions to this research and comments on the draft report.

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EXECUTIVE SUMMARY

- Located at Lewis Field (next to Cleveland Hopkins International Airport) and Plum Brook Station (Sandusky, Ohio), the NASA Glenn Research Center performs research and development to advance aviation, enable exploration of the universe, and improve life on Earth. Its scientists and engineers deliver advanced flight systems for spacecraft and improve efficiency and safety in aircraft, often in partnership with U.S. companies, universities, and other government institutions. The center's core capabilities concentrate on air-breathing and in-space propulsion, power and energy storage, aerospace communications, materials for extreme environments, biomedical technologies and high-value space experiments in the physical sciences-- all focused on solving important, practical aerospace problems and opening new frontiers (scientific, technological, and economical) for our nation.¹
- NASA Glenn's physical plant 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 physical plant. The estimated replacement cost is approximately \$3.5 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: Exploration, Science, Space Operation, Space Technology, and Aeronautics Research. Within the Human **Exploration & Operations mission portfolio**, NASA Glenn provided engineering and technical services and performed a variety of analyses and integration tasks to support development of the Space Launch System (SLS) and the Orion Multi-Purpose Crew Vehicle; 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. NASA Glenn also developed numerous microgravity science experiments that were operated on the International Space Station.

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; co-managing (with the Department of Energy) the Advanced Stirling Radioisotope Generator (ASRG) project; managing the In-Space Propulsion Technology (ISPT) Program and developing its associated technologies including propulsion systems (e.g. solar electric propulsion), spacecraft bus (e.g. power, extreme environments), sample return, and re-entry; 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 high altitude balloon research, technology/tools coordination, and science advisory groups.
- In support of the **Space Technology** mission, NASA Glenn led technology demonstration projects to advance solar electric propulsion capability as well as cryogenic fluid management technologies to enable future missions. NASA Glenn also led game-changing technology projects related to advanced space power systems, nuclear systems, and other technologies.
- 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, Electric Propulsion, power management, propulsion systems analysis, materials and Communications for subsonic, supersonic, hypersonic and vertical lift aircraft systems, and through its program management efforts to support efficient, quiet, and reliable flight in any atmosphere at any speed. 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 2015. 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 economic 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's spending on the economies of Northeast Ohio (NEO) and Ohio. This model measures economic impact in terms of growth in output (sales), value added (output less intermediary goods), number of new and supported jobs, labor income, and tax revenues. This year's study uses the same methodology to measure NASA

Glenn's impact on the economies of Northeast Ohio and Ohio as was used for the previous study. However, as this marks the second year since IMPLAN Group LLC improved the detail of its data tables, this report includes more accurate and direct comparisons between FY 2014 and FY 2015 than were possible in previous years. The table below summarizes NASA Glenn's economic impact on Northeast Ohio and the state of Ohio during FY 2015.

Economic Impact	Northeast Ohio	State of Ohio
Output	\$1,321 million	\$1,416 million
Value Added	\$682.1 million	\$724.9 million
Employment	6,588 jobs	7,214 jobs
Labor Income	\$467.5 million	\$492.5 million
Taxes	\$115.4 million	\$123.4 million

Note: Labor income accounts for the income of all NASA Glenn employees, both residents of the study area and those who live outside of the study area and spend only a portion of their income in the region (commuter spending). Direct value added impact was assessed as a percentage of output, whereas in studies prior to FY 2013 we accounted only for labor income as a direct value added impact.

- NASA Glenn's activities in Northeast Ohio in FY 2015, stimulated by \$624.7 million in direct spending originating primarily from outside of the region, generated an increased demand in output (sales) valued at \$1,321 million for goods and services produced in the region. The value added increased by \$682.1 million as a result of NASA Glenn's activities. In addition, 6,588 jobs were created and supported in the region, and labor income in Northeast Ohio increased by \$467.5 million. NASA Glenn's activities in Northeast Ohio also generated \$115.4 million in local, state, and federal taxes.
- NASA Glenn's activities in Ohio in FY 2015, stimulated by \$624.7 million in direct spending originating primarily from outside of the state, generated an increased demand in output (sales) for products and services produced across the state valued at \$1,416 million.
- Ohio value added increased by \$724.9 million as a result of NASA Glenn's activities. In addition, 7,214 jobs were created and supported in Ohio, and labor income across the state increased by \$492.5 million. NASA Glenn operations in Ohio also generated \$123.4 million in local, state, and federal taxes.

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

NASA GLENN RESEARCH CENTER: AN OVERVIEW

- In FY 2015, NASA Glenn's civil service employment totaled 1,563. During the past five years, Glenn civil service employment had a peak of 1,711 employees in 2011. Overall, during the past five fiscal years, NASA Glenn's civil service employment has decreased by 8.7% (-148 employees).
- NASA Glenn employs highly educated and highly skilled civil service workers. In FY 2015, 86% of NASA Glenn's employees had at least a bachelor's degree, increasing from 69% in 2004. Of all NASA Glenn's civil service employees, 17% held doctoral degrees, 38% held master's degrees, and 31% held bachelor's degrees. Compared to FY 2014, the level of educational attainment of NASA Glenn's civil service employees has increased slightly. The number of employees holding bachelor's degrees or higher increased 1% between FY 2014 and FY 2015. The rising share of scientists and engineers employed at NASA Glenn between FY 2011 and FY 2015 is a contributing factor to the increasing share of highly educated workers, especially those possessing master's degrees. NASA Glenn aims to increase the share of its civil servant workforce dedicated to research and technology while reducing the cost of support personnel.
- Scientists and engineers constitute a majority of NASA Glenn's employees, a trend that has continued since before FY 2010. In FY 2015, scientists and engineers accounted for 69% of the civil service employees. The share of scientists and engineers at NASA Glenn has gradually increased since FY 2011 from 65% to 69% in 2015. This continues a long-term shift in the employment share of scientists and engineers over the decade. Between FY 2011 and FY 2015, the share of scientists and engineers has increased from 65% to 69%.
- NASA Glenn civil service employees received total compensation of \$228 million in FY 2015. In this report, total compensation includes both payroll (\$177.1 million) and employee benefits (\$51.0 million). Between FY 2014 and FY 2015, total compensation increased by \$1,256,314 (0.55%).² Additionally, between FY 2011 and FY 2015, total compensation shrank by \$9.2 million (4.04%) when adjusted for inflation. In FY 2015, NASA Glenn payroll stood at \$177.1 million, representing a decrease of \$0.7 million (-0.4%) since FY 2014.³ Between FY 2011 and FY 2015, payroll decreased by \$11.7 million (-6.45%), adjusting for inflation.⁴
- NASA Glenn's total revenue in FY 2015 was \$671.5 million, decreasing in FY 2015 by \$6.4 million (-0.95%). Overall, NASA Glenn's revenue decreased by \$67.1 million (-9.1%) from FY 2011 to FY 2015 (in nominal dollars); after a brief increase from 2013 to 2014, Glenn's revenue has decreased once again.
- In FY 2015, NASA Glenn allocated its spending of \$399.7 million to vendors in 48 states, Washington, D.C., and ten foreign countries. In FY 2015, NASA Glenn increased its total expenditures by 2.9% compared to \$388.7 of expenditures in FY 2014 (an increase of \$11.1 million in nominal dollars). Total expenditures decreased by 19.2% (\$95.2 million) between FY 2011 and FY 2015.
- In FY 2015 Ohio was the largest beneficiary of expenditures, receiving \$290.2 million of NASA Glenn's total expenditures. With an \$14.7 million increase (in nominal dollars) compared to FY 2014, the share of NASA Glenn's expenditures in Ohio increased from 70.9% in FY 2014 to 72.6% in FY 2015.

² Total nominal compensation increased by 0.55% (\$1.3 million) between FY 2014 and FY 2015.

³ Total nominal payroll decreased by 0.4% (\$0.77 million) between FY 2014 and FY 2015.

⁴ Total nominal payroll decreased by 2% (\$3.4 million) between FY 2011 and FY 2015.

- Other than Ohio, two states (Maryland and California) each received over \$10 million, or at least 3.5% of NASA Glenn's total expenditures during FY 2015. Maryland received \$27.0 million (6.8%) and California \$14.2 million (3.6%), making them the second- and third-largest beneficiaries of NASA Glenn spending. Maryland saw a nominal increase of \$2.4 million in spending when compared to FY 2014. California saw a nominal decline of \$3.1 million in spending.
- Over the last fiscal year, NASA Glenn decreased its expenditures in foreign countries, from \$734,480 in FY 2014 to \$454,650 in FY 2015. This spending made up only 0.11% of NASA Glenn's total expenditures in FY 2015. The largest beneficiaries were the United Kingdom with \$0.10 million and Canada with \$0.13 million.
- Northeast Ohio received \$248.8 million of NASA Glenn's total expenditures in Ohio, accounting for 85.7% of total Ohio spending in FY 2015. Northeast Ohio also accounted for 62.2% of NASA Glenn's total spending in FY 2015. Cuyahoga County was by far the largest recipient of NASA Glenn spending in Northeast Ohio, accounting for 99.0% of said spending. Additionally, Cuyahoga County represented 84.9% of spending in Ohio, as well as 61.6% of total NASA Glenn spending in FY 2015.
- NASA Glenn Research Center awards funding to colleges, universities, and other nonprofit institutions in the form of R&D contracts and grants for assisting NASA in their research and development activities. NASA Glenn awarded \$9.5 million to colleges and universities in 28 states, the District of Columbia, and the United Kingdom in FY 2015. Compared to FY 2014, this represented a \$1 million reduction of academic grants from NASA Glenn (-9.6% in nominal dollars).
- Universities in five states--California, Ohio, Massachusetts, Illinois, and Pennsylvania -- each received over \$0.7 million in funding from NASA Glenn in FY 2015. The academic funding awarded in these five states collectively accounted for 48.8% of the total grants in FY 2015. Academic institutions in Ohio received \$0.9 million, which accounted for the second largest share (9.85%) of NASA Glenn's academic awards in FY 2015. NASA Glenn's academic awards to Ohio decreased by 30.3% (-0.406 million), between FY 2014 and FY 2015, continuing a downward trend that began in 2012.
- Within the state of Ohio, academic institutions in Northeast Ohio received \$0.58 million in FY 2015. Northeast Ohio academic institutions accounted for both 6.13% of NASA Glenn's total academic awards and 62.3% of all academic grants given in Ohio. NASA Glenn reduced its awards to the universities and academic institutions in Northeast Ohio by 52.2% (-0.63 million) compared to FY 2014. NASA Glenn's funding to Ohio academic institutions located outside of Northeast Ohio's eight counties increased by 183.9% (\$0.22 million) compared to FY 2014.
- NASA Glenn continues to be an important institution influencing the economies of both Northeast Ohio and the state of Ohio. NASA Glenn's employees are part of the knowledge-intensive labor force that advances the nation, generates wealth in the region, and attracts other creative workers to reside in Ohio.

A. INTRODUCTION

This report presents an analysis of the economic impact of the National Aeronautics and Space Administration's John H. Glenn Research Center (NASA Glenn) during its fiscal year (FY) 2015. It uses an input-output model, which reflects the buy-sell relationships among industries, the household sector, and the government sector in a region, to estimate the effect of NASA Glenn's spending on the economies of both Northeast Ohio and the state of Ohio.⁵

This model assesses economic impact in terms of growth in total output (sales); value added (output less intermediary goods); household earnings, number of new and supported jobs, and taxes.⁶ The report also provides an overview of NASA Glenn and describes some of its research and development (R&D) activities. It looks at changes in NASA Glenn's employees in terms of payroll, occupation, and place of residence.

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

The analysis was conducted by the Center for Economic Development at Cleveland State University's Maxine Goodman Levin College of Urban Affairs. This FY 2015 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2015.⁷

⁵ For purposes of this study, Northeast Ohio is defined as Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties.

⁶ 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 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 include research supplies, utilities, research services of intermediary steps of research, etc.

⁷ 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 test 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 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 and energy storage, 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.⁸

B.1. NASA GLENN TEST FACILITIES

NASA Glenn's physical plant 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 physical plant. The estimated current replacement value of Lewis Field and Plum Brook Station is over \$3.5 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 zero gravity 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 the largest space simulation chamber, the largest mechanical vibration table, the most powerful resonant 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, the only cold soak start/restart rocket engine test facility, and the only clean air hypersonic tunnel.

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.

⁸ 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) and its integration within the Orion MPCV Program. The ESM provides power, propulsion, and communications for Orion's Crew Module (CM).
- Providing the Solar Electric Propulsion for the Asteroid Redirect/Retrieval Mission. Propose extension of this technology and vehicle for Human exploration cargo transfer vehicles.
- Managing contractual and technical development for the Universal Stage Adapter connecting the Upper Stage of the SLS to the 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 critical-path environmental testing of the integrated Orion spacecraft at Plum Brook 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.

- Conducting high-value space life and physical science research (specifically combustion science and fluid physics) on the International Space Station, from research objective definition to experiment equipment provision and operation.
- 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, 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, 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 technology for Technology Demonstration Missions, the Asteroid Redirect/Retrieval Mission, and other 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 kilo-watt 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.

Science

- Managing the Radioisotope Power Systems Program and developing associated 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.
- Managing the In-Space Propulsion Technology (ISPT) Program and developing its associated technologies including propulsion systems (e.g. solar electric propulsion), spacecraft bus (e.g. power, extreme environments), sample return, and re-entry. Conducting system and mission studies to validate benefits.
- 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 high altitude balloon research, 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 as Deputy 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 as Deputy 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.
- Developing radios through a cooperative agreement and 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 as the Deputy the Hypersonics Project, and supporting vehicle studies, performing propulsion testing, and developing high temperature seals and analytic tool development to advance hypersonic technology for the nation.

C. NASA GLENN RESEARCH CENTER: ECONOMIC OVERVIEW

This section presents an economic overview of the NASA Glenn Research Center during FY 2015. Changes between FY 2011 and FY 2015 are described in terms of payroll, revenues, expenditures, academic awards, occupational

distribution, number of employees, employee residence locations, and income taxes paid by NASA Glenn employees.

C.1. EMPLOYMENT AND OCCUPATIONS

The total labor force of NASA Glenn Research Center includes two types, civil service employees and local contractors. Federal laboratories commonly contract companies and individuals to conduct specific tasks and services, which allows for more flexibility in performance and their labor costs. The number of contracted employees can be easily adjusted aligning with the Glenn's scope of work and new projects.

In comparison with contracted employees, the NASA civil service employment has been relatively constant in order to retain highly skilled workers with long-term core expertise. These workers are essential for efficient and effective execution of aerospace projects that often last many years. Over the last five years,

from FY 2011 to FY 2015, NASA Glenn has averaged 1,644 civil service employees yearly. Table 1 shows the total number of NASA Glenn's civil service employees and the shares of four main occupational categories over time. In FY 2015, NASA Glenn's civil service employment totaled 1,563. During the past five years, Glenn civil service employment had a peak of 1,711 employees in 2011. NASA Glenn's has since decreased its core employment by 8.7% through FY 2015. Overall, during the past five fiscal years, NASA Glenn's civil service employment has decreased by 148 workers. Compared to the previous year, FY 2014, total Glenn employment decreased by 61 employees or 3.8% in FY 2015.

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2011-FY 2015

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
2011	1,711	20%	4%	65%	10%
2012	1,659	21%	4%	67%	9%
2013	1,664	21%	3%	68%	8%
2014	1,624	21%	3%	68%	8%
2015	1,563	23%	2%	69%	6%

Note: Table does not include local contractors.⁹

⁹ A detailed listing of NASA Glenn's local contractors can be found at [http://www.grc.nasa.gov/WWW/Procure/ContractorList/ On-siteServiceContractorListing.htm](http://www.grc.nasa.gov/WWW/Procure/ContractorList/On-siteServiceContractorListing.htm)

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

In FY 2015, scientists and engineers continue to be the largest occupational category, a historical trend that has continued even before FY 2011. In FY 2015, scientists and engineers accounted for 69% of the civil service employees. The share of scientists and engineers at NASA Glenn has gradually increased since FY 2011 from 65% (1,112 employees) to 69% (1,078 employees) in FY 2015. Although the net loss in this occupational category was 34 employees, a significant increase of the share (4%) is due to overall decreased NASA Glenn employment. However, even this small change is consistent with the long-term shift in the employment share of scientists and engineers over the last 10 years. Between FY 2005 and FY 2015, the share of scientists and engineers has increased from 58% to 69%.

Over the last five years, the number of technicians employed by NASA Glenn has decreased by 77 employees, from 171 in FY 2011 to 94 in FY 2015. The technician group accounted for 6% of NASA Glenn's civil service employment in FY 2015. The decrease in employment of technicians between FY 2011 and FY 2015 (dropping from 10% to 6% of total employment) can be seen as the other side of the coin which is the increase in employment of scientists and engineers. Looking back, this downward trend continues over the long-term as technicians accounted for 17% of the workforce in FY 2004.

The administrative professional category remains the second-largest occupational group after scientists and engineers, a position which has been held in all prior study years. The administrative professional category's share of total civil service employment has averaging

around 21% since before FY 2010. Between FY 2011 and FY 2012, the share of the administrative professional group increased slightly from 20% to 21%, slightly increasing to 23% in FY 2015.

The number in clerical occupations accounted for 4% of the total civil service employees in FY 2011 and FY 2012, fell to 3% in FY 2013 and FY 2014, and fell an additional percentage point, to 2% in FY 2015. Overall, the clerical staff category has seen a decrease of 37 employees since FY 2011. NASA Glenn employs highly educated and highly skilled civil service workers; 86% of NASA Glenn's employees had at least a bachelor's degree in FY 2015, increasing from 69% in 2004. Of all NASA Glenn's civil service employees, 17% held doctoral degrees, 38% held master's degrees, and 31% held bachelor's degrees. Compared to FY 2011, the level of educational attainment of NASA Glenn's civil service employees has increased, as the number of employees holding bachelor's degrees or higher increased 4% between FY 2011 and FY 2015.

In addition to its own employment, NASA Glenn involved 1,562 on- or near-site contractors in FY 2015 (Table 2). During the past five years, NASA Glenn's engagement with local contractors peaked in FY 2011 at 1,858. Since FY 2011, employment of contractors dropped by 13% through FY 2013, with the largest drop-off occurring between FY 2011 and FY 2012. Between FY 2013 and FY 2014, however, engagement of contractors increased by 30, from 1,643 to 1,673 to be followed by the FY 2015 further decrease, which is more in line with the five-year trend. From FY 2014 to FY 2015, contractor employment has dropped by 111, or 7%. Between FY 2011 and FY 2015, the total on- or near-site contractor employment has decreased by 296 or 19%.

The total number of NASA Glenn employees, including both civil service employees and local contractors, was 3,125 in FY 2015. The total labor force peaked in FY 2011 with 3,569

employees, and has declined each subsequent year. NASA Glenn lost a net 148 civil service employees and lost 269 on- or near-site local contractors between FY 2011 and FY 2015.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2011-FY 2015

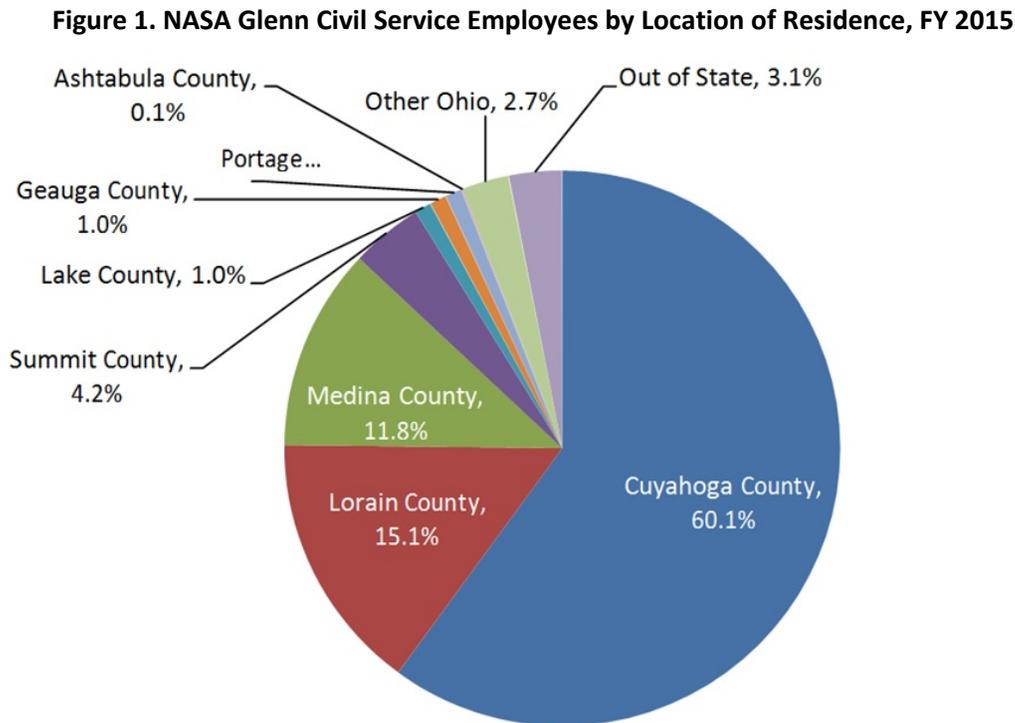
Fiscal Year	Employment of On- or Near-Site Contractors
2011	1,858
2012	1,688
2013	1,643
2014	1,673
2015	1,562

C.2. PLACE OF RESIDENCE FOR GLENN EMPLOYEES

NASA Glenn Research Center's Lewis Field is located in Cuyahoga County, the heart of Northeast Ohio. NASA Glenn also includes Plum Brook Station, located near Sandusky, Ohio, in Erie County, west of the main facility. Most civil service employees working at NASA Glenn live in Cuyahoga County or the surrounding counties that comprise Northeast Ohio.¹⁰ Figure 1 shows the breakdown of employees' postal addresses by geographic region. During FY 2015, almost all of NASA Glenn's civil service employees (1,472 employees or 94.2% of the total employment base) resided in Northeast Ohio.

Specifically, 60.1% of civil servants (939 employees) lived in Cuyahoga County, the same county as NASA Glenn. NASA Glenn employees also lived in Lorain (236 employees; 15.1%), Medina (184 employees; 11.8%), and Summit

Counties (65 employees; 4.2%), with a small number in other surrounding Northeast Ohio counties. In FY 2015, only 43 of the total 1,563 employees (2.7%) lived in other than Northeast Ohio locations within Ohio, and 48 employees (3.1%) listed a postal address in another state. Compared to FY 2014, the distribution of NASA Glenn employment across regions within and outside of areas of study, Northeast Ohio and Ohio, structurally changed very little. While, the number of NASA Glenn employees who reside in Cuyahoga County has decreased by 38, the share of employees living in this county had a very small change from 60.2% in FY 2014 to 60.1% in FY 2015. Those classified as living out of state, increased from 2.8% to 3.1% in the structure of employment by the place of living, adding however only 3 employees living outside of Ohio between FY 2014 and FY 2015.



¹⁰ Northeast Ohio includes Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties.

The places of residence of NASA Glenn's civil service employees by occupation are shown in Table 3. The largest share, 60.1% of NASA Glenn's scientists and engineers, administrative professionals, and clerical employees lived in Cuyahoga County in FY 2015, also the highest share of employees by place of residence in each occupational category. Technicians, had somewhat lower share of residents in Cuyahoga County, 51.1% residing there, while clerical staff had the highest share, 62.5% in the county.

Between 4% and 7% of NASA Glenn's technicians, administrative professionals, and scientists and engineers have postal addresses outside of Northeast Ohio. Clerical employees were most likely to live in Northeast Ohio, with only 3.1% living outside of the region, and none living outside Ohio. Scientists and engineers were the more likely than other occupational categories to live outside Northeast Ohio (6%) and the most likely to reside outside Ohio.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2015

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	94.1%	96.9%	94.0%	95.4%	94.2%
Cuyahoga County	61.1%	62.5%	60.4%	51.1%	60.1%
Lorain County	16.6%	25.0%	14.3%	15.9%	15.1%
Medina County	9.8%	6.3%	11.9%	20.5%	11.8%
Summit County	4.8%	0.0%	4.3%	2.3%	4.2%
Lake County	0.3%	3.1%	1.0%	2.3%	1.0%
Geauga County	0.3%	0.0%	1.2%	1.1%	1.0%
Portage County	1.2%	0.0%	0.9%	1.1%	1.0%
Ashtabula County	0.0%	0.0%	0.0%	1.1%	0.1%
Other Ohio	3.8%	3.1%	2.3%	4.6%	2.7%
Out of State	2.1%	0.0%	3.7%	0.0%	3.1%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

The total compensation NASA Glenn civil service employees received in FY 2015 reached \$228 million.¹¹ In this report, total compensation includes both payroll (\$177.1 million) and employee benefits (\$51.0 million). Over the last year, between FY 2014 and FY 2015, total compensation slightly increased, by \$1,256,314 (0.55%).¹² However, between FY 2011 and FY 2015, total compensation decreased by \$9.1 million (4.04%).

In FY 2015, NASA Glenn payroll was \$177.1 million, showing a decrease of \$0.7 million (-0.4%) since FY 2014.¹³ Between FY 2011 and FY 2015, payroll decreased by \$11.7 million (-6.5%).¹⁴

During FY 2015, the employee benefits were growing, continuing the trend from even before FY 2011. The growth of benefits partially offsets the declining real value of payroll. In 2011, payroll made up 80% of total compensation. By 2015, however, this share had dropped to 78%.

The declining value of payroll as a component of total compensation (not including benefits) can also be seen in the gradual changes in the average wage per employee - trend illustrated by many industries in the U.S. and regionally. Between FY 2011 and FY 2015, however, the total average wage per civil service employee, after adjusting for inflation, increased from \$110,305 to \$114,841, an increase of 4.1%.¹⁵

¹¹ All dollar value comparisons in this section are adjusted for inflation.

¹² Total nominal compensation increased by 0.5% (\$1.1 million) between FY 2014 and FY 2015.

¹³ Total nominal payroll decreased by 0.4% (\$0.77 million) between FY 2014 and FY 2015.

¹⁴ Total nominal payroll *decreased* by 0.2% (\$3.4 million) between FY 2010 and FY 2014.

¹⁵ The average wage per employee in nominal terms increased 9% (\$9,372) between FY 2011 and FY 2015.

C.4. NASA GLENN EXPENDITURES, FY 2015

In FY 2015, NASA Glenn allocated its spending of \$399.7 million to vendors in 48 states, Washington, D.C., and ten foreign countries. In FY 2015, NASA Glenn increased its total expenditures by 2.85% compared to \$388.7 million of expenditures in FY 2014 (an increase of \$11.1 million in nominal dollars). However, between FY 2011 and FY 2015, the total expenditures of NASA Glenn decreased by 19.23% (\$95.2 million).

When adjusted for inflation to 2015 dollars, the changes in expenditures are larger.¹⁶ Between FY 2014 and FY 2015, expenditures increased by 2.9% (\$11.2 million), while still showing a decrease compared to FY 2011: expenditures for FY 2015 dropped by 22.8%, representing a reduction of \$117.8 million in constant 2015 dollars.¹⁷

Figure 2 shows the geographic distribution of NASA Glenn's spending during FY 2015. Ohio continues to be the largest beneficiary of expenditures, receiving \$290.2 million of NASA Glenn's total expenditures. With a \$14.7 million increase (in nominal dollars) compared to FY 2014, the share of NASA Glenn's expenditures in Ohio increased from 70.9% in FY 2014 to 72.6% in FY 2015.

Northeast Ohio received \$248.8 million of NASA Glenn's total expenditures in Ohio, accounting for 85.7% of total Ohio spending in FY 2015, significant increase in both the total amount and the share compared to FY 2014. Northeast Ohio accounted for 62.2% of NASA Glenn's total spending in FY 2015. Cuyahoga County was by far the largest recipient of NASA Glenn spending in Northeast Ohio, accounting for 99% of said spending. Additionally, Cuyahoga County

represented 84.9% of spending in Ohio as well as 62% of total NASA Glenn spending in FY 2015.

NASA Glenn spent more than \$290.2 million or 72.7% of its FY 2015 expenditures in Ohio. Other than Ohio, two states (Maryland, and California) each received over \$10 million or at least 3.5% of NASA Glenn's total expenditures during FY 2015. Maryland received \$27.0 million (6.75%) and California received \$14.2 million (3.55%), making them the second- and third-largest beneficiaries of NASA Glenn spending. Maryland saw a nominal increase in spending when compared to FY 2014, \$2.4 million. California saw a nominal decline of \$3.1 million in spending compared to FY 2014.

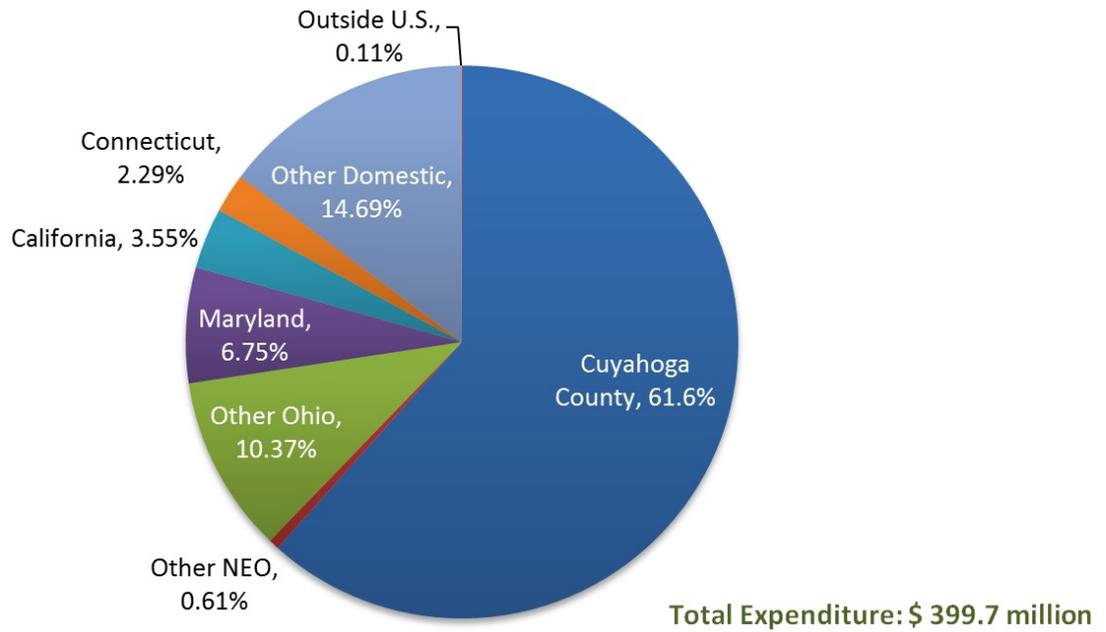
Aside from the two states listed above, Connecticut saw the largest nominal dollar decline in expenditures at \$3.4 million. Two other states with large declines included Virginia (\$1.7 million) and Colorado (\$1.7 million). Arkansas represented the highest percent decline in spending with a drop of 96% from FY 2014. The state of Washington was the largest beneficiary of new spending in FY 2015, seeing an increase of \$3.3 million (336%) when compared to FY 2014 (See Appendix Table A.1. for more information).

In FY 2015, NASA Glenn decreased its expenditures in foreign countries by 38% compared to FY 2014, to \$454.650. This spending is only 0.1% of NASA Glenn's total expenditures in FY 2015. The largest recipients among foreign countries were Canada with \$0.13 million and Germany with \$0.11 million (See Appendix Table A.1. for more information).

¹⁶ Inflation was adjusted using CPI-U for the Cleveland MSA.

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

Figure 2. NASA Glenn Spending in Selected Regions, FY 2015



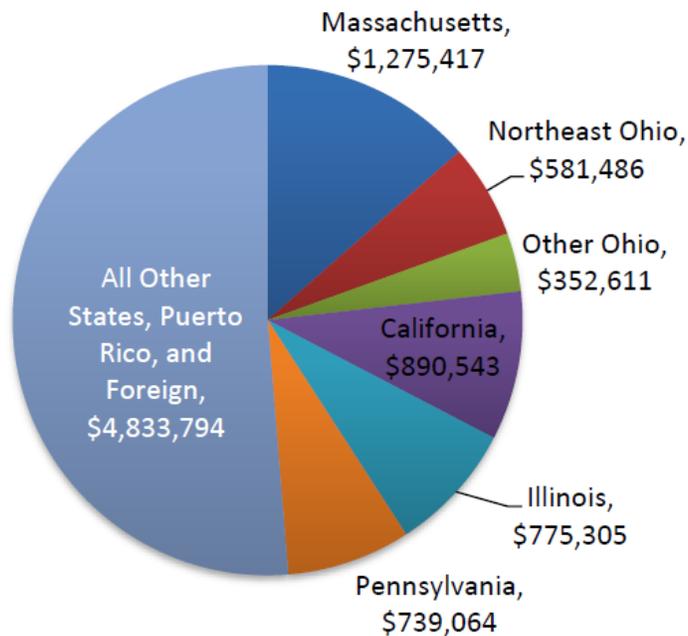
C.5. NASA GLENN AWARDS TO ACADEMIC AND OTHER INSTITUTIONS

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

NASA Glenn awarded \$9.5 million to colleges and universities in 29 states, Washington, D.C., and the United Kingdom in FY 2015. Compared to FY 2014, this represented a reduction of academic grants from NASA Glenn totaling \$1 million (-9.6% in nominal dollars).

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 academic funding awarded in the top four states in FY 2015 collectively accounted for 41% of the total grants, compared to the top four states representing 44% of total grants during FY 2014. (See Appendix Table A.2. for more information.)

Figure 3. NASA Glenn Awards to Colleges and Universities, FY 2015



Total Academic Awards: \$9.5 million

Notes: Figures in nominal dollars "Other Ohio" refers to colleges and universities located outside the 8-county definition of Northeast Ohio used in this report.

Academic institutions in Ohio received \$0.9 million of total NASA Glenn's academic awards in FY 2015, the second largest share (9.9%) among universities in different states. The largest beneficiary of academic funding in FY 2015 was Massachusetts with the share of 13.5%. NASA Glenn's academic awards to Ohio decreased substantially compared to the last fiscal year, changing by 32.1% (-0.4 million), between FY 2014 and FY 2015.

Within the state of Ohio, academic institutions in Northeast Ohio received \$0.56 million in FY 2015. Northeast Ohio academic institutions accounted for both 5.9% of NASA Glenn's total academic awards and 61.7% of all academic grants given in Ohio. Compared to FY 2014, NASA Glenn reduced its awards to the universities and academic institutions in Northeast Ohio by 53.8% (\$0.65 million). Reversing the previous year's trend, NASA Glenn's funding to Ohio academic institutions located outside of Northeast Ohio's eight counties increased by 180.9% (\$0.22 million) compared to FY 2014.

In FY 2015, among the states outside Ohio, the state of Massachusetts received \$1.3 million, California received \$0.9 million, and Illinois received \$0.8 million in academic grants from NASA Glenn.

Table 4 shows the distribution of NASA Glenn awards to colleges and universities in Ohio from FY 2011 to FY 2015 (inflated to 2015 dollars). Total academic grants awarded in Ohio decreased by 84.8%, from \$6.2 million in FY 2011 to \$0.9 million in FY 2015. Following the downward trend of NASA Glenn's academic awards, between FY 2014 and FY 2015 NASA Glenn reduced its academic funding to Ohio universities and colleges by 30.3% or \$0.41 million (adjusted to 2015 dollars).

Ohio State University and Case Western Reserve University each received more than \$0.25 million from NASA Glenn in FY 2015. Case Western Reserve University received the highest amount of funding in FY 2015. CWRU, with funding in the amount of \$0.33 million, accounted for 35.6% of total awards to colleges and universities in Ohio in FY 2015. However, academic awards to Case decreased by 33.6% (\$0.17 million) between FY 2014 and FY 2015. NASA Glenn's academic funding to Ohio State University increased 15 times (by \$0.25 million) from FY 2014 to FY 2015. OSU educational grants represented 28.7% of total awards to colleges and universities in Ohio.

In FY 2015, the University of Akron received \$0.22 million, Ohio University received \$59,343, and the University of Dayton received \$23,948. The University of Dayton received funding from NASA Glenn for the first time since FY 2009, when it was awarded \$47,940.

Table 4. NASA Glenn Educational Grants in Ohio by Academic Institution, FY 2011-FY 2015

OHIO COLLEGES & UNIVERSITIES	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2015 Share of Total
Case Western Reserve University	\$840,049	\$698,153	\$306,384	\$500,424	\$332,467	35.6%
Ohio State University	\$555,113	\$386,309	\$57,562	\$17,995	\$268,320	28.7%
University of Akron	\$1,445,584	\$1,553,680	\$1,866,641	\$614,132	\$219,374	23.5%
Ohio University	\$190,250	\$177,429	\$92,643	\$68,979	\$59,343	6.4%
Kent State University	\$19,433	0	0	0	\$20,180	2.2%
Cleveland State University	\$741,552	\$548,719	\$381,931	\$100,915	\$9,465	1.0%
University of Dayton	0	0	0	0	\$23,948	2.6%
University of Toledo	\$2,140,058	\$1,587,857	\$1,617,961	\$35,163	\$1,000	0.1%
University of Cincinnati	\$183,392	\$132,795	\$42,303	0	0	0%
Wright State University	\$34,439	0	0	\$1,999	0	0%
TOTAL	\$6,149,870	\$5,084,941	\$4,365,425	\$1,339,607	\$934,097	100%

Notes:

Table is sorted by FY 2015 column.

Data inflated to 2015 dollars.

C.6. NASA GLENN REVENUES

NASA Glenn's total revenue in FY 2015 was \$671.5 million. Of the past five years, NASA Glenn's total revenue was lowest in FY 2013 but after increasing in FY 2014 has declined slightly in FY 2015. Compared to FY 2014, the revenues decreased by \$6.4 million (-1%). NASA Glenn's total revenue has decreased by \$67.1 million (-9.1%) from FY 2011 to FY 2015 (in nominal dollars).

NASA Glenn's revenue consists of two sources: NASA direct authority and reimbursable commitments (Table 5). The share of revenue from NASA's direct authority steadily declined between FY 2011 and FY 2014, dropping from 94.4% to 91.3%, but increased in FY 2015 to 93.0%. In FY 2015, NASA Glenn received \$624.6 million of revenue directly from NASA and an additional \$46.91 million from reimbursable commitments.

Table 5 also shows that reimbursable funding has changed over the past five years, 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 have decreased by 20.7% (\$12.2 million in nominal dollars) from FY 2014 to FY 2015. This change returns the value to roughly the same amount it was in FY 2013.

Federal funding remains the largest source of revenue for reimbursable commitments accounting for 65.9% or \$30.9 million. From FY 2014 to FY 2015, reimbursable commitments from the Department of Defense (DoD) showed a 194% decrease, with each branch of the armed forces seeing large cuts in funding. In FY 2015, federal agencies besides the Department of Defense accounted for the largest share of total reimbursable commitments (47.1%), with the DoD (18.8%) and domestic and non-federal entities (34.1%) accounting for the balance.

Table 5. NASA Glenn Revenues, FY 2011-FY 2015

Description	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
NASA Direct Authority	\$696,917	\$647,256	\$608,600	\$618,825	\$624,619
Total Reimbursable Commitments	\$41,680	\$40,402	\$46,457	\$59,112	\$46,879
Total FY Authority	\$738,597	\$687,657	\$655,057	\$677,937	\$671,498
NASA Budget %	94.4%	94.1%	92.9%	91.3%	93.0%

Note: Data in thousands of nominal dollars.

C.7. TAXES PAID BY NASA GLENN EMPLOYEES

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

Table 6 shows 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. The total income tax paid by NASA Glenn's employees in FY 2015 was comparable to the FY 2014 total, changing by less than 1%.

Excluding federal taxes, in FY 2015 NASA Glenn's employees paid \$9.0 million in income taxes. This represented a decrease of 0.1% from FY 2014, a drop of a little over \$72,000 (in nominal dollars). Compared to FY 2011, NASA

Glenn employees paid \$814,000 less in income taxes in FY 2015 (in nominal dollars).

Accounting for 99.6% of the total state and local income taxes paid in FY 2015, the state of Ohio and the city of Brook Park were the two largest recipients of income taxes paid by NASA Glenn's employees. The state of Ohio's share of income tax in FY 2015, excluding federal taxes, was 62.8% (\$5.7 million). Over the past five years, NASA Glenn employees paid annually an average of more than \$6.0 million in income taxes to the state of Ohio. The city of Brook Park received \$3.3 million in income tax from NASA Glenn employees in FY 2015, a slight decrease (0.5%) compared to FY 2014.

NASA Glenn employees paid \$27,596 in income tax to the city of Fairview Park in FY 2015. In addition, income tax paid to the city of Cleveland remained low, peaking in FY 2012 at \$14,205. In FY 2015, NASA Glenn employees paid \$9,706 in income taxes to the city of Cleveland, an increase of almost 39% when compared to FY 2014.

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
2011	\$3,421,825	\$12,755	\$26,097	\$6,384,735	-	\$9,845,412
2012	\$3,370,391	\$14,205	\$26,008	\$6,309,804	-	\$9,720,408
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
5-Year Total	\$16,772,582	\$5,7167	\$132,929	\$30,188,960	\$48,002,338	\$95,153,975

Note: Data in nominal dollars. Federal taxes in FY 2011, FY2012 and FY 2013 were not reported.

D. ECONOMIC IMPACT OF NASA GLENN

This section discusses the methodology and results of research on the economic impact of NASA Glenn on Northeast Ohio and the state of Ohio in FY 2015.¹⁸ Total impact is measured in terms of output (sales); employment; value added; household earnings; and taxes contributed to local, state, and federal governments. In FY 2015, data became available on the federal taxes paid by NASA Glenn employees. This figure

was added to the total tax impact created by NASA Glenn in FY 2015.

Each of the economic impact categories is estimated as the sum of three components: direct impact, indirect impact, and induced impact.¹⁹ NASA Glenn's total impact on Northeast Ohio and the state of Ohio are estimated separately.

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 2015 and generated a demand for its operation by purchasing goods and services across a number of supply industries.

This new demand for goods and services is called "change in final demand," which represents the direct impact of NASA Glenn spending.²⁰ The increase in demand from NASA's expenditures (i.e. change in final demand) in the region results in economic impacts on 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 needs to buy supplies (goods and services) as intermediate inputs in the process of its research and development activities. Additionally, economic impact is also assessed from purchases using income received by

NASA Glenn employees who buy goods and services for their households using their wages. Assessment of intermediate goods purchasing is represented in the indirect economic impact, while the spending patterns of NASA Glenn employees and employees of their suppliers are reflected in the assessment of induced effects.

Indirect impact measures the value of labor, capital, and other inputs of production needed to produce the goods and services required by NASA Glenn as supplies for its operation. Induced impact measures the change in spending by local households due to earnings by Glenn employees and increased earnings employees in local industries who produce goods and services for NASA Glenn and its suppliers.

For the calculation of direct value added impact, NASA Glenn is treated as a research and development institution, which assumes that NASA Glenn's intermediate expenditure

¹⁸ For this analysis, Northeast Ohio is limited to eight counties: Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit.

¹⁹ The change in final demand is the direct economic impact created by NASA Glenn on Northeast Ohio and Ohio.

²⁰ Change in final demand or direct impact, is defined as the total purchases of goods and services for NASA Glenn's overall operations.

pattern is similar to other, comparable research institutions in the area.

Economic impact analysis accounts for inter-industry buy-sell relationships within the respective economy in the research area (NEO or Ohio). These relationships determine how the economy responds to changes in buying and selling patterns. Input-output (I-O) models estimate inter-industry relationships at the county, regional, state, or country level by measuring the distribution of inputs purchased and outputs sold by each industry, the government sector, and the household sector. By using I-O models' multipliers, it is possible to estimate the impact of one additional dollar or one additional job required for NASA Glenn operation and the resultant ripples through the target economies. This impact continues, creating additional expenditures and jobs. The economic multiplier measures the extent of the ripple effect that an initial expenditure has on the regional economy.²¹

This study utilizes regional I-O multipliers from the IMPLAN Professional model.²² Specifically, SAM multipliers are used to estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.²³ For this study, we used the method called "bill of goods" and applied it to industry change. We matched each category of NASA Glenn's expenditures to the industry from which it buys products. This technique enables the research to match

goods that NASA Glenn bought to goods and services produced by different industries in the targeted region.

When estimating regional economic impact there are three factors that need to be addressed: (1) purchases from companies located outside of the study's region need to be excluded, (2) total payroll accounting for the commuting pattern of NASA Glenn employees who live outside the study area needs to be adjusted, and (3) the share of revenues received from local sources needs to be considered. For this analysis, NASA Glenn's economic impact on the Northeast Ohio economy is generated only by purchases of goods produced from 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, goods and services purchased from businesses and other entities located outside of the 8-county region were excluded from the model. Likewise, all goods and services purchased from businesses and entities located outside of the state were excluded when estimating impact on the state of Ohio.

The local spending of employees residing outside of the 8-county region for the Northeast Ohio economic impact portion and outside of the state for the Ohio economic impact portion were included via adjustments

²¹ 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.

²² 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.

²³ 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.

of total payroll by commuting pattern. IMPLAN takes into account 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 part of their income in the area where they work. Because all of NASA Glenn's revenues were received from federal sources (from outside of the study area), no further adjustments were required. IMPLAN measures economic impact using five variables: employment, labor income, value added, output, and taxes:

- Employment impact measures the number of jobs created in the region as a result of NASA Glenn expenditures.
- Labor income impact measures the additional labor earnings created in the region due to NASA Glenn expenditures.
- Value added impact measures the additional value added created in the region as a result of NASA Glenn expenditures. Value added is calculated as output less the value of intermediary goods.²⁴

- 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 and 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.²⁵ Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio economy through its spending in the region in FY 2015.

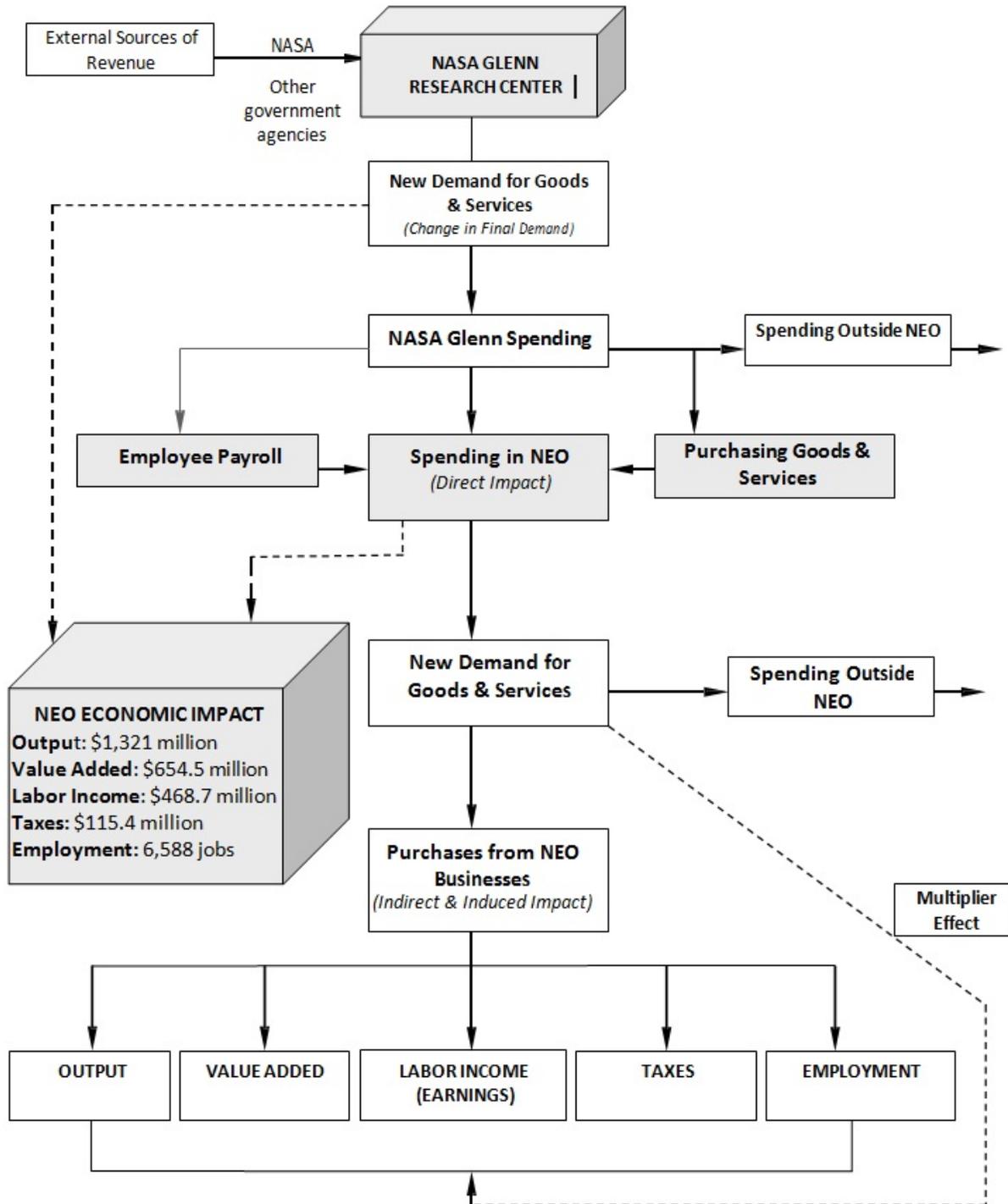
Through its attraction of federal dollars, NASA Glenn created new demand for goods and services (change in final demand, which is also treated as a direct impact). Some of this demand was generated for goods and services provided by vendors outside Northeast Ohio and Ohio, resulting in dollars leaking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

²⁴ 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.

²⁵ The summation of direct, indirect, and induced impacts across industries in the impact tables (Tables

7-14) may reflect rounding discrepancies created by multiple iterations of IMPLAN modeling. According to IMPLAN, the 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 2015



D.2. ECONOMIC IMPACT ON NORTHEAST OHIO, FY 2015

This section describes NASA Glenn's economic impact on Northeast Ohio's economy in FY 2015. The analysis includes a detailed overview of the changes in output (sales), employment, labor income (earnings), value added, and taxes generated by NASA Glenn's services in Northeast Ohio.

D.2.1. Output Impact on Northeast Ohio, FY 2015

To calculate an output income, 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 calculations of the output impact on Northeast Ohio. Local spending is then categorized by products purchased from different industries in the regional economy. Based on an IMPLAN classification system of industries, the spending is coded across 536 IMPLAN sectors.²⁶ IMPLAN industry sectors are similar to the description of industries used in the North American Industry Classification System (NAICS) but do not fully correspond to the NAICS system. Appendix Table A.3. provides detailed NASA Glenn expenditures in Northeast Ohio by NAICS industry.

About 47% of NASA Glenn total expenditures in Northeast Ohio was spent for employee compensation. NASA Glenn's largest expenditures on goods and services in Northeast Ohio in FY 2015 were made on professional, scientific and technical services (25.9%), including about 16.3% of total expenditures being spent on scientific research and development. NASA Glenn's spending in Northeast Ohio has a significant economic impact on the regional economy.

Table 7 presents the total output impact of NASA Glenn of the economy of Northeast Ohio, comprised of direct, indirect, and induced impacts. NASA Glenn's total expenditures for operations represent the direct output impact for Northeast Ohio. This impact includes the regional margin of purchases from the retail industry. Indirect impact is estimated as all direct purchases of goods and services made from industries in Northeast Ohio and the contributions of individual industries that supply the producers of the goods and services consumed by NASA Glenn. Finally, induced impact is estimated from the spending of employees of Glenn and its suppliers.

²⁶ 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-relate

Table 7. Output Impact in Northeast Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting	\$ -	\$62,274	\$221,239	\$283,513
Mining	\$ -	\$887,224	\$724,123	\$1,611,348
Utilities	\$ -	\$24,755,968	\$8,290,919	\$33,046,887
Construction	\$ -	\$43,801,301	\$4,165,017	\$47,966,318
Manufacturing	\$ -	\$5,346,528	\$7,287,074	\$12,633,602
Wholesale Trade	\$ -	\$4,843,739	\$15,550,036	\$20,393,774
Retail Trade	\$ -	\$7,592,083	\$25,989,243	\$33,581,326
Transportation and Warehousing	\$ -	\$4,518,732	\$8,672,382	\$13,191,113
Information	\$ -	\$5,935,108	\$14,539,769	\$20,474,876
Finance and Insurance	\$ -	\$9,358,223	\$38,105,856	\$47,464,078
Real Estate and Rental	\$ -	\$20,234,689	\$62,984,594	\$83,219,283
Professional, Scientific, and Tech Services	\$ -	\$159,136,534	\$14,113,335	\$173,249,868
Management of Companies	\$ -	\$3,862,109	\$3,957,537	\$7,819,646
Administrative and Waste Services	\$ -	\$77,265,187	\$8,882,075	\$86,147,261
Educational Services	\$ -	\$5,353,750	\$6,089,442	\$11,443,192
Health and Social Services	\$ -	\$44,360	\$53,735,007	\$53,779,367
Arts, Entertainment, and Recreation	\$ -	\$1,442,635	\$6,549,110	\$7,991,745
Accommodation and Food Services	\$ -	\$2,185,612	\$16,323,144	\$18,508,755
Other Services	\$ -	\$4,506,003	\$13,249,619	\$17,755,622
Government & non-NAICs	\$624,738,137	\$1,591,947	\$4,220,129	\$630,550,212
Total Output	\$624,738,137	\$382,724,003	\$313,649,649	\$1,321,111,788

For output impact, the change in final demand or direct impact (\$624,738,137) 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 amount of \$627,780,570 in 2015 dollars equates to \$624,738,137 while adjusted for inflation and shown in the table in 2016 dollars (Inflation 219.4 based on CPI-U for the Cleveland MSA's available data for 2016).

The total output impact of NASA Glenn on Northeast Ohio was \$1.32 billion in FY 2015.

NASA Glenn's \$624.7 million worth of expenditures resulted in an output (sales) change of \$1.32 billion across all industry sectors (Table 7). For example, NASA Glenn's spending caused a \$173.2 million increase in total sales by the Professional, Scientific, and Technical services industry and a \$48 million increase in sales (direct, indirect, and induced impacts) by the Construction industry. If NASA Glenn did not exist in Northeast Ohio, the regional economy would suffer an \$86.1 million decrease in output in the Administrative and Waste Services industry. Thus, the impact of NASA Glenn's operation 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, 47.3% (\$624.7 million in 2016 dollars) is accounted for by NASA Glenn's direct spending, which constitutes the direct economic impact to Northeast Ohio. The remaining output impact of \$696.4 million (52.7%) is due to the indirect and induced components as NASA Glenn purchases directly from companies and first-round suppliers ripple through the economy.

A detailed analysis of the IMPLAN modeling results indicates that the \$696.4 million 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 increase sales, employment, and earnings primarily due to NASA Glenn's operations. Among these industries are utilities, construction, information, professional and scientific services, administrative and support services, and education. The increase in output due to indirect and induced economic impacts for these industries in FY 2015 was \$386 million or 55.4% of NASA Glenn's overall indirect and induced impact on Northeast Ohio.

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 (see below), owner-occupied buildings, finance and insurance, and entertainment and food.²⁷ The increase in output due to indirect and induced economic impacts for these industries in FY 2015 was \$236.4 million, or 34%, 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 2015 was \$73.8 million or 10.6% of the total impact.

²⁷ 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 costs, and other expenditures related to the upkeep of the space in the same way expenses are captured for rental properties.

The output distributions for select NASA Glenn-driven industries and consumer-driven industries are shown in Figure 5 and Figure 6, respectively. Each of the industries presented in Figure 5 had additional sales of at least \$10 million in FY 2015. Each of the industries presented in Figure 6 had additional sales of at least \$4 million in FY 2015.

The scientific research and development industry generated the largest output impact; it increased by \$83.6 million in FY 2015 due to NASA Glenn's operations (Figure 5). This amount is the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn's spending on research services. The increase of \$83.6 million accounted for 21.7% of the \$386 million increase in output for all NASA Glenn-driven industries. Other industries shown in Figure 5 can be interpreted similarly.

Figure 6 presents consumer-driven industries of the economy that saw large increases in sales. The Funds, Trusts, and Other Financial Vehicles industry generated the largest output impact; it increased by \$40.6 million in FY 2015 due to NASA Glenn's operations in Northeast Ohio. This amount is the summation of the indirect and induced impacts generated primarily by NASA Glenn employees and other workers for rental activities. The increase of \$40.6 million accounted for 17.2% of the \$236.4 million increase in output for all industries within the consumer-driven sector.

Figure 5. Increase in Sales for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2015

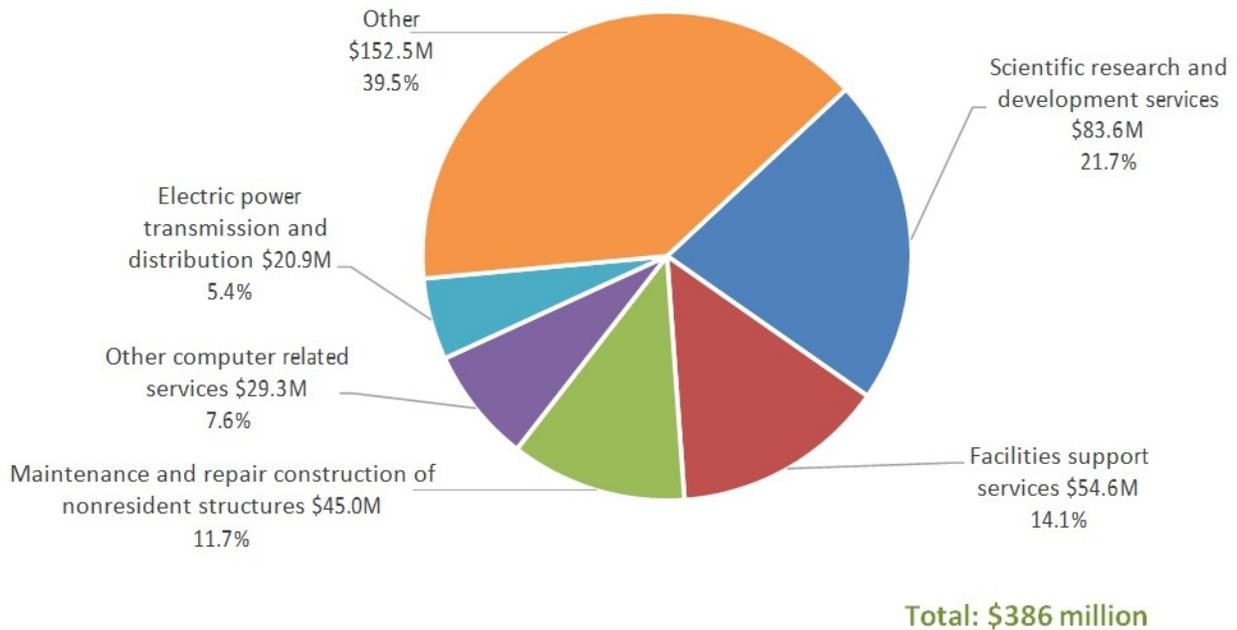
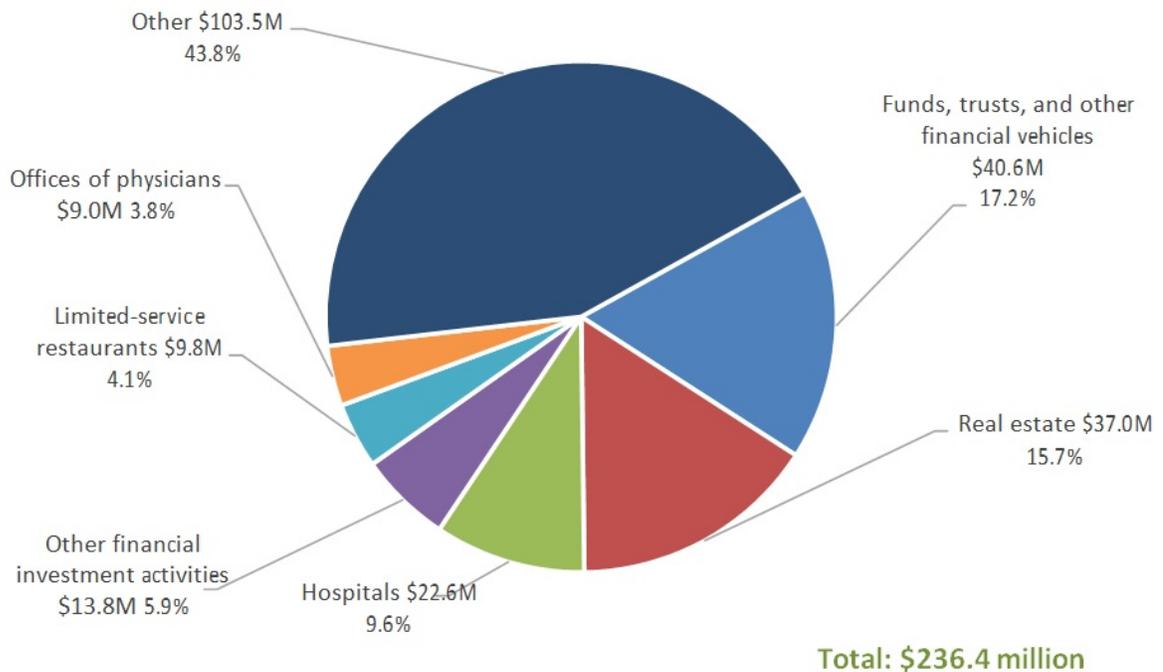


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2015



D.2.2. Employment Impact on Northeast Ohio, FY 2015

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). NASA Glenn's spending triggered increased employment in industries which provide supplies to NASA Glenn operations (indirect impact).

In addition, money spent by employees of NASA Glenn, employees of the businesses from which NASA Glenn buys goods and services, and employees of the companies in the supply chain generate indirect and induced employment effect on the regional economy. The total employment impact equals the sum of NASA Glenn's employment (direct impact), indirect impact, and induced impact. Table 8 shows the number of new and supported jobs by industry sector.

Table 8. Employment Impact in Northeast Ohio, FY 2015

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		1	4	6
Mining		2	2	4
Utilities		24	6	30
Construction		322	24	347
Manufacturing		17	16	33
Wholesale Trade		21	65	86
Retail Trade		131	337	468
Transportation and Warehousing		29	57	86
Information		15	33	49
Finance and Insurance		32	153	186
Real Estate and Rental		72	99	170
Professional, Scientific, and Tech Services		960	99	1,059
Management of Companies		16	16	31
Administrative and Waste Services		820	134	954
Educational Services		179	89	267
Health and Social Services		0	522	522
Arts, Entertainment, and Recreation		21	73	94
Accommodation and Food Services		44	299	343
Other Services		52	207	259
Government & non-NAICs	1,563	9	22	1,594
Total Employment	1,563	2,767	2,258	6,588

Notes:

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

The total employment impact of NASA Glenn on the Northeast Ohio economy in FY 2015 was 6,588 jobs. Of these 6,588 jobs, 1,563 (23.7%) were directly employed at NASA Glenn Research Center. As a result of Glenn's direct spending on goods and services, an additional 2,767 full-time and part-time jobs (42%) were supported and created in the region as indirect economic impact. The rest of the employment impact, 2,258 jobs (34.3%), 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 5,025 jobs created in Northeast Ohio due to the indirect and induced impacts, 2,706 (53.8%) were in NASA Glenn-driven industries, 1,829 (36.4%) were in consumer-driven industries, and 471 (9.8%) were in other industries.²⁸ The job distribution for select NASA Glenn-driven industries is shown in Figure 7. The job distribution for select consumer-driven industries is shown in Figure 8. The industries presented in Figures 7 and 8 are the leading industries in terms of most created and supported employment (a minimum of 140 and 50 employees per industry, respectively).

The scientific research and development industry generated the highest number of additional jobs. Companies engaged in scientific R&D (professional, scientific, and technical services sector) saw an increase of 398 jobs in FY 2015 due to NASA Glenn's operation in Northeast Ohio (Figure 7). These jobs are the summation of the indirect and induced employment impacts generated primarily, but not exclusively, by NASA Glenn's spending on R&D contractors in Northeast Ohio. The 398 jobs accounted for 14.7% of the 2,706 jobs that were created in all industries within the NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted similarly.

The real estate industry saw the largest increase among consumer-driven industries; the increase of 152 jobs in FY 2015 was due to NASA Glenn's spending that generates labor income in regional supply industries (Figure 8). These jobs are the summation of the direct, indirect, and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in the real estate industry in Northeast Ohio. The 152 jobs accounted for 8.3% of the 1,829 jobs that were created in all consumer-driven industries.

²⁸ 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 2015

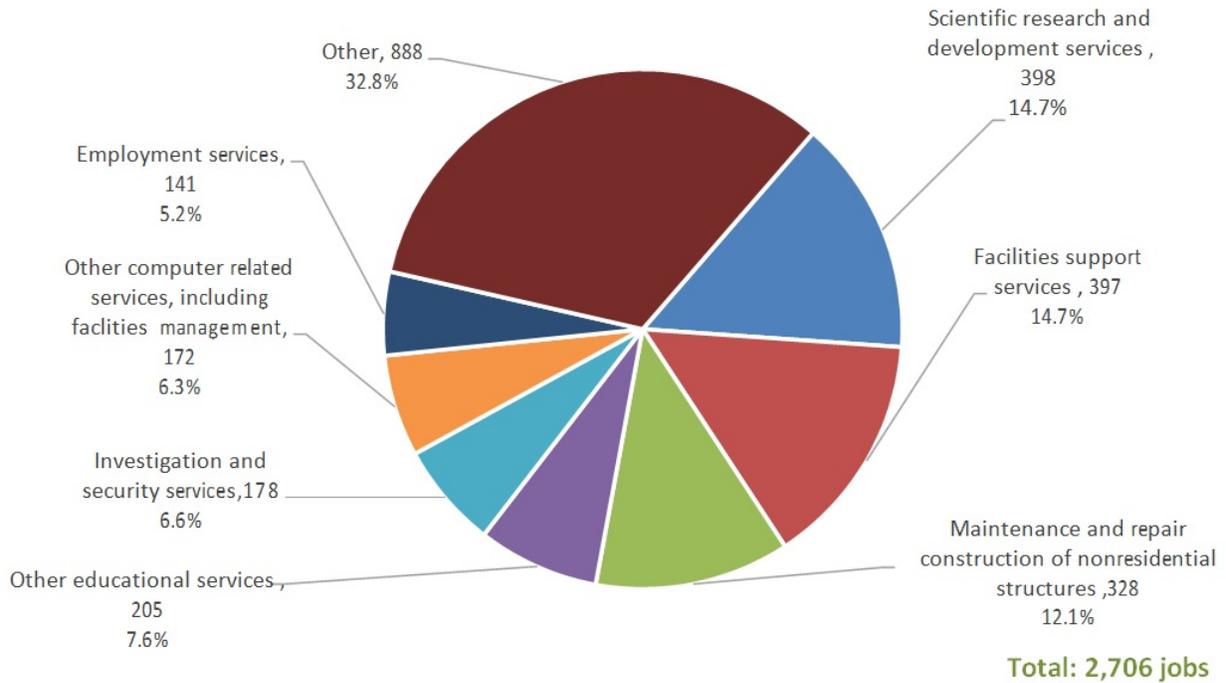
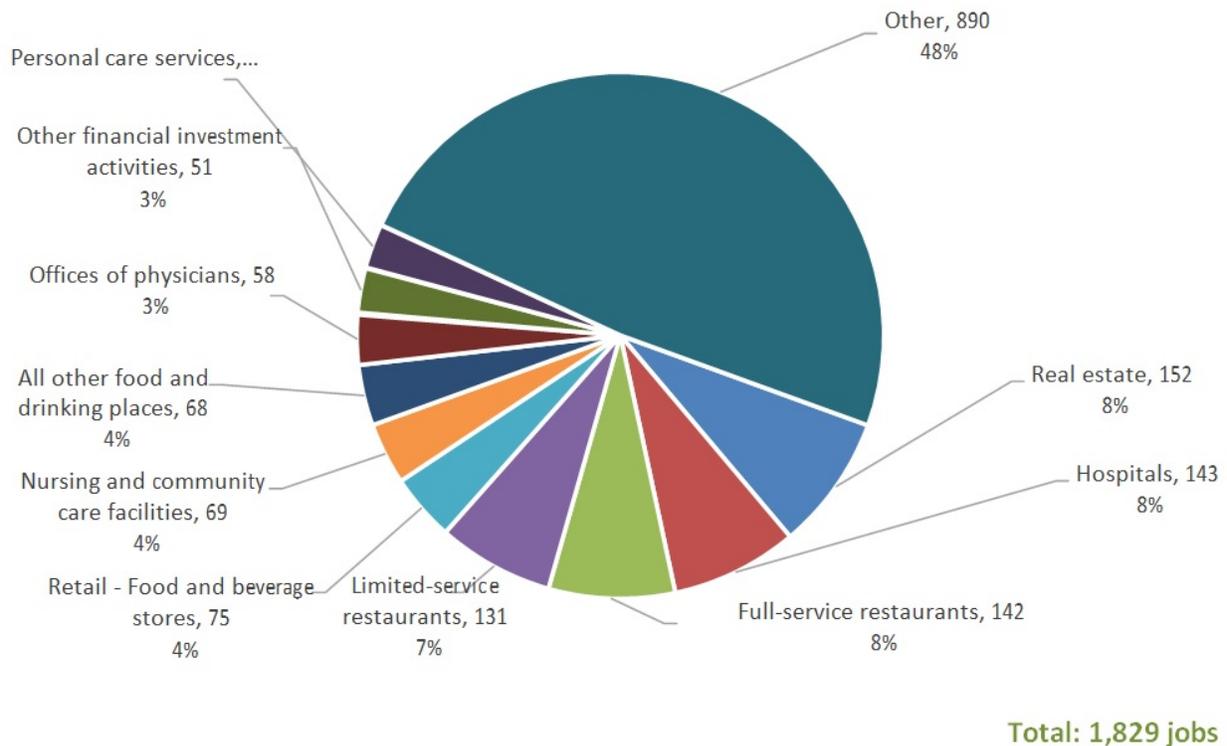


Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2015



D.2.3. LABOR INCOME IMPACT ON NORTHEAST OHIO, FY 2015

Labor income impact is the estimated total change in labor income paid to employees of local businesses due to spending by NASA Glenn for goods and services purchased in Northeast Ohio and the money paid to employees of NASA Glenn. The total wages and benefits paid to NASA Glenn employees account for the employment base of NASA Glenn located within Northeast Ohio. It also accounts for a part of the income that employees who live outside of Northeast Ohio and commute to work spend in the region.

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

Table 9. Labor Income Impact in Northeast Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting	\$ -	\$38,541	\$124,219	\$162,760
Mining	\$ -	\$314,258	\$228,946	\$543,204
Utilities	\$ -	\$2,450,035	\$785,111	\$3,235,145
Construction	\$ -	\$15,196,300	\$1,302,818	\$16,499,119
Manufacturing	\$ -	\$1,169,625	\$1,094,344	\$2,263,969
Wholesale Trade	\$ -	\$1,736,471	\$5,561,028	\$7,297,500
Retail Trade	\$ -	\$3,424,468	\$11,090,857	\$14,515,325
Transportation and Warehousing	\$ -	\$1,492,829	\$2,854,463	\$4,347,291
Information	\$ -	\$1,072,701	\$2,323,659	\$3,396,359
Finance and Insurance	\$ -	\$2,294,769	\$9,294,075	\$11,588,844
Real Estate and Rental	\$ -	\$3,513,363	\$4,719,002	\$8,232,365
Professional, Scientific, and Tech Services	\$ -	\$72,177,847	\$7,489,901	\$79,667,748
Management of Companies	\$ -	\$1,927,183	\$1,974,801	\$3,901,984
Administrative and Waste Services	\$ -	\$26,493,417	\$4,753,842	\$31,247,259
Educational Services	\$ -	\$3,471,634	\$3,374,443	\$6,846,077
Health and Social Services	\$ -	\$23,369	\$29,493,863	\$29,517,232
Arts, Entertainment, and Recreation	\$ -	\$645,135	\$2,194,499	\$2,839,634
Accommodation and Food Services	\$ -	\$940,785	\$6,320,415	\$7,261,199
Other Services	\$ -	\$2,345,913	\$6,759,230	\$9,105,143
Government & non-NAICs	\$222,186,710	\$827,736	\$1,967,435	\$224,981,881
Total Labor Income	\$222,186,710	\$141,556,377	\$103,706,950	\$467,450,037

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 inflation and shown in the table in 2016 dollars (Inflation 219.4 based on CPI-U for the Cleveland MSA's available data for 2016).

Total labor income in Northeast Ohio increased by \$467.5 million as a result of NASA operation in FY 2015. Of the \$467.5 million of the total labor income, \$222.2 million (47.5%) constituted wages and benefits paid directly to NASA Glenn employees (i.e., change in final demand or direct effect measured in 2016 dollars). Of the total impact, \$141.6 million (30.2%) represented indirect impact, or the money paid to employees of companies in Northeast Ohio that supply goods and services to NASA Glenn. The remaining earnings constitute induced effect of \$103.7 million (22.2%); they occurred as the effects of NASA Glenn's spending rippled through the Northeast Ohio economy via labor income spending.

Of the \$245.3 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, \$140.9 million (57.4%) was generated in NASA Glenn-driven industries, \$78.1 million (31.8%) was reported in consumer-driven industries, and \$24.6 million (10.8%) occurred in other industries.²⁹

The labor income distribution for select NASA Glenn-driven industries is shown in Figure 9. The labor income distribution for select consumer-driven industries is shown in Figure 10. The select industries shown in Figures 9 and 10 each added over \$5 million and \$2.5 million, respectively.

In the NASA Glenn-driven industries, people who were engaged in scientific research and development services saw their labor income increase by \$30.5 million in FY 2015 (Figure 9). These earnings are the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn using scientific research and development services in Northeast Ohio. The \$30.5 million spent of scientific research and development accounted for 21.7% of the \$143.1 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 \$11.2 million in FY 2015 (Figure 10). These earnings are the summation of the indirect and induced impacts generated by consumer spending for doctors' services. The \$11.2 million accounted for 14% of the \$78.1 million labor income increase that occurred in all consumer-driven industries.

²⁹ 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 2015

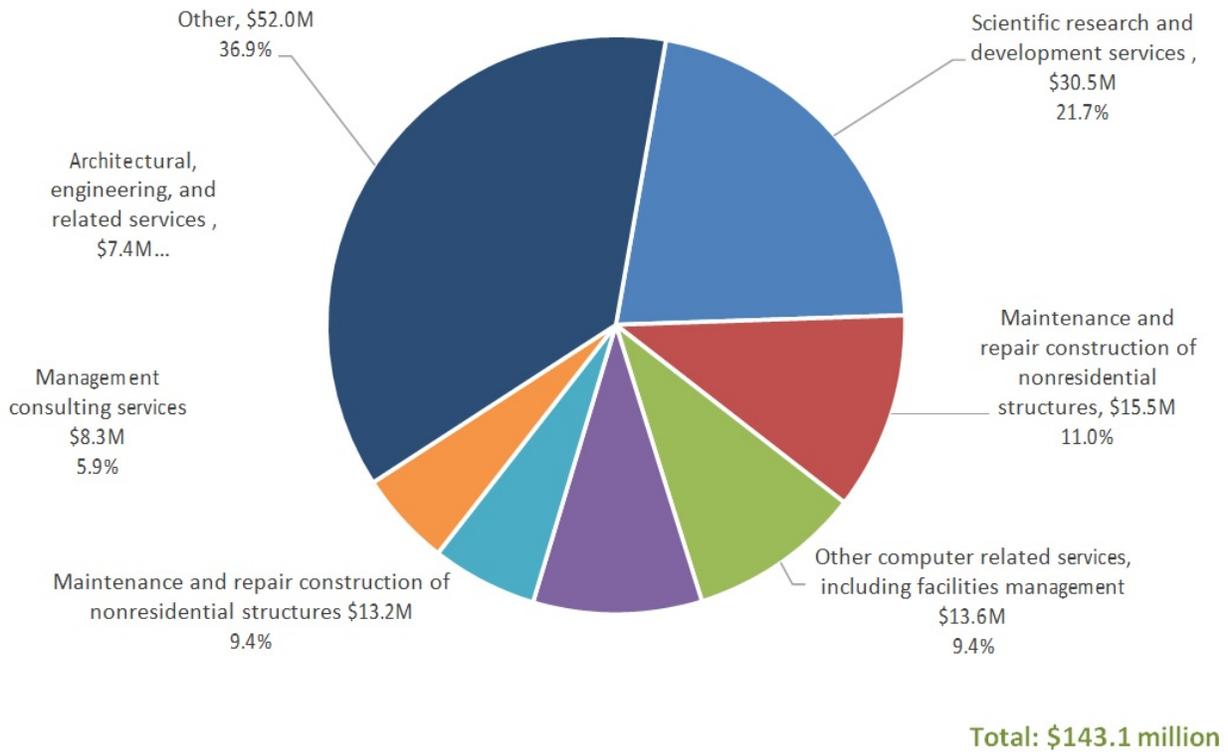
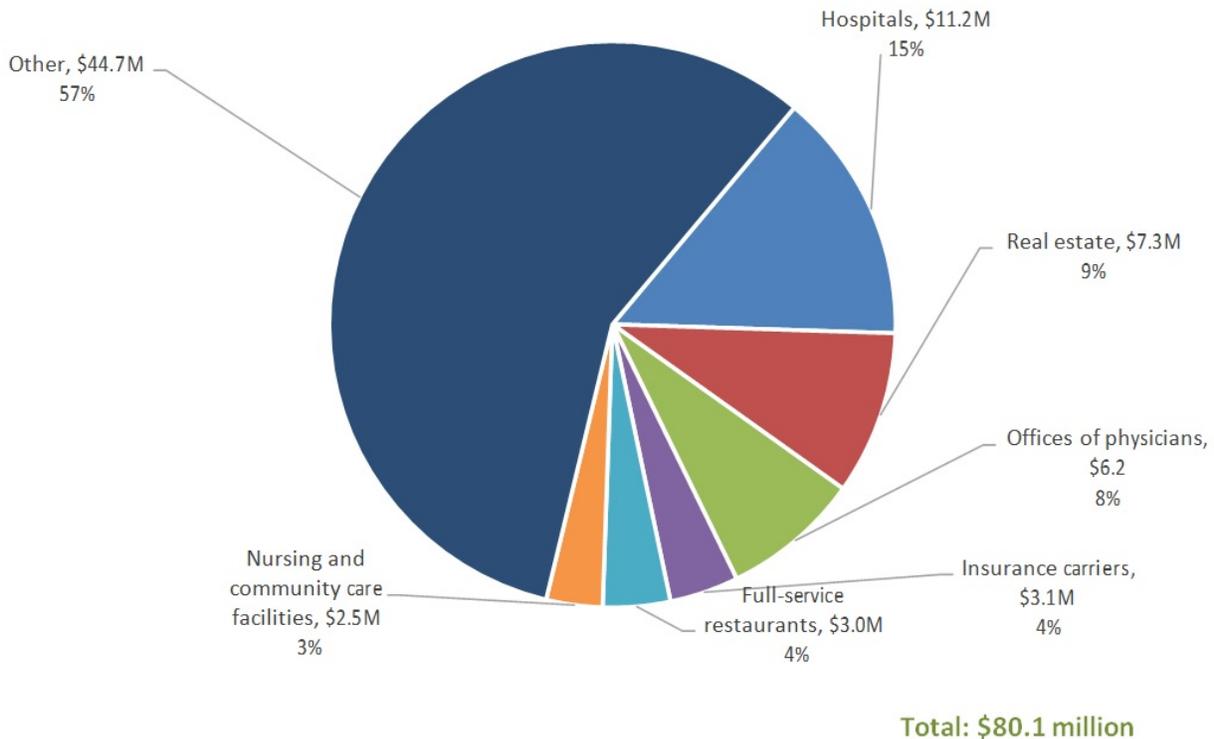


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2015



D.2.4. Value Added Impact on Northeast Ohio, FY 2015

The total value added impact³⁰ in Northeast Ohio was \$682.1 million, which resulted from NASA Glenn's regional spending on goods and services. NASA Glenn's spending led to a \$682.1 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, \$287.4 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.

Induced impact represents sales, excluding intermediary goods and services, in all industries that produced products for industries in which income was affected by the demand for products and services created by NASA Glenn. The total value added impact was found by adding the direct, indirect, and induced impacts. Table 10 shows the value added impact by industry sector.

³⁰ "Value added" measures the economic impact of all goods and services produced in Northeast Ohio because of the operation of NASA Glenn, excluding intermediary

goods which are goods used in the production of other goods and not for final consumption.

Table 10. Value Added Impact in Northeast Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting	\$ -	\$45,990	\$170,437	\$216,427
Mining	\$ -	\$377,430	\$276,161	\$653,591
Utilities	\$ -	\$12,033,588	\$4,006,772	\$16,040,360
Construction	\$ -	\$18,312,761	\$1,559,761	\$19,872,523
Manufacturing	\$ -	\$1,846,052	\$2,308,108	\$4,154,160
Wholesale Trade	\$ -	\$3,155,571	\$10,105,678	\$13,261,249
Retail Trade	\$ -	\$5,439,602	\$17,243,797	\$22,683,399
Transportation and Warehousing	\$ -	\$2,037,462	\$3,859,136	\$5,896,598
Information	\$ -	\$2,100,997	\$5,708,941	\$7,809,938
Finance and Insurance	\$ -	\$6,131,484	\$20,682,780	\$26,814,264
Real Estate and Rental	\$ -	\$15,254,806	\$44,121,496	\$59,376,302
Professional, Scientific, and Tech Services	\$ -	\$84,131,306	\$9,297,801	\$93,429,108
Management of Companies	\$ -	\$2,395,204	\$2,454,386	\$4,849,590
Administrative and Waste Services	\$ -	\$44,591,002	\$6,147,302	\$50,738,304
Educational Services	\$ -	\$3,283,011	\$3,625,293	\$6,908,304
Health and Social Services	\$ -	\$27,002	\$33,106,338	\$33,133,341
Arts, Entertainment, and Recreation	\$ -	\$768,381	\$3,861,673	\$4,630,053
Accommodation and Food Services	\$ -	\$1,122,546	\$8,372,200	\$9,494,746
Other Services	\$ -	\$3,341,492	\$9,494,933	\$12,836,425
Government & non-NAICs	\$287,379,543	\$542,148	\$1,375,128	\$289,296,818
Total Value Added	\$287,379,543	\$206,937,836	\$187,778,121	\$682,095,500

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.

Total value added in Northeast Ohio increased by \$682.1 million in FY 2015 as a result of NASA Glenn's spending on goods and services. Of this total amount, \$287.4 million (42.1%) accounts for the change in final demand or direct impact, calculated as total output less intermediate expenditures, or the large portion of the value added in the wages and salaries paid to NASA Glenn employees. Another \$206.9 million (30.4%) represented 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 \$187.8 million (27.5%). This was the result of the ripple effects NASA Glenn's spending had on Northeast Ohio's economy.

Of the \$394.7 million increase in value added generated across Northeast Ohio due to the indirect (\$206.9 million) and induced impacts (\$187.8 million), \$194.8 million (49.5%) was reported in NASA Glenn-driven industries, \$160.3 million (41%) was generated in consumer-driven industries, and \$35.1 million (9.5%) was reported in other industries.³¹

The value added distribution for select NASA Glenn-driven industries is shown in Figure 11. The value added distribution for select consumer-driven industries is shown in Figure 12. Each of the select industries shown in Figures 11 and 12 added at least \$7.5 million and \$5 million each, respectively.

The scientific research and development services industry, the largest NASA Glenn-driven industries, saw a value added increase of \$39.3 million in FY 2015 (Figure 11). This increase in value added is a result of the indirect and induced impacts' summation, generated primarily, but not exclusively, by NASA Glenn using scientific research and development services in Northeast Ohio. The \$39.3 million accounted for 20.2% of the \$194.8 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 \$31.8 million in FY 2015 (Figure 12). This value added increase is a result of the summation of the indirect and induced impacts generated by consumer spending at real estate establishments. The \$31.8 million accounted for 19.9% of the \$160.3 million value added increase that occurred in all consumer-driven industries.

³¹ 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 2015

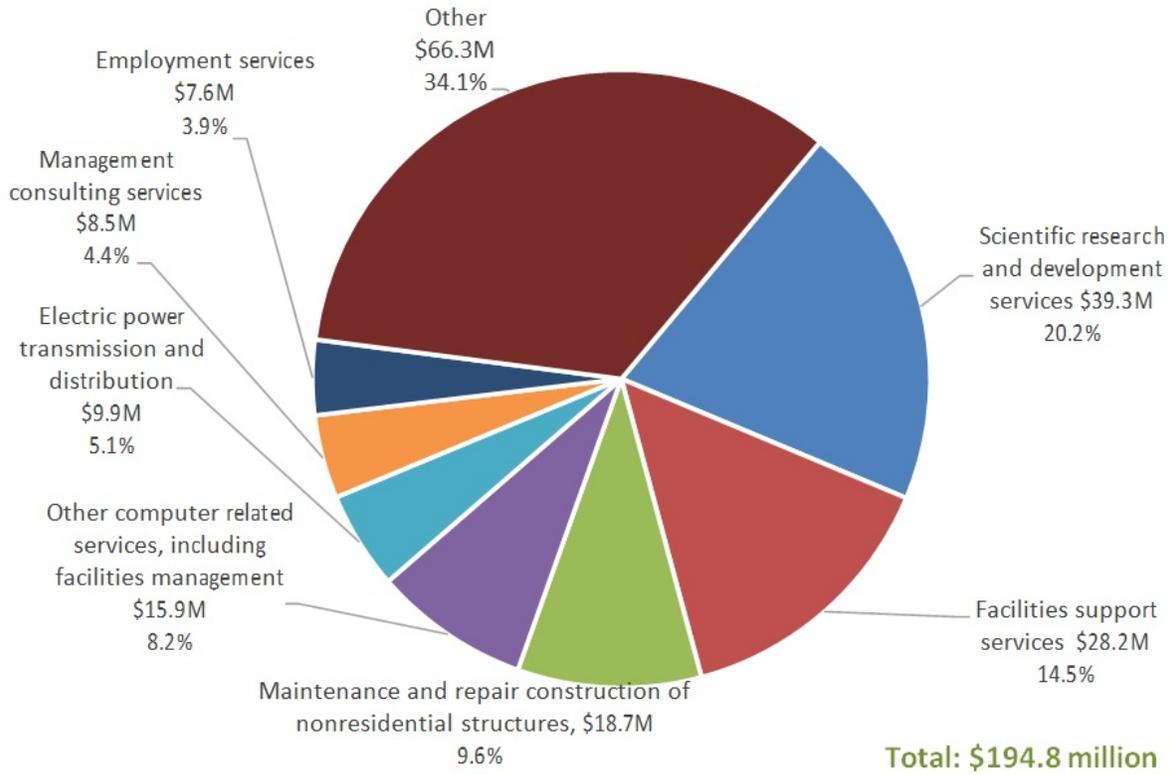
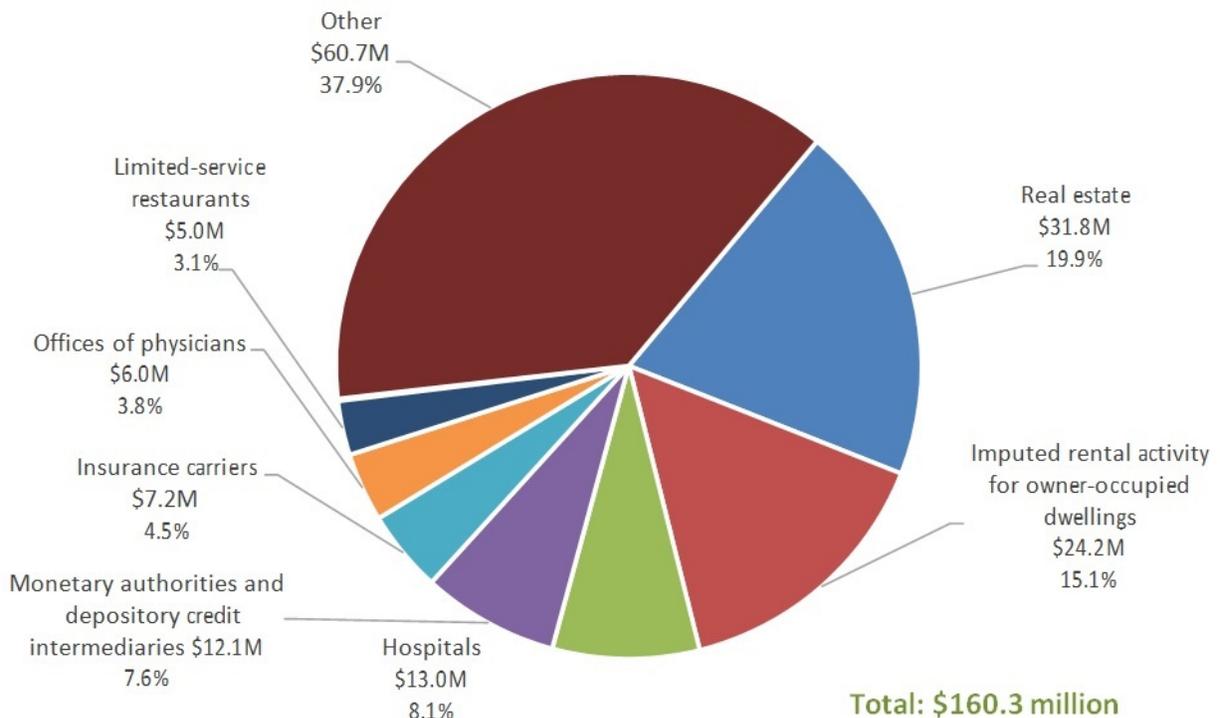


Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2015



D.2.5. Tax Impact on Northeast Ohio, FY 2015

NASA Glenn's operation in Northeast Ohio generated a total of \$115.4 million in tax revenues in FY 2015 (in 2016 dollars). The direct tax impact paid by NASA Glenn's employees was \$32.9 million, \$41.1 million was indirect tax impact, and \$41.4 came from induced tax impact.

D.2.6. FY 2015 Northeast Ohio Impact Summary

Economic activity conducted by NASA Glenn generated the following total economic impact on Northeast Ohio (in 2016 dollars):

- Total Output Impact: \$1,321 M
- Total Employment Impact: 6,588 jobs
- Total Labor Income Impact: \$467.5 M
- Total Value Added Impact: \$682.1 M
- Total Tax Impact: \$115.4 M

The economic impact of NASA Glenn Research Center's activities on Northeast Ohio reflects the benefits of total expenditures of \$472.1 million. These expenditures include a total amount of \$248.8 million spent on purchases in Northeast Ohio in FY 2015 and expenditures on labor income paid to NEO employees and commuters at the amount of \$223.3 million (in 2015 dollars).

Excluding expenditures on labor income, 49% (almost \$122 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 24.7% (\$61.4 million) was spent on administrative and support services; and 16.2% (\$40.4 million) was spent on construction - the three largest groups of NASA Glenn expenditures in Northeast Ohio.³² These three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio and, together, accounted for \$223.9 million or almost 90% of all NASA Glenn's FY 2015 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, utilities accounted for 6.5%; education 2.1%, wholesale and retail trade 0.8%; and manufacturing, 0.3%. Other sectors' expenditures were less than 1%.

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

³² Amounts in parentheses detailing percentage numbers are presented in 2015 dollars and correspond to Appendix Table A.3.

D.3. ECONOMIC IMPACT ON THE STATE OF OHIO, FY 2015

Assessment of the economic impact of NASA Glenn operations on Ohio's economy in FY 2015 followed a methodology similar to the calculation of economic impact of NASA Glenn on Northeast Ohio. For the state of Ohio, we accounted 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 2015.

D.3.1. Output Impact on the State of Ohio, FY 2015

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

NASA Glenn's expenditures were divided into two categories: (1) spending on goods and services purchased from companies and other institutions located in the state of Ohio (local) and (2) spending on 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. Then, the spending is assigned to 536 IMPLAN sectors similar to the NAICS code industrial classification. Table A.4 in Appendix A provides a detailed list of NASA Glenn's expenditures by industry in the state of Ohio.

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

Table 11. Output Impact in the State of Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting	\$ -	\$168,119	\$1,206,190	\$1,374,309
Mining	\$ -	\$1,398,511	\$1,393,870	\$2,792,380
Utilities	\$ -	\$26,088,955	\$10,219,249	\$36,308,204
Construction	\$ -	\$44,409,668	\$4,761,389	\$49,171,056
Manufacturing	\$ -	\$11,624,462	\$22,090,646	\$33,715,108
Wholesale Trade	\$ -	\$5,170,410	\$15,657,454	\$20,827,864
Retail Trade	\$ -	\$7,961,249	\$29,076,650	\$37,037,899
Transportation and Warehousing	\$ -	\$5,855,637	\$10,970,887	\$16,826,525
Information	\$ -	\$7,269,485	\$16,451,727	\$23,721,212
Finance and Insurance	\$ -	\$10,995,097	\$40,355,787	\$51,350,885
Real Estate and Rental	\$ -	\$18,832,173	\$65,134,680	\$83,966,852
Professional, Scientific, and Tech Services	\$ -	\$168,144,759	\$13,071,353	\$181,216,112
Management of Companies	\$ -	\$4,391,522	\$4,743,556	\$9,135,078
Administrative and Waste Services	\$ -	\$110,576,900	\$9,682,053	\$120,258,954
Educational Services	\$ -	\$5,682,995	\$5,940,303	\$1,1623,298
Health and Social Services	\$ -	\$44,756	\$58,688,418	\$58,733,174
Arts, Entertainment, and Recreation	\$ -	\$1,410,192	\$6,244,208	\$7,654,400
Accommodation and Food Services	\$ -	\$2,611,758	\$18,640,454	\$21,252,212
Other Services	\$ -	\$5,609,518	\$14,756,681	\$20,366,199
Government & non-NAICs	\$624,738,137	\$1,004,382	\$2,939,984	\$628,682,503
Total Output	\$624,738,137	\$439,250,547	\$352,025,541	\$141,6014,225

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 2016 dollars (Inflation 219.4 is based on CPI-U for the Cleveland MSA's available data for 2016). Due to majority of spending and economic benefits occurring in Northeast Ohio, the Cleveland's inflation rate is applied to Ohio figures.

The total output impact of NASA Glenn Research Center's spending of goods and services on the state of Ohio was \$1,416 million in FY 2015. Glenn's expenditures of \$624.7 million resulted in an increase of \$1,416 million in output (sales) across all industry sectors (Table 11). For example, NASA Glenn's spending affected a \$181.2 million increase in sales in professional, scientific, and technical services (including direct, indirect, and induced impacts), as well as a \$120.3 million increase in sales in the administrative and waste services sector - two largest sectors of output in Ohio.

Of the total output impact, 44.1% (\$624.7 million) was accounted for by the change in final demand or direct impact due to NASA Glenn's activities bringing resources from outside of Ohio into the state. Approximately \$439.3 million (31.0%) of the total output impact was a result of indirect spending by NASA Glenn on goods and services purchased within the state of Ohio. The remaining output impact of \$352.0 million (24.9%) was due to the induced impact of NASA Glenn's spending rippled throughout the state economy.³³

An analysis of the IMPLAN model shows that the \$791 million increase in sales generated by the indirect and induced impacts can be divided into the same broad categories that were identified for Northeast Ohio: NASA Glenn-driven industries (\$421.9 million, 53%), consumer-driven industries (\$256.5 million, 34%), and other industries (\$112.6 million, 14%).³⁴

The output distribution for select NASA Glenn-driven industries is shown in Figure 13. The output distribution for select consumer-driven industries is shown in Figure 14. The select industries shown in Figures 13 and 14 each added over \$10 and \$5 million, respectively.

The scientific research and development services industry in the state of Ohio saw an increase in revenue of \$92.5 million in FY 2015 (Figure 13). This amount is the summation of the indirect and induced impacts generated by NASA Glenn's spending. This increase of \$92.5 million accounted for a 21.9% share of the \$421.9 million increase in output value for all NASA Glenn-driven industries. Other industries shown in Figure 13 can be interpreted similarly.

The real estate industry experienced an activity increase of \$37.5 million in FY 2015 (Figure 14). This amount is the summation of the indirect and induced impact components generated primarily by NASA Glenn employees and other workers using medical services. This increase of \$37.5 million represented a 14% share of the \$265.5 million increase in output for all consumer-driven industries. Other industries shown in Figure 14 can be interpreted similarly.

³³ All figures are reported in 2016 dollars.

³⁴ NASA Glenn-driven sectors include utilities, construction, information, education, professional and scientific services, and administrative and support

services. Consumer-driven sectors include retail, healthcare, real estate, other services, owner-occupied buildings, finance and insurance, and entertainment and food.

Figure 13. Increase in Sales for Select NASA Glenn-Driven Industries in Ohio, FY 2015

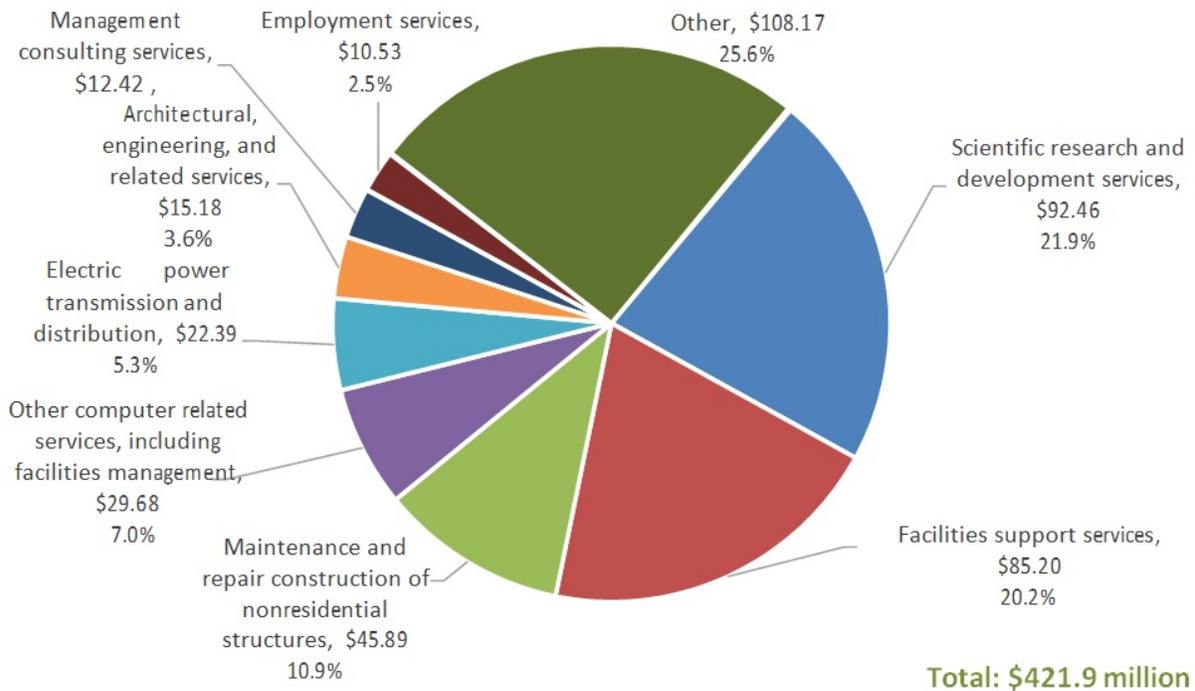
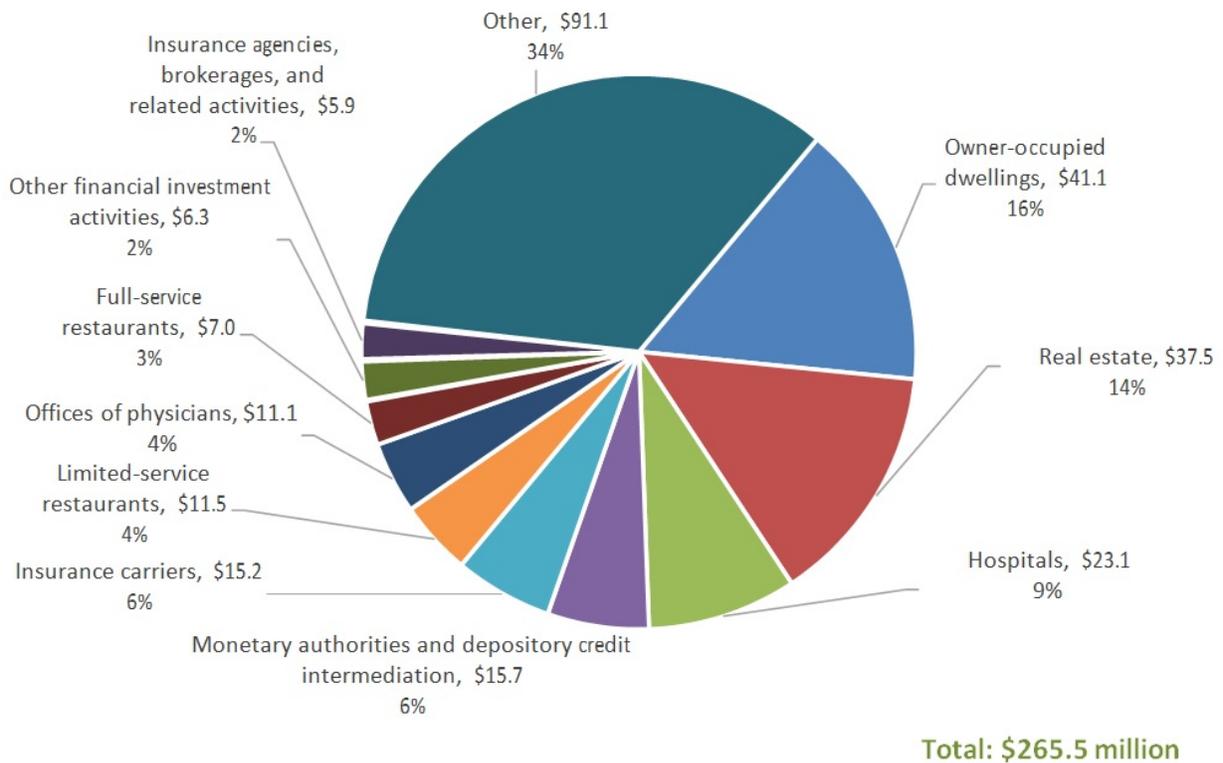


Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2015



D.3.2. Employment Impact on the State of Ohio, FY 2015

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

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

Table 12. Employment Impact in the State of Ohio, FY 2015

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		3	13	16
Mining		5	5	9
Utilities		23	8	31
Construction		326	28	354
Manufacturing		31	35	66
Wholesale Trade		23	68	91
Retail Trade		143	382	525
Transportation and Warehousing		41	77	118
Information		18	37	56
Finance and Insurance		41	165	205
Real Estate and Rental		77	105	183
Professional, Scientific, and Tech Services		1,027	102	1,128
Management of Companies		17	19	36
Administrative and Waste Services		1,036	145	1,181
Educational Services		186	91	276
Health and Social Services		0	582	582
Arts, Entertainment, and Recreation		23	77	100
Accommodation and Food Services		52	340	391
Other Services		62	224	286
Government & non-NAICs	1,563	7	10	1,580
Total Employment	1,563	3,140	2,511	7,214

Notes:

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

Employment increased by 7,214 jobs in Ohio in FY 2015 due to NASA Glenn's spending in the state. Of these 7,214 jobs, 1,563 people (22%) were directly employed at NASA Glenn. As a result of NASA Glenn's direct spending for goods and services purchased in Ohio through their supply industries, 3,140 jobs (44%) were supported and created (indirect effect). The remaining employment --2,511 jobs (35%) --was the induced impact resulting from spending wages and salaries of NASA Glenn's workers and supply companies' employees through the state economy.

Of the 5,651 jobs created in Ohio due to the indirect and induced effects, 3,026 (53%) were found in NASA Glenn-driven sectors, 2,019 (36%) were in consumer-driven sectors, and 606 (11%) were created in other sectors.³⁵

The job distribution for select NASA Glenn-driven industries is shown in Figure 15. The job distribution for select consumer-driven industries is shown in Figure 16. Each of the selected industries shown in Figures 15 and 16 supported or added over 140 and 50 jobs, respectively.

Because of NASA Glenn's spending in Ohio, 572 jobs were added to the facilities services industry during FY 2015 (Figure 15). These jobs are the summation of the direct, indirect, and induced employment impacts generated primarily, but not exclusively, by NASA Glenn's need for facilities support services. The 572 jobs accounted for a 19% share of the 3,026 jobs that were created in all NASA Glenn-driven industries.

The full-service restaurants industry experienced an increase of 166 jobs in FY 2015 (Figure 16). The 153 jobs were supported or created due to NASA Glenn employees and employees of Glenn's supply industries dining in full-time restaurants in Ohio. These jobs accounted for a 8.2% share of the 2,019 jobs that were created in all consumer-driven industries in the state.

³⁵ 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 2015

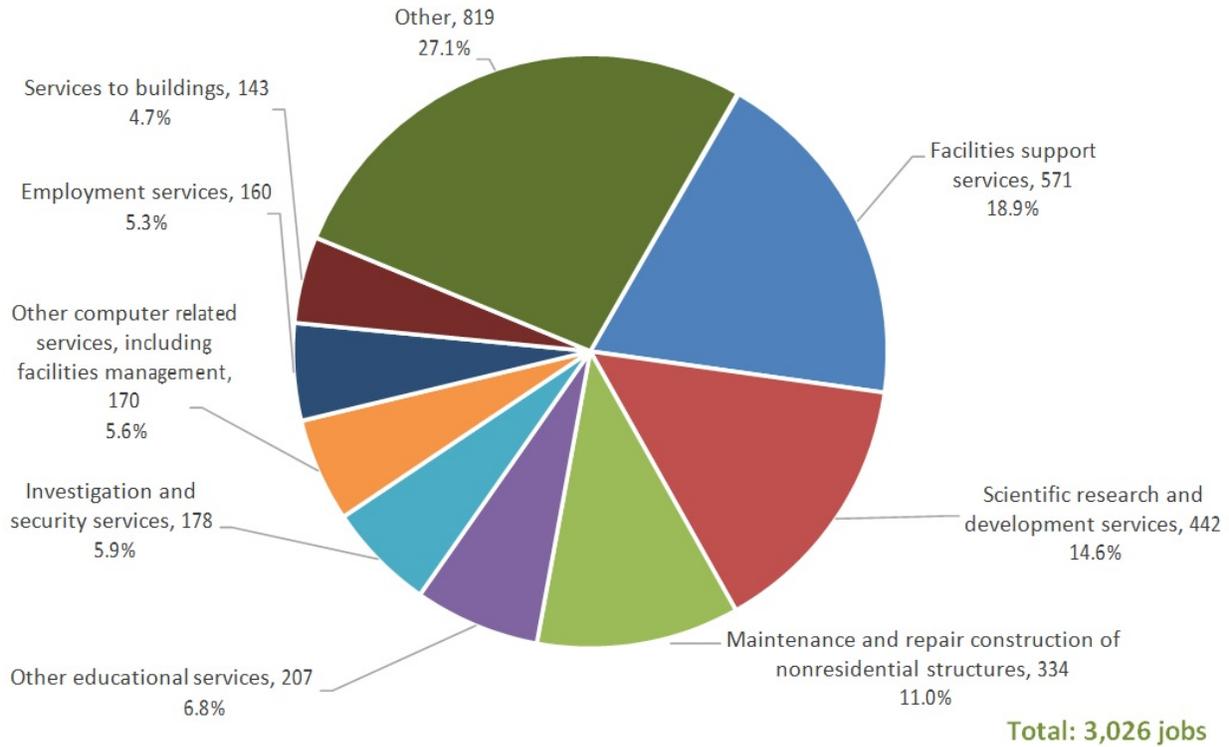
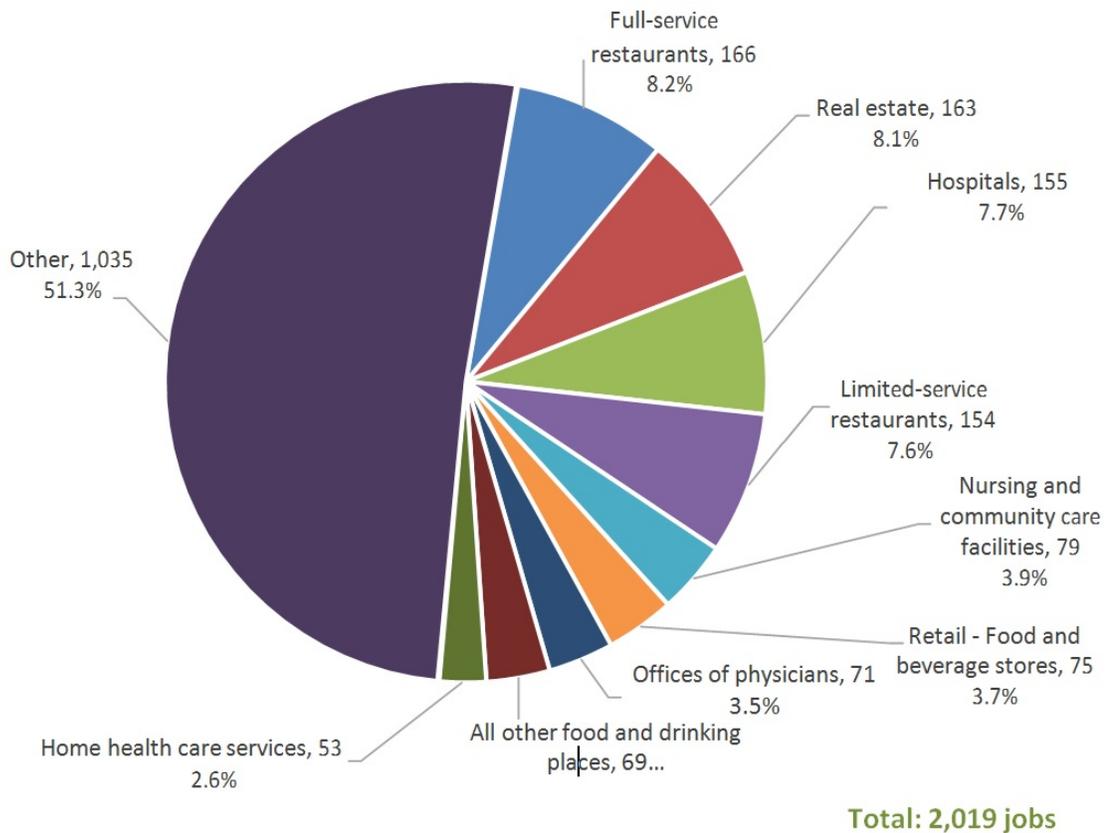


Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2015



D.3.3 Labor Income Impact on the State of Ohio, FY 2015

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

Money paid to the employees of both the companies from which NASA Glenn buys its supplies and the suppliers of these companies represented the indirect earnings impact. Induced impact was generated through the spending of workers in all industries who were employed as a result of the increased demand for products and services created by NASA Glenn. Adding the direct, indirect, and induced impacts defines the total labor income impact of NASA Glenn. Table 13 shows the labor income impact by industry sector.

Table 13. Labor Income Impact in the State of Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing, Hunting	\$ -	\$75,219	\$425,671	\$500,890
Mining	\$ -	\$361,139	\$272,494	\$633,633
Utilities	\$ -	\$2,733,055	\$981,969	\$3,715,023
Construction	\$ -	\$15,458,376	\$1,493,677	\$16,952,054
Manufacturing	\$ -	\$2,047,724	\$2,348,322	\$4,396,046
Wholesale Trade	\$ -	\$1,804,109	\$5,441,618	\$7,245,727
Retail Trade	\$ -	\$3,537,081	\$12,243,128	\$15,780,209
Transportation and Warehousing	\$ -	\$2,409,091	\$4,485,470	\$6,894,561
Information	\$ -	\$1,359,767	\$2,695,428	\$4,055,195
Finance and Insurance	\$ -	\$2,687,242	\$9,853,682	\$12,540,925
Real Estate and Rental	\$ -	\$3,214,971	\$4,330,889	\$7,545,860
Professional, Scientific, and Tech Services	\$ -	\$74,717,492	\$6,676,414	\$81,393,906
Management of Companies	\$ -	\$2,224,932	\$2,403,287	\$4,628,219
Administrative and Waste Services	\$ -	\$37,060,276	\$5,146,750	\$42,207,026
Educational Services	\$ -	\$3,584,957	\$3,184,159	\$6,769,115
Health and Social Services	\$ -	\$22,518	\$31,867,019	\$31,889,537
Arts, Entertainment, and Recreation	\$ -	\$582,429	\$1,984,364	\$2,566,793
Accommodation and Food Services	\$ -	\$1,079,970	\$6,960,523	\$8,040,493
Other Services	\$ -	\$2,995,173	\$7,388,609	\$10,383,782
Government & non-NAICs	\$ 222,933,925	\$444,915	\$976,155	\$224,354,994
Total Labor Income	\$ 222,933,925	\$158,400,437	\$111,159,629	\$492,493,991

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 inflation and shown in the table in 2016 dollars (Inflation 219.4 is based on CPI-U for the Cleveland MSA's available data for 2016).

Total labor income in the state of Ohio increased by \$492.5 million as a result of NASA Glenn's spending on goods and services in FY 2015. Of this amount, \$222.9 million (45%) included wages and benefits paid to NASA Glenn employees (change in final demand or direct impact). Income received by employees of companies across the state from which NASA Glenn buys its supplies and suppliers of those companies (indirect impact) represented \$158.4 million (32%). The remaining earnings impact (induced component), estimated to be \$111.2 million (23%), was the result of NASA Glenn employees' spending and spending of their suppliers employees' rippling through the Ohio economy.

Of the \$269.6 million increase in labor income attributed to the indirect and induced impacts, \$155.0 million (58%) was observed in Glenn-driven industries, \$83.0 million (31%) occurred in consumer-driven industries, and \$28.6 million (12%) was reported in other industries.³⁶

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 selected industries shown in these figures experienced the most gains in earnings (over \$7.2 million and \$2.6 million each in Figures 17 and 18, respectively).

In the NASA Glenn-driven industries, employees in Scientific research and development services across the state of Ohio saw their labor income increase by \$33.5 million in FY 2014 (Figure 17). These earnings are the summation of the indirect and induced impacts generated by NASA Glenn's purchases of computer-related services. The \$33.5 million represented a 21.6% of the \$155.0 million earnings increase that occurred in all NASA Glenn-driven industries.

In the consumer-driven industries, employees working for offices of physicians industry experienced an increase in labor income of \$7.7 million in FY 2015 (Figure 18). This amount is the summation of the indirect and induced impacts generated primarily by the spending of NASA Glenn employees and other workers for insurance. The \$7.7 million accounted for a 9.2% share of the \$83.0 million earnings increase that was reported by all consumer-driven industries.

³⁶ See section D.2.1. Output Impact on Northeast Ohio, FY 2015 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 2015

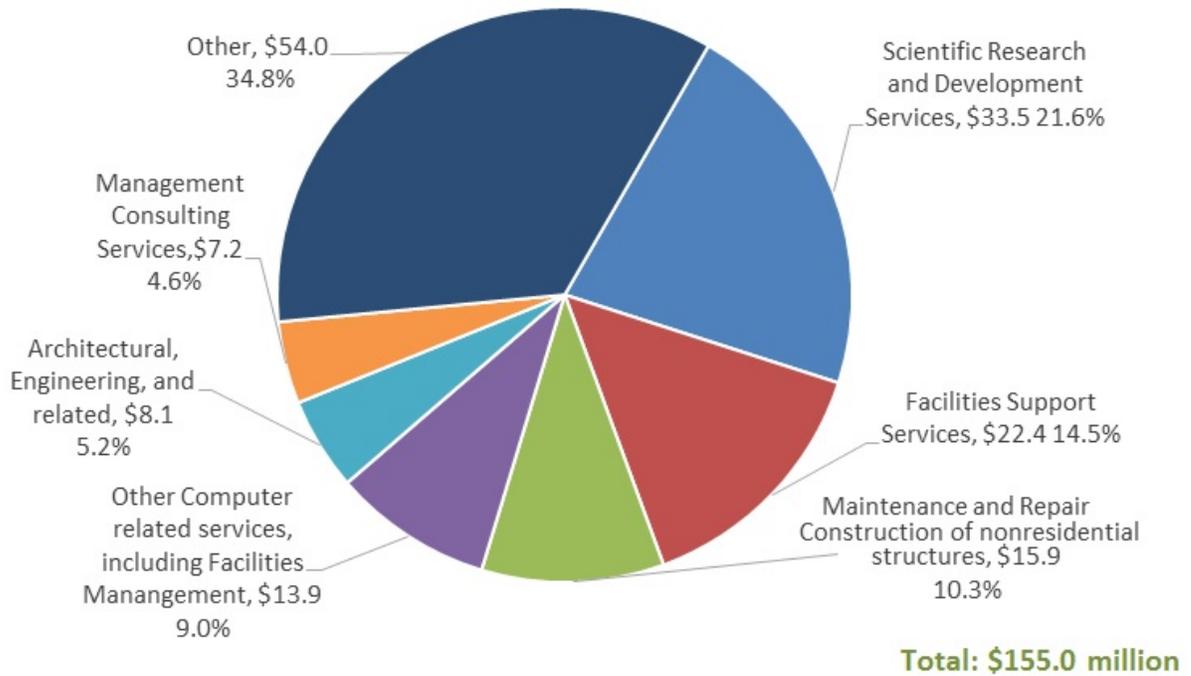
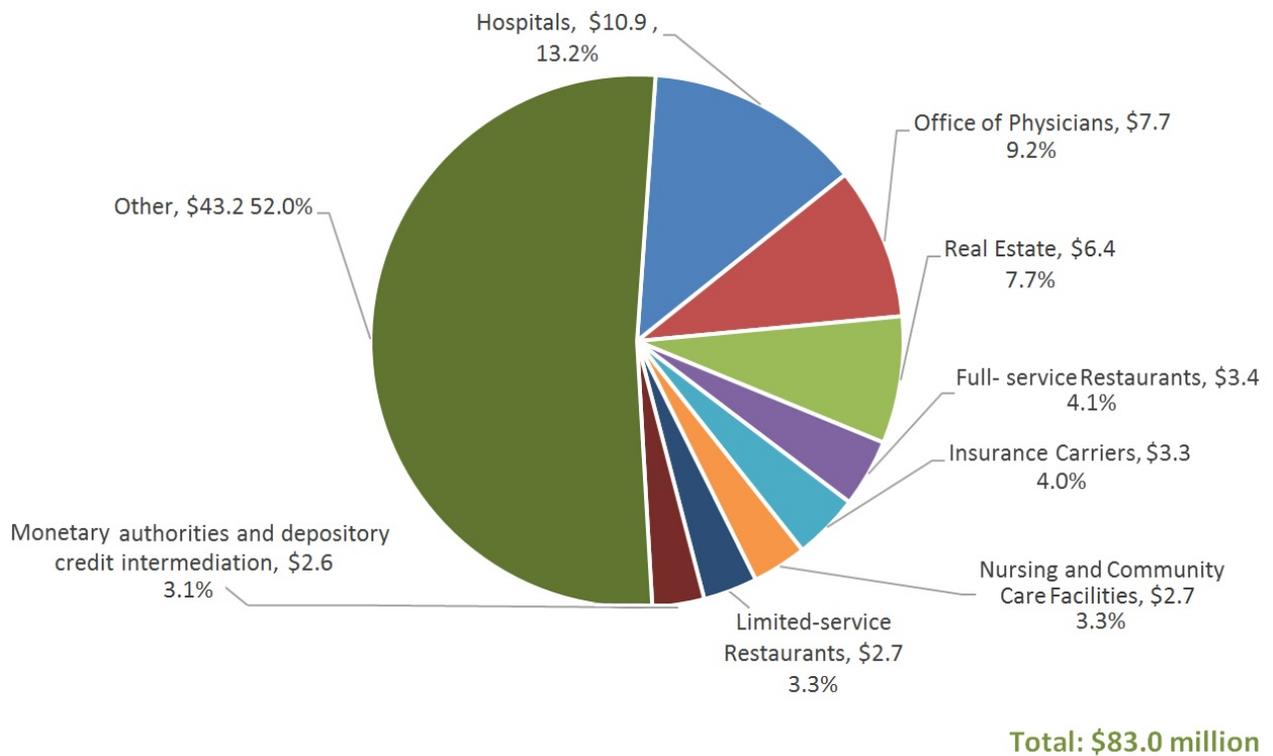


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2015



D.3.4. Value Added Impact on the State of Ohio, FY 2015

NASA Glenn's spending created an increase of \$724.9 million in value added for all industries in Ohio.³⁷ Of this total amount, \$287.4 million (39.6%) was the change in final demand or direct impact calculated as total output less intermediate expenditures made in the state. The largest portion of the value added is the wages and salaries paid to NASA Glenn

employees. Another \$234.7 million (32.4%) represented the value of goods and services, less intermediary goods, of companies in Ohio that supply NASA Glenn (i.e., indirect impact). The remaining value added impact (induced component) was estimated at \$202.9 million (28%). It occurred as a result of NASA Glenn's spending rippling through the Ohio economy. The total value added impact is a summation of the direct, indirect, and induced impacts.

Table 14. Value Added Impact in the State of Ohio, FY 2015 (in 2016 dollars)

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting	\$ -	\$108,309	\$750,776	\$859,085
Mining	\$ -	\$534,732	\$425,409	\$960,141
Utilities	\$ -	\$12,763,555	\$4,921,139	\$17,684,694
Construction	\$ -	\$18,547,005	\$1,780,917	\$20,327,922
Manufacturing	\$ -	\$3,728,119	\$6,425,889	\$10,154,008
Wholesale Trade	\$ -	\$3,312,259	\$9,990,552	\$13,302,812
Retail Trade	\$ -	\$5,645,650	\$19,149,143	\$24,794,793
Transportation and Warehousing	\$ -	\$2,768,506	\$5,139,562	\$7,908,068
Information	\$ -	\$2,590,207	\$6,625,787	\$9,215,994
Finance and Insurance	\$ -	\$7,000,111	\$22,049,146	\$29,049,256
Real Estate and Rental	\$ -	\$13,632,059	\$44,596,002	\$58,228,061
Professional, Scientific, and Tech Services	\$ -	\$87,128,213	\$8,179,297	\$95,307,510
Management of Companies	\$ -	\$2,760,219	\$2,981,484	\$5,741,703
Administrative and Waste Services	\$ -	\$65,456,160	\$6,659,223	\$72,115,383
Educational Services	\$ -	\$3,425,564	\$3,418,718	\$6,844,282
Health and Social Services	\$ -	\$26,018	\$35,674,792	\$35,700,809
Arts, Entertainment, and Recreation	\$ -	\$687,040	\$3,428,509	\$4,115,549
Accommodation and Food Services	\$ -	\$1,328,618	\$9,496,172	\$10,824,789
Other Services	\$ -	\$4,223,162	\$10,347,555	\$14,570,717
Government & non-NAICs	\$287,379,543	\$(989,026)*	\$809,149	\$287,199,666
Total Value Added	\$287,379,543	\$234,676,479	\$202,849,220	\$724,905,242

Notes:

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.

³⁷ "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).

Total value added in the state of Ohio increased by \$724.9 million as a result of NASA Glenn's spending on goods and services in FY 2015. Of this total amount, \$287.4 million (39.6%) included the wages and benefits paid directly to NASA Glenn employees and other added values (change in final demand or direct impact). Another \$234.7 million (32.4%) represented the value of goods and services (less intermediary goods) created by companies in Ohio due to operations of NASA Glenn (indirect impact). The remaining value added impact (induced component), assessed at \$208.2 million (28%), occurred as the effects of NASA Glenn's spending rippled through the Ohio economy.

Of the \$437.5 million increase in value added generated across Ohio due to the indirect and induced impacts, \$221.4 million (51%) was observed in NASA Glenn-driven industries, \$140.5 (32%) was generated in consumer-driven industries, and \$75.6 million (17%) was reported in other industries.³⁸

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 over \$7 and \$3 million, respectively.

Within the NASA Glenn-driven industries, persons engaged in facilities support services saw the sector's value added increase by \$47.3 million in FY 2015 (Figure 19). This increase is a result of the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn's spending on facilities support services. The \$47.3 million accounted for 21.4% of the \$221.4 million value added increase that was reported by all NASA Glenn-driven industries.

In the consumer-driven industries, employees of the real estate industry saw the sector's value added increase by \$28.2 million in FY 2015 (Figure 20). This increase is a result of the summation of the indirect and induced impacts generated by consumer spending within the industry. The increase of \$28.2 million accounted for 20.1% of the \$140.5 million value added increase that occurred in all consumer-driven industries.

³⁸ See section D.2.1 Output Impact on Northeast Ohio, FY 2015 for definitions of NASA Glenn-driven, consumer-driven, and other industries.

Figure 19. Increase in Value Added for NASA Glenn-Driven Industries in Ohio, FY 2015

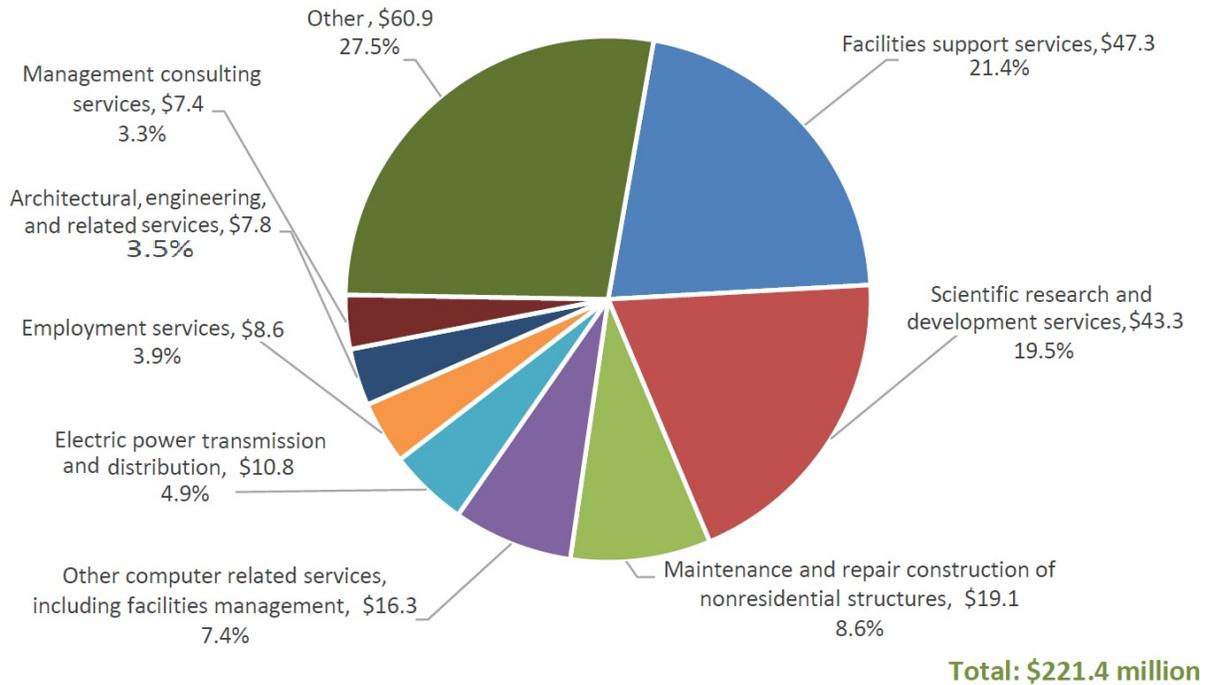
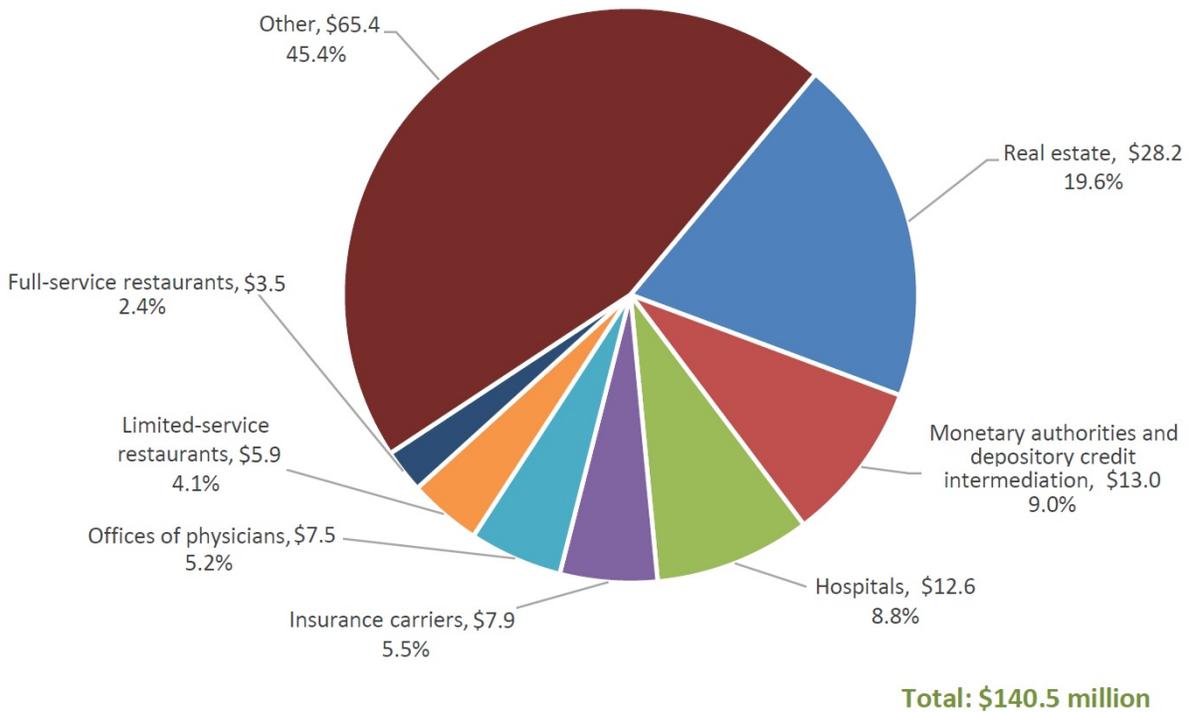


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2015



D.3.5. Tax Impact on the State of Ohio, FY 2015

NASA Glenn's operation and economic impact on the state of Ohio in FY 2015 increased tax revenues by a total of \$123.4 million. Of that amount, direct tax impact was \$32.91 million in Glenn's employee taxes on wages, \$45.13 million indirect tax impact, and \$45.35 million - induced tax impact.

D.3.6. FY 2015 Ohio Impact Summary

The economic activity of NASA Glenn in the state of Ohio generated the following total economic impact (in 2016 dollars):

- Total Output Impact: \$1,416 M
- Total Employment Impact: 7,214 jobs
- Total Labor Income Impact: \$492.5 M
- Total Value Added Impact: \$724.9 M
- Total Tax Impact: \$123.4 M

The impact of NASA Glenn's expenditures on the state of Ohio is slightly higher than the impact on Northeast Ohio because the Ohio models capture more buy-sell relationships in the larger geographic area. However, the majority of NASA Glenn's spending in Ohio occurred in Northeast Ohio.

In FY 2015, NASA Glenn's expenditures in the state of Ohio were \$514.3 million, including labor income (adjusted for commuter spending). These Ohio expenditures were only \$42.2 million more than in Northeast Ohio (in 2016 dollars).

NASA Glenn slightly increased the total spending in Ohio in FY 2015 compared to FY 2014. Ohio's professional, scientific, and technical services sector saw an \$11.0 million increase in spending (almost a 9% gain in 2015 dollars). However, Ohio's sector saw a nearly

\$7.7 million decrease in spending (a 7.8% drop in 2015 dollars).³⁹

Compared to the expenditures made in Northeast Ohio in FY 2015, the largest share of the total payments, excluding labor income, was spent on professional, scientific, and technical services in Ohio (41.4% in Ohio, compared to 49.0% in Northeast Ohio). More than 90.0% of NASA Glenn spending in Ohio (\$260.9 million), excluding labor income, went to the following industry sectors: professional, scientific and technical services (\$120.3 million); administrative and support services (\$98.9 million); construction (\$29.3 million); and utilities (\$12.7 million).⁴⁰ Additionally, 2.9% (\$8.1 million) went toward the education sector and 1.0% (\$2.9 million) for wholesale and retail trade.

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.

³⁹ The majority (\$40M) of the increase in administrative and support services and corresponding reduction in professional, scientific, and technical services is due to an IMPLAN Code change for a large contractor supporting NASA Glenn's Plum Brook Station.

⁴⁰ Amounts in parentheses detailing percentage numbers are presented in 2015 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2015

State	Spending	Share
Ohio	\$290,239,487	72.61%
Maryland	\$26,967,874	6.75%
California	\$14,203,442	3.55%
Connecticut	\$9,144,878	2.29%
Virginia	\$5,703,274	1.43%
Pennsylvania	\$5,350,441	1.34%
Texas	\$4,731,655	1.18%
Florida	\$4,289,573	1.07%
Washington	\$4,240,910	1.06%
Georgia	\$3,459,959	0.87%
Massachusetts	\$3,266,961	0.82%
New Hampshire	\$2,503,124	0.63%
New York	\$2,264,256	0.57%
Illinois	\$2,235,220	0.56%
Michigan	\$2,060,114	0.52%
Colorado	\$1,834,831	0.46%
Oregon	\$1,641,422	0.41%
Missouri	\$1,527,999	0.38%
New Jersey	\$1,453,091	0.36%
Iowa	\$1,383,810	0.35%
Wisconsin	\$1,351,116	0.34%
Arizona	\$1,225,783	0.31%
Indiana	\$1,196,002	0.30%
Alabama	\$1,155,680	0.29%
New Mexico	\$964,860	0.24%
North Carolina	\$776,343	0.19%
Minnesota	\$753,754	0.19%
District of Columbia	\$693,290.50	0.17%
Utah	\$357,057	0.09%
Nevada	\$342,479	0.09%
Oklahoma	\$334,340	0.08%
Montana	\$234,211	0.06%
Delaware	\$213,002	0.05%

State	Spending	Share
South Carolina	\$185,473	0.05%
Tennessee	\$181,049	0.05%
Rhode Island	\$162,052	0.04%
Kansas	\$150,158	0.04%
Mississippi	\$105,888	0.03%
Vermont	\$97,291	0.02%
Nebraska	\$93,860	0.02%
South Dakota	\$90,806	0.02%
West Virginia	\$56,674	0.01%
Idaho	\$16,310	0.00%
Kentucky	\$13,937	0.00%
Hawaii	\$13,169	0.00%
Arkansas	\$7,569	0.00%
Louisiana	\$7,000	0.00%
Alaska	\$54,744	0.00%
Maine	\$2,302	0.00%
U.S. Total (No ND or WY)	\$399,289,245	99.89%
Outside U.S.	\$454,650	0.11%
Canada	\$133,357	0.03%
France	\$77,006	0.02%
Germany	\$106,154	0.03%
Great Britain	\$100,713	0.03%
Italy	\$2,046	0.00%
Netherlands	\$5,285	0.00%
Portugal	\$2,048	0.00%
Singapore	\$1,841	0.00%
Spain	\$21,600	0.01%
Switzerland	\$4,601	0.00%
Total	\$399,743,895	100%

Table A.2. NASA Glenn Funding Allocated to Academic Institutions by State, FY 2015

State	Amount	Share
Massachusetts	\$1,275,417	13.45%
Ohio	\$934,097	9.85%
California	\$890,544	9.39%
Illinois	\$775,305	8.18%
Pennsylvania	\$739,066	7.80%
Michigan	\$653,898	6.90%
Maryland	\$600,156	6.33%
Texas	\$442,476	4.67%
New Jersey	\$387,549	4.09%
Colorado	\$327,491	3.45%
New York	\$297,238	3.14%
Georgia	\$289,602	3.05%
Indiana	\$244,979	2.58%
Delaware	\$202,113	2.13%
Florida	\$190,839	2.01%
Iowa	\$165,495	1.75%
North Carolina	\$163,954	1.73%
Oregon	\$145,752	1.54%
Connecticut	\$144,295	1.52%
New Mexico	\$127,800	1.35%
Mississippi	\$105,888	1.12%
South Carolina	\$83,333	0.88%
Alabama	\$75,182	0.79%
Virginia	\$74,268	0.78%
Missouri	\$39,289	0.41%
Montana	\$20,426	0.22%
Utah	\$17,604	0.19%
Kansas	\$16,441	0.17%
Hawaii	\$13,169	0.14%
District of Columbia	\$4,560	0.05%
Outside US	\$32,572	0.34%
The United Kingdom Total	\$32,572	0.34%
Total	\$9,480,792	100.00%

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2015

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			\$16,144,039.31
	Electric power transmission and distribution	49	\$14,048,187.05
	Natural gas distribution	50	\$600,491.93
	Water, sewage and other systems	51	\$1,495,360.33
Construction			\$40,423,935.72
	Construction of other new nonresidential structures	58	\$757,656.78
	Maintenance and repair construction of nonresidential structures	62	\$39,666,278.94
Manufacturing			\$725,722.17
	Printing	154	\$1,509.37
	Industrial gas manufacturing	162	\$1,907.42
	Iron and steel mills and ferroalloy manufacturing	217	\$3,958.00
	Rolled steel shape manufacturing	219	\$10,264.89
	Plate work manufacturing	239	\$159,848.70
	Sheet metal work manufacturing	241	\$3,460.00
	Machine shops	249	\$228,876.21
	Metal coating and nonprecious engraving	252	\$14,020.00
	Valve and fittings, other than plumbing, manufacturing	254	\$87,800.28
	Other fabricated metal manufacturing	261	\$6,240.00
	Industrial mold manufacturing	278	\$13,096.42
	Speed changer, industrial high-speed drive, and gear manufacturing	284	\$3,421.77
	Pump and pumping equipment manufacturing	287	\$3,403.75
	Overhead cranes, hoists, and monorail systems manufacturing	292	\$3,826.20
	Industrial process furnace and oven manufacturing	297	\$5,890.00
	Industrial process variable instruments manufacturing	317	\$95,134.21
	Electricity and signal testing instruments manufacturing	319	\$7,050.59
	Irradiation apparatus manufacturing	321	\$3,885.34
	Watch, clock, and other measuring and controlling device manufacturing	322	\$72,129.02
Wholesale & Retail Trade			\$2,104,946.62
	Wholesale trade	395	\$298,115.78
	Retail - Motor vehicle and parts dealers	396	\$28,310.88
	Retail - Miscellaneous store retailers	406	\$1,778,519.96

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
Transportation			\$13,055.65
	Truck transportation	411	\$2,138.31
	Transit and ground passenger transportation	412	\$10,917.34
Information and Telecommunication			\$2,400.00
	Book publishers	419	\$2,400.00
Real Estate and Rental & Leasing			\$66,496.77
	Commercial and industrial machinery and equipment rental and leasing	445	\$66,496.77
Professional, Scientific, & Technical Services			\$122,033,176.37
	Legal services	447	\$5,986.50
	Accounting, tax preparation, bookkeeping, and payroll services	448	\$975,070.76
	Architectural, engineering, and related services	449	\$5,935,259.13
	Other computer related services, including facilities management	453	\$27,324,989.17
	Management consulting services	454	\$3,680,452.79
	Environmental and other technical consulting services	455	\$7,029,423.65
	Scientific research and development services	456	\$77,012,019.32
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	\$69,975.05
Administrative & Support and Waste Management Services			\$61,408,641.49
	Facilities support services	463	\$52,717,400.63
	Investigation and security services	467	\$6,311,327.72
	Services to buildings	468	\$2,165,402.40
	Other support services	470	\$1,400.00
	Waste management and remediation services	471	\$213,110.74
Education			\$5,114,242.34
	Junior colleges, colleges, universities, and professional schools	473	\$581,486.09
	Other educational services	474	\$4,532,756.25
General Medical and Surgical Hospitals			\$41,875.00
	Hospitals	482	\$41,875.00

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
Arts, Entertainment, & Recreation			\$587,511.42
	Museums, historical sites, zoos, and parks	493	\$587,511.42
Other Services, Except Public Administration			\$128,025.37
	Electronic and precision equipment repair and maintenance	506	\$128,025.37
Labor Income			\$223,268,744.29
	Employee Compensation (c)		\$223,268,744.29
TOTAL EXPENDITURES IN NEO			\$472,062,812

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 2015. 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 2015 dollars.

Table A.4. NASA Glenn Detailed Expenditures in the State of Ohio, FY 2015

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			\$16,259,076.49
	Electric power transmission and distribution	49	\$14,048,187.05
	Natural gas distribution	50	\$600,491.93
	Water, sewage and other systems	51	\$1,610,397.51
Construction			\$40,555,168.74
	Construction of other new nonresidential structures	58	\$757,656.78
	Maintenance and repair construction of nonresidential structures	62	\$39,797,511.96
Manufacturing			\$1,857,204.18
	Printing	154	\$1,509.37
	Industrial gas manufacturing	162	\$1,907.42
	Polystyrene foam product manufacturing	192	\$7,513.50
	Iron and steel mills and ferroalloy manufacturing	217	\$3,958.00
	Rolled steel shape manufacturing	219	\$10,264.89
	Plate work manufacturing	239	\$159,848.70
	Sheet metal work manufacturing	241	\$3,460.00
	Metal tank (heavy gauge) manufacturing	244	\$21,084.00
	Machine shops	249	\$319,686.62
	Turned product and screw, nut, and bolt manufacturing	250	\$258.53
	Metal heat treating	251	\$1,069.11
	Metal coating and nonprecious engraving	252	\$14,020.00
	Valve and fittings, other than plumbing, manufacturing	254	\$289,964.96
	Other fabricated metal manufacturing	261	\$6,240.00
	All other industrial machinery manufacturing	271	\$10,804.50
	Air purification and ventilation equipment manufacturing	275	\$8,110.20
	Industrial mold manufacturing	278	\$13,096.42
	Speed changer, industrial high-speed drive, and gear manufacturing	284	\$3,421.77
	Pump and pumping equipment manufacturing	287	\$22,205.75
	Overhead cranes, hoists, and monorail systems manufacturing	292	\$3,826.20

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
	Industrial process furnace and oven manufacturing	297	\$8,424.92
	Scales, balances, and miscellaneous general purpose machinery manufacturing	300	\$24,958.08
	Industrial process variable instruments manufacturing	317	\$95,107.39
	Electricity and signal testing instruments manufacturing	319	\$7,050.59
	Analytical laboratory instrument manufacturing	320	\$51,817.17
	Irradiation apparatus manufacturing	321	\$3,885.34
	Watch, clock, and other measuring and controlling device manufacturing	322	\$121,759.02
	Lighting fixture manufacturing	326	\$198,500.00
	Carbon and graphite product manufacturing	341	\$18,353.91
	Truck trailer manufacturing	347	\$295,955.94
	Aircraft manufacturing	357	\$128,262.00
	Office supplies (except paper) manufacturing	387	\$879.88
Wholesale & Retail Trade			\$2,486,064.19
	Wholesale trade	395	\$518,514.62
	Retail - Motor vehicle and parts dealers	396	\$28,310.88
	Retail - Miscellaneous store retailers	406	\$1,939,238.69
Transportation			\$13,055.65
	Truck transportation	411	\$2,138.31
	Transit and ground passenger transportation	412	\$10,917.34
Information & Telecommunication			\$2,400.00
	Book publishers	419	\$2,400.00
Real Estate and Rental & Leasing			\$66,496.77
	Commercial and industrial machinery and equipment rental and leasing	445	\$66,496.77
Professional, Scientific, & Technical Services			\$131,430,225.35
	Legal services	447	\$86,901.97
	Accounting, tax preparation, bookkeeping, and payroll services	448	\$975,070.76
	Architectural, engineering, and related services	449	\$7,149,367.06
	Computer systems design services	452	\$3,615.00
	Other computer related services, including facilities management	453	\$27,324,989.17
	Management consulting services	454	\$3,688,885.22

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
	Environmental and other technical consulting services	455	\$7,029,423.65
	Scientific research and development services	456	\$85,077,909.02
	Marketing research and all other miscellaneous professional, scientific, and technical services	460	\$94,063.50
Administrative & Support and Waste Management Services			\$91,205,952.11
	Facilities support services	463	\$82,514,711.25
	Investigation and security services	467	\$6,311,327.72
	Services to buildings	468	\$2,165,402.40
	Other support services	470	\$1,400.00
	Waste management and remediation services	471	\$213,110.74
Education			\$5,442,905.28
	Junior colleges, colleges, universities, and professional schools	473	\$910,149.03
	Other educational services	474	\$4,532,756.25
General Medical and Surgical Hospitals			\$41,875.00
	Hospitals	482	\$41,875.00
Arts, Entertainment & Recreation			\$587,511.42
	Museums, historical sites, zoos, and parks	493	\$587,511.42
Other Services, Except Public Administration			\$162,467.54
	Electronic and precision equipment repair and maintenance	506	\$132,625.37
	Commercial and industrial machinery and equipment repair and maintenance	507	\$5,643.00
	Grant-making, giving, and social advocacy organizations	514	\$24,199.17
Government Enterprise			\$129,084.44
	Other federal government enterprises	520	\$129,084.44
Labor Income			\$224,019,598.08
	Employee Compensation (c)		\$224,019,598.08
TOTAL EXPENDITURES IN OHIO			\$514,259,085.24

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 2015. 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 2015 dollars.