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College of Urban Affairs

Prepared for:
NASA JOHN H. GLENN RESEARCH CENTER

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

The NASA John H. Glenn Research Center:

An Economic Impact Study Fiscal Year 2020

June 2021

CENTER FOR ECONOMIC DEVELOPMENT

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THE NASA JOHN H. GLENN RESEARCH CENTER: AN ECONOMIC IMPACT STUDY FISCAL YEAR 2020

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EXECUTIVE SUMMARY

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

- NASA Glenn's campuses include more than 198 buildings that contain a unique collection of world-class laboratories and test facilities. Since the groundbreaking for the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics (forerunner to NASA) on January 23, 1941, more than $1,040 million has been invested in the construction of NASA Glenn's campuses. The estimated current replacement value of Lewis Field and Armstrong Test Facility is approximately $4.1 billion.

- The Lewis Field Campus and Armstrong Test Facility each host large-scale facilities that are uniquely and specifically designed to test aviation and spaceflight hardware. Both locations enable NASA, other governmental agencies, and academic and industry partners from across the country to perform specialized research and testing to support the Agency's Aeronautics, Space and Science Missions, as well as the country's interests in these areas.

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

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

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

- This report is structured with the following sections: Sections A and B consist of the report's introduction and background describing NASA Glenn's campuses, their location, and the mission of the Center. Section C provides an economic overview of NASA Glenn, including information about its employment and occupations, employee residences, payroll, expenditures, awards to academia and other institutions, revenues, and taxes paid by NASA Glenn employees. Section D describes the economic impact created by NASA Glenn Research Center on two regions, an 8-county Northeast Ohio region and the State of Ohio during Fiscal Year (FY) 2020. This report is an update of several earlier studies that described NASA Glenn and measured its economic impact on Northeast Ohio and Ohio.

ECONOMIC IMPACT GENERATED BY NASA GLENN RESEARCH CENTER SPENDING

The NASA Glenn Research Center creates the economic benefits within the regional economies of Northeast Ohio and Ohio by employing local labor, paying high wages to their employees who spend most of their income locally, engaging local contractors, and collaborating with local higher education institutions providing them with research grants and contracts. This study uses a multi-regional input-output (I-O) model to estimate the effect of NASA Glenn Research Center's spending on the economies of Northeast Ohio (NEO) and Ohio. This model measures economic impact in terms of growth in output (sales), value added (output less intermediary goods), number of new and supported jobs, labor income, and tax revenues. This study uses a methodology to measure NASA Glenn's impact on the economies of Northeast Ohio and Ohio based on the inter-relationships of two connected regions. This general methodology is the same as was used to prepare the FY 2019 Economic Impact Study and is comparable with previous studies. Two main changes in the methodology are made to improve modeling for receiving better results; they include (1) using the Multi-Regional Input-Output analysis (consistent with FY 2019 study, but for the first year run on IMPLAN's online platform) and (2) including direct impact at the amount of expenditures made in the region of impact (compared to the total NASA Glenn budget used in the previous studies). The Multi-Regional Input-Output analysis better accounts for the Ohio regional supply chain, calculating the impact for the larger region as the economic impact of NASA Glenn on Northeast Ohio and on the remainder of Ohio.[2]

This report accounts for diverse economic sectors and illustrates the impact they make on the regional economies of Northeast Ohio and the State of Ohio. The table below summarizes NASA Glenn's economic impact on Northeast Ohio and the State of Ohio during FY 2020.

Economic Impact	Northeast Ohio	State of Ohio
Output	$1,714.9 million	$1,800.1 million
Value Added	$1,063.0 million	$1,108.2 million
Employment	8,514 jobs	8,974 jobs
Labor Income	$770.7 million	$805.7 million
Taxes	$148.1 million	$154.6 million

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

- In FY 2020, NASA Glenn's $540.7 million of direct spending in Northeast Ohio, originating primarily from outside of the region, resulted in an output (Sales) change of $1.7 billion across all industry sectors. The value added increased by $1.1 billion as a result of NASA Glenn's operation. In addition, 8,514 jobs were created and supported in the region, and labor income in Northeast Ohio increased by $770.7 million. NASA Glenn's activities in Northeast Ohio also generated $148.1 million in local, state, and federal taxes.

[2] In this study, the modeling was first time conducted using online IMPLAN platform.

- NASA Glenn's activities in Ohio in FY 2020, stimulated by $558.5 million in direct spending in the state originating primarily from outside of the state, generated an increased demand in output (sales) for products and services valued at $1.8 billion.
- Ohio value added increased by $1.1 billion as a result of NASA Glenn's activities in the state. In addition, 8,974 jobs were created and supported in Ohio, and labor income across the state increased by $805.7 million. NASA Glenn operations in Ohio also generated $154.6 million in local, state, and federal taxes.
- Direct NASA Glenn spending had the greatest impact in the areas of scientific research and development, administrative and waste management services, facilities support services, maintenance and repair construction of nonresidential structures, computer related services, educational services, investigation and security services, and architectural, engineering, and related services.
- Spending by NASA Glenn personnel and other workers was in line with typical consumer spending patterns. Industries that benefited the most from NASA Glenn spending included real estate and rental services, hospitals and healthcare offices, insurance carriers, food services, and nursing and community care facilities.

NASA GLENN RESEARCH CENTER: AN OVERVIEW

- In FY 2020, NASA Glenn had 1,581 civil service employees, including 348 Administrative Professionals (22%), 16 Clerical workers (1%), 1,154 Scientists & Engineers (73%), and 63 Technicians (4%). Compared to FY 2019, the total Glenn service employment has increased by three workers, adding one employee in the Administrative Professional category and 18 in the Scientists & Engineers category, while decreasing by 16 staff in Technical occupation.
- The civil service employees at NASA Glenn are highly educated and skilled. In FY 2020, about 90% of civil service workers had a bachelor's degree or higher. Of all NASA Glenn's civil service employees, 18% held doctoral degrees, 39% held master's degrees, and 33% held bachelor's degrees. Compared to FY 2019, the educational attainment of NASA Glenn's civil service employees has increased slightly.[3]
- In FY 2020, the largest occupational category continued to be Scientists & Engineers. This occupation was the largest among all categories over the last five years, a historical trend that is continued even before FY 2016. The Scientists & Engineers accounted for 73% of the civil service employees at NASA Glenn in FY 2020.
- The total number of NASA Glenn employees, including civil service employees and local contractors in FY 2020, was 3,324. This showed an increase of 70 workers from FY 2019 to FY 2020, the highest total combined employment at NASA Glenn during the last five years.
- NASA Glenn civil service employees received $245.9 million in total compensation in FY 2020. The total compensation included both payroll, $184.6 million, and employee benefits, $61.4 million.
- The total compensation increased by $8.5 million (3.6%) between FY 2019 and FY 2020, in nominal dollars. In the same time period, NASA Glenn's nominal payroll has increased by $4.0 million (2.2%).
- During the last five years, total compensation increased by $17.6 million (7.7%) from $228.3 million in FY 2016 to $245.9 million in FY 2020, and the payroll increased by $8.9 million (5.1%) in nominal dollars.
- In FY 2020, NASA Glenn allocated $623.6 million to vendors in 46 states, the District of Columbia, and nine foreign countries. Compared to its total expenditures of $586.5 million in FY 2019, NASA Glenn increased its spending by 6.3%, or $37.1 million in nominal dollars. This translates to an increase of $28.0 million (or 4.7%) between FY 2019 and FY 2020 when adjusting for inflation.
- Ohio continues to receive the largest share of the total expenditures with $316.0 million. The expenditures made in Ohio accounted for 50.7% of NASA Glenn's total spending and reflecting a $7.3 million increase in nominal dollars. [4] Although there was an increase in absolute value spent in Ohio between FY 2019 and FY 2020, the share of expenditures to the state decreased from 52.6% in FY 2019 to 50.7% in FY 2020.
- Northeast Ohio received over 96.1% of NASA Glenn's total expenditures in the State of Ohio in FY 2020, a total of $303.8 million. Cuyahoga County received the largest share of expenditures spent both within Northeast Ohio and in the State of Ohio, receiving 99.2% and 95.3%, respectively.

[3] These counts do not include Student Trainees.

[4] Total expenditures increased by $7.3 million in nominal dollars and $2.6 million in real dollars adjusted for inflation between FY 2019 and FY 2020.

- After Ohio, the state that received the largest share of NASA Glenn spending in FY 2020 was California. California received $129.9 million (or 20.8% of total expenditures). Alabama received the third-largest share of expenditures in FY 2020. Alabama experienced an increase of $16.7 million, or 61.9% in the nominal dollar, and $16.3 million or 59.5% in the real dollar between FY 2019 and FY 2020. Washington and Illinois received the fourth and fifth largest share of expenditures in FY 2020.
- NASA Glenn's expenditures in foreign countries decreased from $1.3 million to $0.8 million in nominal dollars between FY 2019 and FY 2020. Great Britain was the largest beneficiary of the foreign countries that received NASA Glenn's contracts.
- In FY 2020, NASA Glenn awarded $13.2 million to colleges and universities in 31 states. Grants accounted for $10.4 million in this total. Compared to FY 2019, this amount represented a reduction of academic grants from NASA Glenn by $1.8 million (12.0%) between FY 2019 and FY 2020, in nominal dollars. NASA Glenn also awarded $2.8 million in contracts to Ohio academic institutions in FY 2020 through on-site contracts. The academic funding awarded in the top five states of Ohio, California, Maryland, Texas, and Georgia collectively accounted for 60.3% of the total awards, compared to 65.4% of total grants made to the top five states in FY 2019 (Ohio, California, Maryland, Michigan, and Texas).
- Ohio saw the most significant decrease in awards between 2019 and 2020, dropping by 27.0%. California and Maryland also experienced 17.8% and 18.5% decline in awards (in nominal dollars), respectively, between FY 2019 and FY 2020. Texas experienced a 16.5% nominal dollars increase in awards.
- Academic institutions in Ohio received $3.9 million of NASA Glenn's academic awards in FY 2020. Ohio accounted for the largest share (29.7%) of NASA Glenn's academic awards for the year.
- Northeast Ohio received 66.7% of the $3.9 million awarded to all of Ohio, totaling $2.6 million. Northeast Ohio received 19.8% of all academic funding given by NASA Glenn in FY 2020. Northeast Ohio's share of awards increased at the state level (56.2% of total Ohio awards in FY 2019) but decreased at the national level (20.2% of total awards in FY 2019).
- Case Western Reserve University (CWRU) and the University of Toledo continued receiving the most significant awards of all Ohio academic institutions in FY 2020. CWRU received $2.2 million (or 55.7% of the total), and the University of Toledo received $1.0 million (or 25.8% of the total). For CWRU, this was a $0.31 million or 16.7% increase in the nominal dollar and a $0.42 million or 24.2% increase in real dollars between FY 2016 and FY 2020. The two universities accounted for 81.5% of NASA Glenn awards to Ohio academic institutions in FY 2020.
- The University of Akron was awarded $240,568 (or 6.1% of the total) in FY 2020 and ranked third by the share of total funding to Ohio academic institutions. Ohio State University received $199,903 (or 5.1% of the total) and ranked fourth. The remainder of the FY 2020 awards from NASA Glenn to Ohio academic institutions went to Cleveland State University ($122,243 or 3.1%), Ohio University ($77,740 or 2.0%), Kent State University ($70,214 or 1.8%), and University of Cincinnati ($14,972 or 0.4%).

- Total revenue in FY 2020 reached $865.3 million, a 13.1% decrease from FY 2019 and a 30.3% increase from FY 2016 without adjustment for inflation. Over the five years, NASA Glenn's revenues ranged from $664.1 million in FY 2016 to $996.2 million in FY 2019 in nominal dollars. Federal funding remains the largest source of revenue for reimbursable commitment, accounting for 93.4%. Between FY 2019 and FY 2020, the Department of Defense accounted for the largest share of total reimbursable commitment (65.8%). The Other Federal Agency had the second-largest share of the total reimbursable commitment (27.6%).
- In FY 2020, the total income tax paid by NASA Glenn employees totaled $32.1 million. This is a slight increase (0.5%) compared to FY 2019. Excluding federal taxes, NASA Glenn employees paid $9.2 million in income taxes at the state and local levels in FY 2020. This is a 2.5% decline from FY 2019, without adjustment for inflation. The amount of taxes paid to local and state governments has increased steadily between FY 2016 and FY 2019, rising from $8.8 million in FY 2016 to $9.4 million in FY 2019.
- NASA Glenn continues to be an essential institution influencing the economic life of both Northeast Ohio and the State of Ohio. NASA Glenn's employees are part of the knowledge-intensive labor force that develops innovation, advances the nation, generates wealth in the region, and attracts other creative workers to reside in Ohio.

A. INTRODUCTION

This report presents an analysis of the economic impact of the National Aeronautics and Space Administration's (NASA) Glenn Research Center (Glenn) on the eight-county Northeast Ohio region and the State of Ohio during FY 2020.[5] This study is based on input-output modeling that reflects the buy-sell relationships between industries, the household sector, and the government sector in a region. The modeling results estimate the economic impact of NASA Glenn's spending on Northeast Ohio and the state of Ohio.[6] Since NEO is a part of Ohio, this study is conducted using Multi-Regional Input-Output (MRIO) analysis, where economic impact accounts for the impact in both regions from the spending in each of these regions. The economic impact illustrated in NEO accounts for the effect of spending in NEO and the economic impact created in NEO when spending was done outside of NEO region; the economic impact in Ohio accounts for the effects created in NEO from spending that occurred in NEO and across the rest of Ohio and economic impact in non-NEO counties from spending in NEO and spending outside of NEO.

The report also provides an overview of NASA Glenn operations and describes some of its Research and Development (R&D) activities. It looks at changes in NASA Glenn's employees in terms of employment, payroll, occupation, and place of residence during FY 2020. The report provides information on NASA Glenn's expenditures and revenues, awards to academic institutions, and taxes contributed by employees.

This analysis was conducted by the Center for Economic Development of Cleveland State University's Maxine Goodman Levin College of Urban Affairs. This FY 2020 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2020.[7]

[5] For purposes of this study, Northeast Ohio includes 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 which are not sold as final products. For example, the value added impact will account for the value of all professional scientific and technical services excluding intermediary goods produced to deliver these services. Such intermediary goods, among others, include research supplies, utilities, research services of intermediary steps of research.

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

B. NASA GLENN RESEARCH CENTER: BACKGROUND

Located at Lewis Field (next to Cleveland Hopkins International Airport) and Armstrong Test Facility (Sandusky, Ohio), the NASA Glenn Research Center performs research, engineering development, and testing to advance aviation, enable exploration of the universe, and improve life on Earth. Its scientists and engineers deliver advanced technology and flight systems for spacecraft and improve efficiency in aircraft, often in partnership with U.S. companies, universities, and other government institutions. The Center's core capabilities concentrate on air-breathing and in-space propulsion, power systems, aerospace communications, materials for extreme environments, biomedical technologies, and high-value space experiments in the physical sciences - all focused on solving important, practical aerospace problems and opening new frontiers (scientific, technological, and economical) for our nation.[8]

B.1. NASA GLENN TEST FACILITIES

NASA Glenn's campuses include more than 198 buildings that contain a unique collection of world-class laboratories and test facilities. Since the groundbreaking for the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics (forerunner to NASA) on January 23, 1941, more than $1,040 million has been invested in the construction of NASA Glenn's campuses. The estimated current replacement value of Lewis Field and Armstrong Test Facility is approximately $4.1 billion.

Glenn's main campus, Lewis Field, is situated on 307 acres of land and contains more than 87 buildings.

Lewis Field has a large inventory of facilities that supports research, development, testing, and evaluation activities. There are approximately 366 research and test facilities located at the Lewis Field site, including 24 major test facilities and over 100 research and development laboratories. The world-class facilities at Lewis Field include large and unique aero-propulsion wind tunnels, micro-gravity and free-fall research facilities, engine test cells, flight research facilities, space environment chambers, vacuum chambers and a host of additional research and development laboratories and test stands.

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

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

[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 critical to programs and projects in all of NASA's missions: Deep Space Exploration Systems, Low Earth Orbit, and Spaceflight Operations, Science, Exploration Technology, and Aeronautics Research.

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

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

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

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

exploration, including biophysics experiments.

- Contributing to the Human Research Program, which performs research and technology related to human health, exercise development for exploration countermeasures, and medical devices, including computational modeling.
- Managing and overseeing the development of system upgrades for and supporting safe and reliable operation of the International Space Station's electrical power system, including Lithium-ion battery development and deployment.
- Leading the development and utilization of new, advanced communications technology, including cognitive, wideband and quantum communications. In addition, performs spectrum management and spectrum analysis for the Agency.
- Providing formulation leadership for the Communications Services Project (CSP) to establish partnerships with commercial satellite communications (SATCOM) companies to develop and demonstrate capabilities that can meet NASA's needs and begin the initial planning for acquisition of commercial SATCOM services.

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

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

universities and institutes using both piloted and unpiloted techniques.

- Supporting NASA Headquarters with assessments and panel membership for Planetary Science, including technology/tools coordination and science advisory groups.

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

- Leading the development and testing of Solar Electric Propulsion technology that can enable future space-based exploration and scientific missions of the future.
- Leading the development of technologies for cryogenic fluids transfer and storage and associated propulsion systems analysis, for both application to the Space Launch System and future transportation systems. This includes ground testing and flight operations support for refueling techniques.
- Managing and developing kilowatt class nuclear power systems for in-space and lunar surface power, including a demonstration of a fission power system in partnership with DOE.
- The Space Technology Research Grants (STRG) program executed by NASA Glenn accelerates the development of high risk/high payoff technologies to support the future space science and exploration needs of NASA, other government agencies and the commercial space sector. STRG challenges the spectrum of academic researchers from graduate students to tenured faculty members to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable.
- The Small Business Innovation Research (SBIR) program provides an opportunity for small, high technology companies and research institutions to participate in government-sponsored research and development efforts in key technology areas. NASA Glenn evaluates and awards more SBIR grants than any other Center.
- NASA Glenn engages the regional ecosystem and encourages involvement with businesses and academia through the Technology Transfer Expanded (T2X) Program. T2X is NASA's focused effort to accelerate commercialization by de-risking innovation through entrepreneurship and focused partnership initiatives to launch and sustain startup companies.
- Through NASA's Technology Transfer Program, NASA Glenn executed a record high 23 license agreements in 2020. These agreements included use of two new license types developed at Glenn, to provide even more flexibility and support to our licensees: the Government Use License, and the Data Usage Agreement.
- The NASA Innovative Advanced Concepts program has nurtured several NASA Glenn concepts and visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace architectures systems, or missions.
- NASA Glenn stimulates and encourages creativity and innovation in a wide spectrum of fledgling technologies through the Center Innovation Fund while addressing the technology needs of NASA and the nation.

Aeronautics Research

- Managing the Advanced Air Transport Technology Project defining the most compelling technical challenges facing the air transport industry as envisioned for the 2030-2040-time horizon. The research explores and advances knowledge, technologies, and concepts to enable giant steps in energy efficiency and environmental compatibility resulting in less fuel burn and less direct impact with the atmosphere.
- Managing the hybrid electric propulsion investments, partnerships, performing technical research, development and testing for hybrid electric elements and subsystems including high power density materials, high efficiency, high power density megawatt class electric machines, more efficient, higher performing combustion and turbine systems.
- Managing and performing research, including testing for propulsion/airframe integration advances to enable changes in air vehicle shapes resulting in significant improvements in fuel efficiency.
- 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.
- Leading the development and performing testing of advanced air-breathing combustion subsystems and systems to achieve higher efficiencies and reduce system emissions due to combustion.
- Managing the propulsion concepts within the Revolutionary Vertical Lift Technologies Project, defining the most compelling technical challenges facing the rotorcraft and vertical lift communities, and performing research, development and testing of hybrid electric propulsion, drive systems, transmissions, and turbomachinery for vertical lift vehicles.
- Managing the propulsion concepts supporting the Commercial Supersonic Technologies Project overseeing vehicle research, integration and testing in the development of tools, technologies and knowledge that will eliminate technical barriers preventing practical commercial supersonic flight. Performing research and development to design tools and innovative concepts for integrated supersonic propulsion systems that can meet airport noise regulations.
- Managing the Aeronautics Evaluation and Test Capabilities Project, combining research, analysis, and test capabilities necessary to achieve future air vehicle development and operations. Providing operations and maintenance oversight while also developing and implementing a construct to make future investment portfolio decisions for Aeronautics and Agency Aerosciences objectives.
- Managing and leading the development of communications protocols for the Unmanned Airspace Systems project by demonstrating secure and reliable unmanned aerial systems-controlled communication via large-scale simulations and flight-testing to validate performance requirements for civil unmanned aerial systems.

- Managing the Convergent Aeronautics Solutions Project, pursuing short duration activities to establish early-stage concept and technology feasibility for high-potential solutions to major-system-level challenges that require NASA and the aviation community to think beyond current concepts, architectures and relationships. Performing technology developments include airframe structures accounting for power system elements and establishing voltage and power limits for hybrid electric aircraft options.
- Managing the Transformative Tools and Technology Project to develop new computer-based tools, models, and associated scientific knowledge that will provide first-of-a-kind capabilities to analyze, understand, and predict performance for a wide variety of aviation concepts. Performing research and technology development of ceramic matrix composite materials, advanced coatings, propulsion analysis, and design tools for future aeronautics concepts.
- Providing requirements and systems engineering approach to embed cyber-security into the future air traffic management system, including developing communications architectures and potential future communications elements, sensors and autonomy solutions, with test and verification, for future airspace operations concepts.
- Managing the propulsion content of the Hypersonics Project, supporting vehicle studies, performing propulsion testing, and developing high temperature seals and analytic tool development to advance hypersonic technology for the nation.

C. NASA GLENN RESEARCH CENTER: ECONOMIC OVERVIEW

This section contains an economic overview of the NASA Glenn Research Center during FY 2020. Changes between FY 2016 and FY 2020 are illustrated with payroll, revenues, expenditures, awards to academic institutions, occupational distribution, number of employees, employees' place of residence, and income taxes paid by NASA Glenn employees. All these indicators describe the importance of NASA Glenn -- a large research enterprise stimulating regional innovation and providing a significant economic impact on Northeast Ohio and Ohio.

C.1. EMPLOYMENT AND OCCUPATIONS

The total labor force of NASA Glenn Research Center includes two types of workers, civil service employees, and local contractors. Federal laboratories commonly contract companies and individuals to conduct specific tasks and services, allowing for more flexibility in performance and labor costs. While hiring civil servants is more complex and lengthier, the number of contractors can be easily adjusted to align the labor with the varying amount and nature of Glenn's scope of work and new projects. Civil service employment has been relatively constant in order to retain workers with core expertise. These workers are essential for NASA Glenn's operations, and they are retained for many years to ensure continuity of research and efficiency of operations.

NASA Glenn's civil service employment includes four main occupational categories: (1) administrative professionals, (2) clerical staff, (3) scientists and engineers, and (4) technicians.

Table 1 illustrates the total number of civil service employees and the shares of the four occupational categories over the last five years. From FY 2016 to FY 2020, NASA Glenn has averaged 1,567 civil service employees yearly. Glenn's civil service employment peaked in FY 2018 with 1,594 workers.

The occupational structure of NASA Glenn's employment has seen only minor changes during the past five years. In FY 2020, NASA Glenn had 1,581 civil service employees, including 348 Administrative Professionals (22%), 16 Clerical workers (1%), 1,154 Scientists & Engineers (73%), and 63 Technicians (4%).

Compared to FY 2019, the total Glenn service employment has increased by three workers, adding one employee in the Administrative Professional category and 18 in the Scientists & Engineers category, while decreasing by 16 in the Technician occupation.

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2016-FY 2020

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
2016	1,572	22%	2%	71%	5%
2017	1,508	22%	2%	71%	5%
2018	1,594	21%	2%	70%	7%
2019	1,578	22%	1%	72%	5%
2020	1,581	22%	1%	73%	4%

Note: The table does not include local contractors.[9]

[9] A detailed listing of NASA Glenn's local contractors can be found at (NASA internal website) https://www.grc.nasa.gov/WWW/Procurement/Related_Websites.html

In FY 2020, the largest occupational category continued to be Scientists & Engineers. This occupation was the largest among all categories over the last five years, a historical trend that is continued even before FY 2016. The Scientists & Engineers accounted for 73% of the civil service employees at NASA Glenn in FY 2020.

The second-largest occupational category is Administrative Professional, accounting for 22% of NASA Glenn employees in FY 2020. This category has maintained a comparatively steady share of NASA Glenn employment over the last five years from 21% to 22% of total civil service employees.

Technicians accounted for 4% of NASA Glenn's civil service employees in FY 2020, a decreased from 7% in FY 2018. NASA Glenn employed 63 technicians in FY 2020. This is down 49 employees from the FY 2018's total of 112.

The smallest civil service employment category at NASA Glenn is the clerical employees, which represented 1% of the total employment in FY 2020. This category has comparatively steady share of NASA Glenn employment, ranging from 1% to 2% or 16 to 32 employees. The employment of clerical occupation peaked in FY 2018 with 32 employees (2%), dropping to 16 workers in FY 2019.

The workers at NASA Glenn are highly educated and skilled civil service employees. In FY 2020, about 90% of civil service workers had a bachelor's degree or higher. Of all NASA Glenn's civil service employees, 18% held doctoral degrees, 39% held master's degrees, and 33% held bachelor's degrees. Compared to FY 2019, the level of educational attainment of NASA Glenn's civil service employees has increased slightly.[10]

Table 2 shows NASA Glenn on- or near-site contractors' employment over the last five years. NASA Glenn contracted work to 1,743 on- or near-site contractors in FY 2020. NASA Glenn contractor employment ranged from 1,625 to 1,743 over the last five years with an average of 1,671 contractors used per year.

The total number of NASA Glenn employees, including both civil service employees and local contractors in FY 2020, was 3,324. This showed an increase of 70 workers from FY 2019 to FY 2020. This is the highest total combined employment at NASA Glenn during the last five years.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2016-FY 2020

Fiscal Year	Employment of On- or Near-Site Contractors
2016	1,625
2017	1,626
2018	1,687
2019	1,676
2020	1,743

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

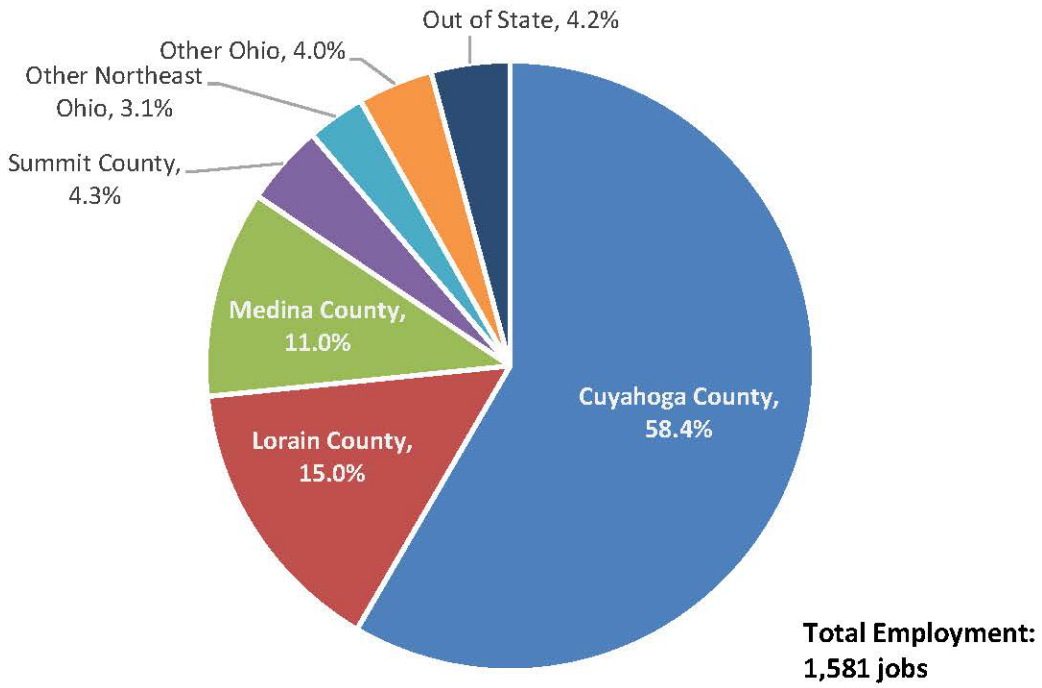
C.2. Place of Residence for Glenn Employees

Regarding the regions of study, NASA Glenn at Lewis Field is located in Cuyahoga County, the center of Northeast Ohio. The geographic site of NASA Glenn is located near Cleveland Hopkins International Airport in Greater Cleveland Area. NASA Glenn also operates the Armstrong Test Facility, located near Sandusky, Ohio, in Erie County to the west of Cleveland. Most civil service employees working at NASA Glenn live in Cuyahoga County or the other surrounding counties that comprise Northeast Ohio.[11]

Figure 1 presents the breakdown of employees' postal addresses by geographic region. In FY 2020, most civil employees (91.8%; 1,451 employees) live in Northeast Ohio. Of the 1,581 total civil servants in FY 2020, 923 employees (58.4%) resided in Cuyahoga County. Many NASA Glenn employees live in Lorain County (15.5%; 237 employees) and Medina County (11.0%; 174 employees). Summit County accounts for 4.3% (or 68 employees). The other Northeast Ohio counties held 3.1% (or 49 employees) of NASA Glenn employee places of residence, and 4.0% (or 63 employees) lived in Ohio Counties outside of Northeast Ohio. Only 4.2% (or 66 employees) of NASA Glenn employees resided outside Ohio.

Compared to FY 2019, the percentage of NASA Glenn employees who reside in Cuyahoga County has decreased by 1.3%. However, the distribution of NASA Glenn employment across Northeast Ohio and Ohio structurally changed very little between FY 2016 and FY 2020.

Figure 1. NASA Glenn Civil Service Employees by Place of Residence, FY 2020



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

Table 3 displays the distribution of NASA Glenn civil service employees by occupation and place of residence. Cuyahoga County, where the NASA Glenn Lewis Field is located, served as the place of residence for the highest share of employees in each occupational category. In FY 2020, over 91% of the employees in all four occupations resided in Northeast Ohio. Technicians were the most likely to live in Northeast Ohio, at 98.6%. All Clerical employees (100%) lived in Northeast Ohio. Approximately 7% and 9% of NASA Glenn's Administrative Professional and Scientist & Engineers lived outside of Northeast Ohio. More than 55% of Administrative Professional, 68% of Clerical, 59% of Scientists & Engineers, and 50% of NASA Glenn's Technicians lived in Cuyahoga County in FY 2020. Of the total NASA Glenn civil service employees, Scientists & Engineers were the most likely to have postal addresses out of state, at 5.2%.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2020

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	93.5%	100.0%	91.0%	98.6%	91.8%
Cuyahoga County	55.8%	68.7%	59.7%	50.1%	58.4%
Lorain County	17.8%	31.3%	13.3%	25.7%	15.0%
Medina County	11.6%	0.0%	10.6%	17.2%	11.0%
Summit County	6.5%	0.0%	3.9%	1.4%	4.3%
Lake County	0.6%	0.0%	1.3%	1.4%	1.1%
Geauga County	0.0%	0.0%	1.4%	1.4%	1.1%
Portage County	1.2%	0.0%	0.8%	0.0%	0.8%
Ashtabula County	0.0%	0.0%	0.0%	1.4%	0.1%
Other Ohio	4.7%	0.0%	3.8%	1.4%	4.0%
Out of State	1.8%	0.0%	5.2%	0.0%	4.2%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

NASA Glenn civil service employees received $245.9 million in total compensation in FY 2020. The total compensation included both payroll, $184.6 million, and employee benefits, at $61.4 million. The total compensation increased by $8.5 million (3.6%) between FY 2019 and FY 2020, in nominal dollars. [12] Simultaneously, NASA Glenn's nominal payroll has increased by $4.0 million (2.2%).[13]

During the last five years, total compensation increased by $17.6 million (7.7%) from $228.3 million in FY 2016 to $245.9 million in FY 2020,[14] and the payroll increased by $8.9 million (5.1%) in nominal dollars[15].

Employee benefits also increased from FY 2016 to FY 2020. The percent of employee benefits in relation to the total compensation has been increasing every year since FY 2016. In FY 2016, the benefits were 23.1% (or $52.7 million) of total compensation increasing to 25.0% (or $61.4 million) of total compensation in FY 2020 in nominal dollars.[16]

Between FY 2019 and FY 2020, the average wage per civil service employee increased from $114,442 to $116,731 (an increase of 2.0%). [17] There was a nominal increase of 4.5% (or $5,005) in total average wage per civil service employee during the last five years.[18]

[12] In real dollars adjusted for inflation, total compensation increased by $6.2 million, or 2.6% between FY 2019 and FY 2020. Inflation for payroll was adjusted using CPI for the Cleveland-Akron-Lorain region).

[13] Total real payroll has decreased by $2.2 million (or 1.2%) from 2019 and FY2020.

[14] In real dollars adjusted for inflation, total compensation increased by $10.3 million (or 4.4%) between FY 2016 and FY 2020.

[15] The real payroll decreased by $3.3 million or 1.8% over the last five years.

[16] Real benefit was $54.4 million in FY2016.

[17] The average wage per employee in real terms increased 1.0%, or $1,188 between FY 2019 and FY 2020.

[18] In real dollar adjusted for inflation, the average wage per employee increased by 1.2%, or $1,426 between FY 2016 and FY 2020.

C.4. NASA GLENN EXPENDITURES, FY 2020

In FY 2020, NASA Glenn allocated $623.6 million to vendors in 46 states, the District of Columbia, and nine foreign countries. Compared to its total expenditures of $586.5 million in FY 2019, NASA Glenn increased its spending by 6.3%, or $37.1 million in nominal dollars. This translates to an increase of $28.0 million (or 4.7%) between FY 2019 and FY 2020 when adjusting for inflation.[19] Between FY 2016 and FY 2020, expenditures increased by 42.0%, representing $184.4 million in constant 2020 dollars.[20]

Figure 2 shows the geographic distribution of NASA Glenn's spending during FY 2020. Ohio continues to receive the largest share of the total expenditures with $316.0 million. The expenditures made in Ohio accounted for 50.7% of NASA Glenn's total spending and reflecting a $7.3 million increase in nominal dollars. [21] Although there was an increase in absolute value spent in Ohio between FY 2019 and FY 2020, the share of expenditures to the state decreased from 52.6% in FY 2019 to 50.7% in FY 2020.

Northeast Ohio received over 96.1% of NASA Glenn's total expenditures in the State of Ohio in FY 2020, a total of $303.8 million. Cuyahoga County received the largest share of expenditures spent both within Northeast Ohio and in the State of Ohio, receiving 99.2% and 95.3%, respectively. The Cuyahoga county also received the largest share of spending across the entire geographic distribution of NASA Glenn's total expenditures in FY 2020 (48.3%).

After Ohio, the state that received the largest share of NASA Glenn spending in FY 2020 was California. California received $129.9 million (or 20.8% of total expenditures). The expenditures in California increased 40.5%, or $37.3 million in the nominal dollar, and $35.8 million (or 38.1%) in real dollars adjusted for inflation between FY 2019 and FY 2020.

Alabama received the third-largest share of expenditures in FY 2020. Alabama experienced an increase of $16.7 million, or 61.9% in the nominal dollar, and $16.3 million or 59.5% in the real dollar between FY 2019 and FY 2020. Washington and Illinois received the fourth and fifth most significant share of expenditures in FY 2020. However, Washington and Illinois experienced a decrease of $9.8 million (or 21.1%) and $4.0 million (or 21.7%) in nominal dollars. [22] (See Appendix Table A.1 for more information on NASA Glenn spending by state.)

NASA Glenn's expenditures in foreign countries decreased from $1.3 million to $0.8 million in nominal dollars between FY 2019 and FY 2020. Great Britain was the largest beneficiary of the foreign countries that received NASA Glenn's contracts. (See Appendix Table A.1 for more information on NASA Glenn foreign country expenditures).

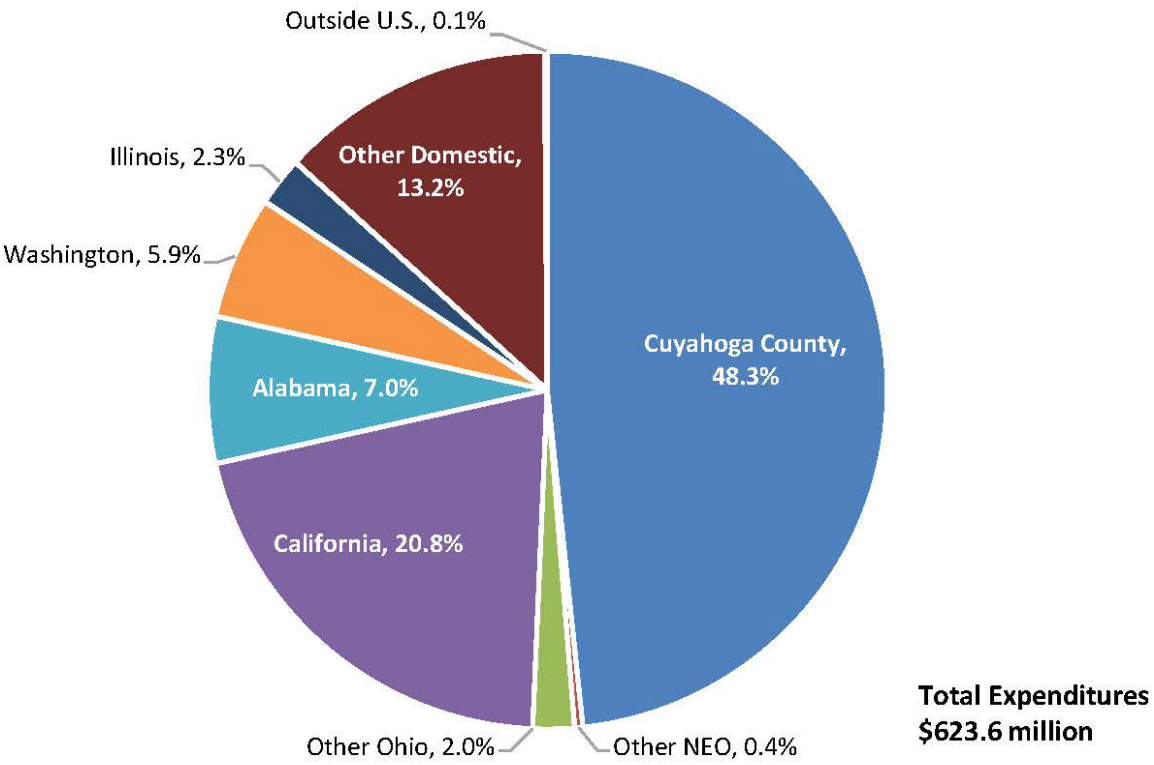
[19] Inflation was adjusted using CPI-US, 255.00 for 2019 and 259.0 for 2020.

[20] Constant or real dollar is an adjusted for inflation value of currencies to compare dollar values from one period to another.

[21] Total expenditures increased by $7.3 million in nominal dollars and $2.6 million in real dollars adjusted for inflation between FY 2019 and FY 2020.

[22] Washington and Illinois experienced a decrease of 10.5 million (or 22.3%) and 4.3 million (or 22.9%) in real dollars.

Figure 2. NASA Glenn Spending in Selected Regions, FY 2020



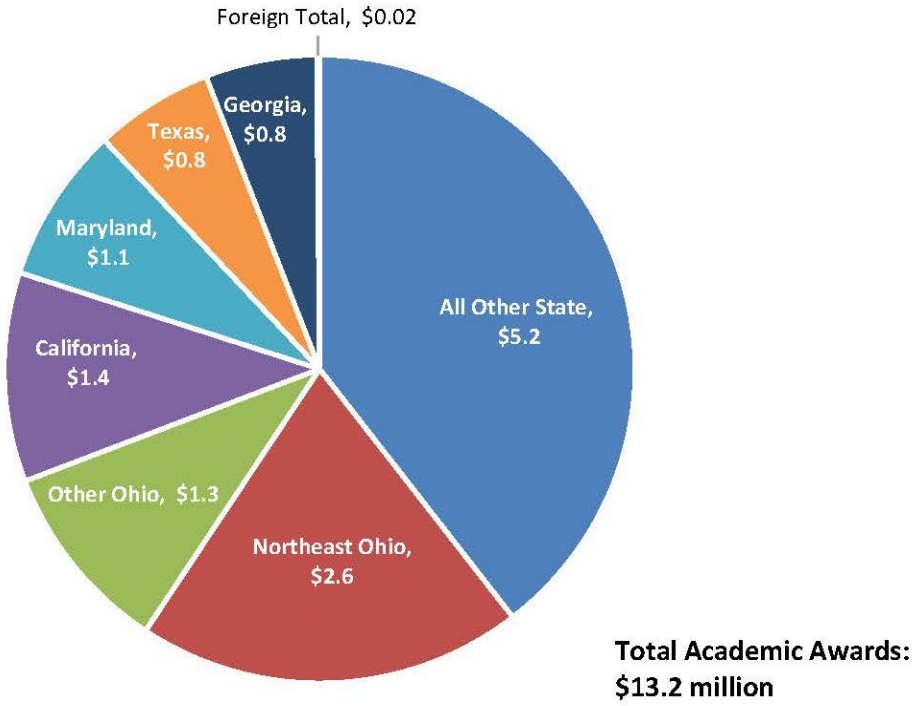
C.5. NASA GLENN AWARDS TO ACADEMIC INSTITUTIONS

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

NASA Glenn awarded $13.2 million to colleges and universities in 31 states. Grants accounted for $10.4 million in this total. Compared to FY 2019, this amount represented a reduction of academic grants from NASA Glenn by $1.8 million (12.0%) between FY 2019 and FY 2020, in nominal dollars. NASA Glenn also awarded $2.8 million in contracts to Ohio academic institutions in FY 2020 through on-site contracts.

The distribution of funding awarded to colleges and universities is shown in Figure 3. This figure illustrates selected states that received a large share of funding in FY 2020. The academic funding awarded in the top five states –Ohio, California, Maryland, Texas, and collectively accounted for 60.3% of the total awards, compared to 65.4% of total grants made to the top five states in FY 2019 (Ohio, California, Maryland, Michigan, and Texas). Ohio saw the most significant decrease in awards between 2019 and 2020, dropping by 27.0%. California and Maryland also experienced a 17.8% and 18.5% decline in awards (in nominal dollars), respectively, between FY 2019 and FY 2020. Texas experienced a 16.5% nominal dollars increase in awards (See Appendix Table A.2. for more information).

Figure 3. NASA Glenn Academic Awards to Colleges and Universities, FY 2020 (in millions)



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

Academic institutions in Ohio received $3.9 million of NASA Glenn's academic awards in FY 2020. Ohio accounted for the largest share (29.7%) of NASA Glenn's academic awards for the year. Northeast Ohio received 66.7% of the $3.9 million awarded to all of Ohio, totaling $2.6 million. Northeast Ohio received 19.8% of all academic funding given by NASA Glenn in FY 2020. Northeast Ohio's share of awards increased at the state level (56.2% of total Ohio awards in FY 2019) but decreased at the national level (20.2% of total awards in FY 2019).

Table 4 shows the distribution of NASA Glenn awards to academic institutions in Ohio from FY 2016 to FY 2020 (shown in 2020 dollars). [23] During the past five years, the total amount of funding to Ohio academic institutions decreased by 29.5%, dropping from $5.6 million in FY 2016 to $3.9 million in FY 2020, after adjusting for inflation.[24] In FY 2019, in FY 2020 total academic funding awarded in Ohio experienced a decline between $1.3 million or 234.7% (FY 2017 is the first year to include both academic grants and contract dollars in the totals).

Case Western Reserve University (CWRU) and the University of Toledo continued receiving the most significant awards of all Ohio academic institutions in FY 2020. CWRU received $2.2 million (or 55.7% of the total), and the University of Toledo received $1.0 million (or 25.8% of the total). For CWRU, this was a $0.31 million or 16.7% increase in the nominal dollar and a $0.42 million or 24.2% increase in real dollars between FY 2016 and FY 2020. The two universities

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

[24] NASA Glenn experienced a decline of its total academic funding in Ohio by 25.0%, from $5.2 million in FY 2016 to 3.9 million in FY 2020 in nominal dollars.

accounted for 81.5% of NASA Glenn awards to Ohio academic institutions in FY 2020.

The University of Akron was awarded $240,568 (or 6.1% of the total) in FY 2020 and ranked third by the share of total funding to Ohio academic institutions. Ohio State University received $199,903 (or 5.1% of the total) and ranked fourth. The remainder of the FY 2020 awards from NASA Glenn to Ohio academic institutions went to Cleveland State University ($122,243 or 3.1%), Ohio University ($77,740 or 2.0%), Kent State University ($70,214 or 1.8%), and University of Cincinnati ($14,972 or 0.4%).

Table 4. NASA Glenn Total Awards in Ohio by Academic Institution, FY 2016-FY 2020

Ohio Colleges and Universities	FY2016	FY2017	FY2018	FY2019	FY2020	FY2020 Share
Case Western Reserve University	$1,869,101	$2,452,677	$2,403,792	$2,261,212	$2,181,675	55.7%
University of Toledo	-	$1,946,294	$1,913,961	$1,780,861	$1,011,875	25.8%
The University of Akron	$580,960	$460,394	$453,013	$436,982	$240,568	6.1%
Ohio State University	$377,129	$335,912	$379,853	$486,878	$199,903	5.1%
Cleveland State University	$345,385	$178,887	$167,591	-	$122,243	3.1%
Ohio University	$82,826	$134,005	$77,852	$76,840	$77,740	2.0%
Kent State University	$42,285	$95,885	$137,149	$179,360	$70,214	1.8%
University of Cincinnati	$2,091,621	$240,847	$137,431	$38,861	$14,972	0.4%
Cuyahoga Community College	$168,094	$139,814	$110,098	$16,209	$0	0.0%
TOTAL	$5,557,402	$5,984,715	$5,780,740	$5,277,205	$3,919,190	100.0%

Notes: The table is sorted by FY 2020 column.
Data inflated to 2020 dollars (Inflation 240.5 based on CPI for the Midwest region).

C.6. NASA Glenn Revenues

Total revenue in FY 2020 reached $865.3 million, a 13.1% decrease from FY 2019 and a 30.3% increase from FY 2016 without adjustment for inflation. Over the five-year period, NASA Glenn's revenues ranged from $664.1 million in FY 2016 to $996.2 million in FY 2019 in nominal dollars.

NASA Glenn's revenue consists of two sources: NASA direct authority and reimbursable commitments. Table 5 illustrates NASA Glenn's revenue by source from FY 2016 to FY 2020. The share of the revenue from NASA's direct authority increased between FY 2016 and FY 2017, growing from 93.9% to 94.9% and slightly declined between FY 2017 and FY 2019, dropping from 94.9% to 93.2%. However, the share of the revenue from NASA's direct authority raised to 95.0% in FY 2020. In nominal dollars, the revenue from NASA's direct authority has continued to grow between FY 2016 and FY 2019; it declined by 11.4% between FY 2019 and FY 2020, dropping from $928.3 million in FY 2019 to $822.2 million in FY 2020.

In addition to the $822.2 million in direct authority revenue in FY 2020, NASA Glenn received $43.0 million in reimbursable commitments. As shown in Table 5, reimbursable funding has fluctuated since FY 2016, reflecting some changes in NASA Glenn's customer base in recent years. Glenn's revenues from reimbursable commitments have decreased by 36.6% within the past year, dropping nearly $24.9 million from FY 2019.

Federal funding remains the largest source of revenue for reimbursable commitment, accounting for 93.4%. Between FY 2019 and FY 2020, the Department of Defense accounted for the largest share of total reimbursable commitment (65.8%), and Other Federal Agency had the second-largest share of the total reimbursable commitment (27.6%). Over the last two years, reimbursable commitments from the Department of Defense saw an 8.9% increase, and the funding from Other Federal Agencies also increased by 2.2%.

Table 5. NASA Glenn Revenues, FY 2016-FY 2020 (in millions of nominal dollars)

Description	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020
NASA Direct Authority	$623.4	$655.9	$697.4	$928.3	$822.2
Total Reimbursable Commitments	$40.7	$35.2	$47.9	$67.9	$43.0
Total FY Authority	$664.1	$691.1	$745.3	$996.2	$865.3
NASA Budget %	93.9%	94.9%	93.6%	93.2%	95.0%

Note: Data in millions of nominal dollars.

C.7. Taxes Paid by NASA Glenn Employees

The taxes paid by NASA Glenn employees directly to local and state governments contribute substantially to the economy of Northeast Ohio and the state. Since NASA Glenn's facilities are primarily located in the cities of Brook Park, Fairview Park, and Cleveland, it affects the distribution of income tax paid by Glenn employees.

Table 6 illustrates income taxes paid by NASA Glenn employees, broken down into the amounts received by federal, state, and local governments. The shown distribution excludes income taxes paid by NASA Glenn employees residing outside the respective regions. In FY 2020, the total income tax paid by NASA Glenn employees totaled $32.1 million. This is a slight increase (0.5%) compared to FY 2019.

Excluding federal taxes, NASA Glenn employees paid $9.2 million in income taxes at the state and local levels in FY 2020. This is a 2.5% decline from FY 2019, without adjustment for inflation. The amount of taxes paid to local and state governments has increased steadily between FY 2016 and FY 2019, rising from $8.8 million in FY 2016 to $9.4 million in FY 2019.

The state of Ohio and the City of Brook Park were the two largest beneficiaries of the income taxes paid by NASA Glenn's employees. Together, they accounted for 99.5% of the total state and local income taxes paid in FY 2020. In FY 2020, 62.2% ($5.7 million) of the income taxes paid at the state and local levels went to the State of Ohio. Since 2016, NASA Glenn employees have paid an annual average of $5.7 million in income taxes to the State of Ohio.

The city of Brook Park received $3.5 million in income tax revenue from NASA Glenn employees in FY 2020, representing a marginal decrease (-0.7%) compared to FY 2019. This accounts for 98.8% of the income taxes paid to the cities of Cleveland, Brook Park, and Fairview Park by NASA Glenn employees in FY 2020, at a total of $3.54 million. The increase of taxes allocated to local cities between FY 2016 and FY 2020 was the following: the city of Brook Park increased by 5.9%, the city of Cleveland – 46.0%, and the city of Fairview Park – 0.1%.

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
2016	$3,303,850	$10,107	$26,636	$5,498,587	$24,070,576	**$32,909,756**
2017	$3,322,949	$10,106	$24,514	$5,588,849	$24,497,919	**$33,444,336**
2018	$3,357,770	$12,039	$22,718	$5,749,268	$22,685,203	**$31,826,998**
2019	$3,522,660	$14,046	$26,332	$5,869,450	$22,467,112	**$31,899,600**
2020	$3,497,273	$14,755	$26,784	$5,660,975	$22,869,119	**$32,068,907**
5-Year Total	**$17,004,502**	**$61,053**	**$126,984**	**$28,367,129**	**$116,589,929**	**$162,149,597**

D. ECONOMIC IMPACT OF NASA GLENN

This section describes the methodology and illustrates the results of research estimating the economic impact NASA Glenn had on Northeast Ohio and the State of Ohio in FY 2020.[25] The economic impact is measured in terms of output (sales), employment, value added, labor income and taxes contributed to local, state, and federal governments.

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

D.1. METHODOLOGY

The main assumption to estimate NASA Glenn's economic impact is that NASA Glenn established its operations in the region at the beginning of FY 2020 and generated demand by purchasing goods and services for its operations from vendors located in Northeast Ohio and Ohio.

This new demand for goods and services is called "change in final demand," which represents the direct impact NASA Glenn's spending has on the economy. [27] The initial NASA expenditures (i.e., change in final demand) in the region result 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 purchases goods and services as intermediate inputs in its research and development activities, which creates a direct impact. The assessment of intermediate goods purchasing is represented in the indirect portion of the economic impact.

Indirect impact measures the value of labor, capital, and other inputs of production needed to produce the goods and services that serve as the supplies required by NASA Glenn for its operation; these supplies are purchased from the supply chain of NASA Glenn in Northeast Ohio and Ohio.

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

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

Economic impact analysis accounts for inter-industry buy-sell relationships within the

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

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

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

respective economy of the research area (Northeast Ohio or Ohio). These relationships determine how the economy responds to changes in buying and selling patterns among industries. Input-output (I-O) models estimate inter-industry relationships at the county, regional, state, or country level by measuring the distribution of inputs purchased and outputs sold by each industry, government, and household. Using I-O models' multipliers makes it possible to estimate the specific impact of one additional dollar spent by or one additional employee hired for NASA Glenn. This impact continues, creating additional expenditures and jobs. The economic multiplier measures the extent to which an initial expenditure affects the regional economy.[28]

This study utilizes regional I-O multipliers from the IMPLAN online application model. [29] Specifically, SAM multipliers estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.[30]

Multi-Regional Input-Output (MRIO) analysis makes it possible to track how an impact on any of the 536 IMPLAN Industries in a Study Area region (i.e., Northeast Ohio (NEO) or Ohio) affect the production of all 536 Industries and household spending in these regions.[31]

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

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

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

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

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

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

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

businesses and entities located outside of the state were excluded when estimating the statewide impact of NASA Glenn.

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

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

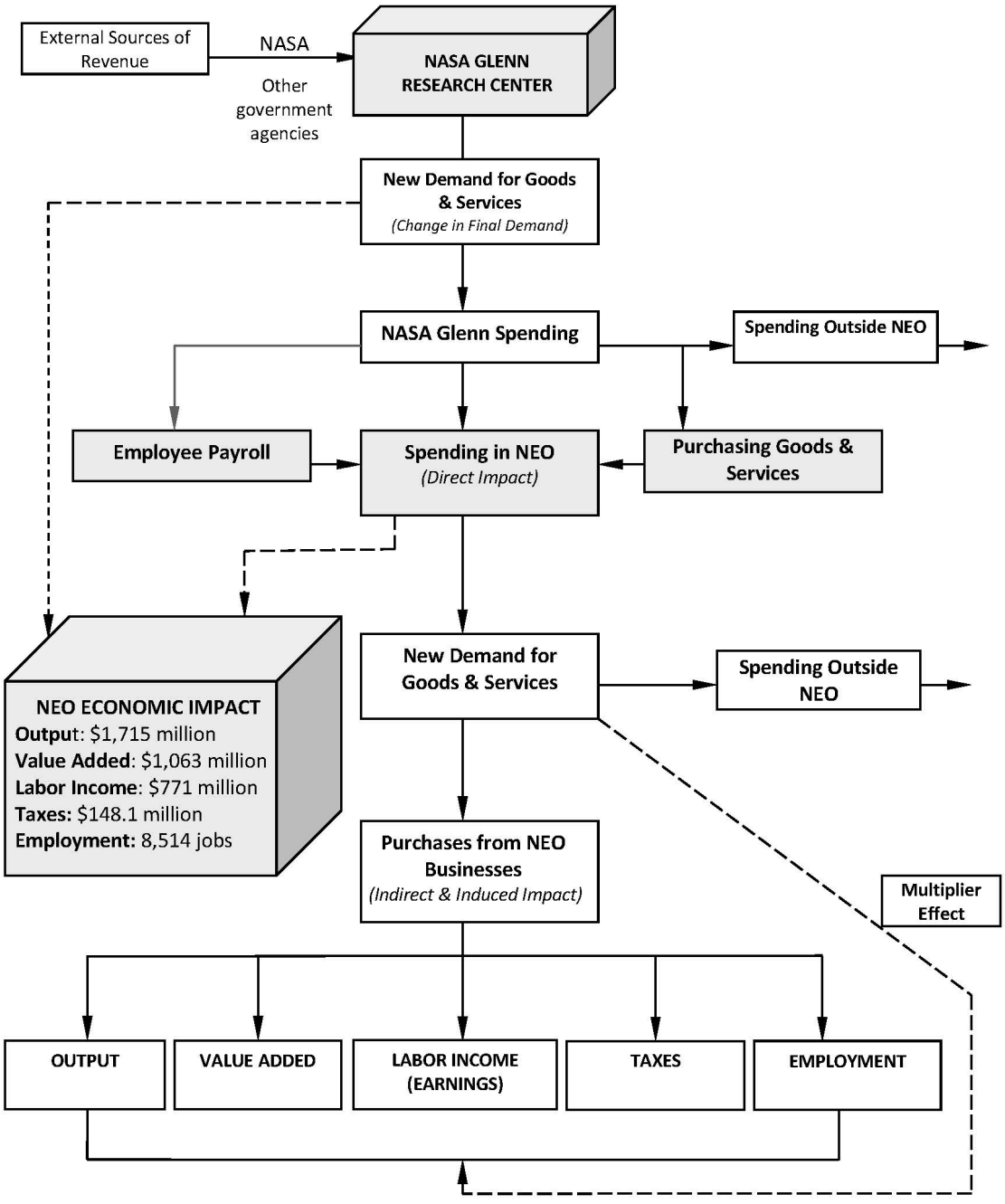
The employment, labor income, value added impact, and output impacts are each a summation of three components: direct impact, indirect impact, and induced impact.[33]
Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio's economy through its spending in the region in FY 2020.

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

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

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

Figure 4. Economic Impact of NASA Glenn Research Center on Northeast Ohio, FY 2020



D.2. Economic Impact on Northeast Ohio, FY 2020

This section of the report illustrates the economic impact of NASA Glenn on the economy of Northeast Ohio in FY 2020. The economic impact is measured by the changes in output (sales), employment, labor income (earnings), value added, and federal, state, and local taxes paid and generated by Glenn's activities.

D.2.1. Output Impact on Northeast Ohio, FY 2020

NASA Glenn's expenditures were divided into three brackets of spending: (1) goods and services purchased from companies and institutions located in Northeast Ohio, (2) spending for goods and services from businesses and other institutions located outside Northeast Ohio but still in Ohio (we called this region Remainder of Ohio), and (3) spending outside of Ohio. The first and second groups of spending create an economic impact on the economy of Northeast Ohio, while the third group is considered a regional leakage (or loss). While the second group of purchases made from companies located in the Remainder of Ohio does not affect NEO directly, the economic impact is created through the multiple chains of suppliers located within NEO and selling their product to the companies located in the Remainder of Ohio. The regional leakages – purchases made outside of Ohio - are not included in calculating the economic impact on Northeast Ohio. Local spending is then categorized by products purchased from different industries in the regional economy, based on an IMPLAN industry classification system that differentiates spending across 546 sectors. IMPLAN sectors are similar to the description of industries used in the North American Industry Classification System (NAICS) but do not fully correspond to the NAICS system. Appendix Table A.3. provides detailed NASA Glenn expenditures in Northeast Ohio by industry in FY 2020.

About 43.8% of NASA Glenn's total expenditures in Northeast Ohio went towards employee compensation. NASA Glenn's largest expenditures on goods and services in Northeast Ohio in FY 2020 were made on professional, scientific, and technical services (35.4%), including about 23.7% of total expenditures on scientific research and development services.

Table 7 illustrates the total output impact of NASA Glenn on the economy of Northeast Ohio, detailed by economic sectors. This output is comprised of direct impacts, indirect impacts, and induced impacts. NASA Glenn's total operational expenditures represent direct output impact for Northeast Ohio, including the regional margin of purchases from the retail industry. The indirect impact is estimated by summing the contributions of individual industries that provide supplies to the producers of the goods and services that NASA Glenn ultimately consumes. Induced impact is derived from measuring the effect of consumer spending due to the demand for products and services created by NASA Glenn.

Table 7. Output Impact in Northeast Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$141,988	$247,759	$389,747
Mining		$883,740	$607,763	$1,491,503
Utilities		$10,472,330	$6,471,611	$16,943,941
Construction		$30,109,175	$3,213,570	$33,322,745
Manufacturing		$6,725,430	$5,650,821	$12,376,251
Wholesale Trade		$7,583,341	$16,688,050	$24,271,391
Retail Trade		$3,686,961	$30,839,872	$34,526,833
Transportation and Warehousing		$5,814,544	$9,617,776	$15,432,320
Information		$9,859,005	$15,416,225	$25,275,229
Finance and Insurance		$12,018,337	$53,016,362	$65,034,700
Real Estate and Rental		$24,929,434	$61,825,593	$86,755,027
Professional, Scientific, and Tech Services		$238,192,766	$17,773,555	$255,966,320
Management of Companies		$11,239,451	$6,282,160	$17,521,611
Administrative and Waste Services		$86,306,191	$11,345,522	$97,651,714
Educational Services		$13,091,369	$5,612,736	$18,704,105
Health and Social Services		$1,603,357	$63,954,005	$65,557,362
Arts, Entertainment, and Recreation		$735,922	$6,988,165	$7,724,087
Accommodation and Food Services		$4,133,521	$19,592,940	$23,726,461
Other Services		$3,836,768	$20,585,141	$24,421,909
Government & non-NAICs	$540,679,541	$342,784,099	$4,303,210	$887,766,850
Total Output	**$540,679,541**	**$814,147,728**	**$360,032,837**	**$1,714,860,106**

Notes: For output impact, the change in final demand or direct impact ($869,478,556) equals the total spending of NASA Glenn for goods and services in and outside of Northeast Ohio, including wages and benefits with minor discrepancies due to IMPLAN rounding errors. The results of the economic impact are shown in 2020 dollars.

The total output impact of NASA Glenn on Northeast Ohio was $1.7 billion in FY 2020.

NASA Glenn's spending of $540.7 million in Northeast Ohio resulted in an output (sales) change of $1.7 billion across all industry sectors (Table 7). Glenn's initial spending triggered a $256.0 million increase in total sales (direct, indirect, and induced) by the Professional, Scientific, and Technical Services industry and a $25.3 million increase in sales by the Information industry. NASA Glenn was also responsible for a $97.7 million increase in total sales by the Administrative and Waste services industry. If NASA Glenn did not exist in Northeast Ohio, the region would lose the output generated by its spending. The three given examples illustrate the idea that the regional impact of NASA Glenn's operation can be best described as the increase in output of affected industries compared to the *hypothetical* absence of NASA Glenn in Northeast Ohio.

Of the total output impact, 31.5% ($540.7 million in 2020 dollars) is accounted for by NASA Glenn's direct spending in Northeast Ohio, which constitutes the direct economic impact to Northeast Ohio. Approximately $814.2 million (47.5%) of the total output impact results from indirect spending by NASA Glenn (purchasing from its suppliers within the region). The remaining output impact of $360.0 million (21.0%) is attributed to the induced impact from NASA Glenn purchases rippling through the regional economy.

Further analysis of the IMPLAN model's results indicated that the indirect and induced portions of the economic impact (totaled $1,174.2 million, or 68.5% of total output) could be divided into three broad categories: NASA Glenn-driven industries, consumer-driven industries, and other industries.

NASA Glenn-driven industries increase sales, employment, and earnings primarily, but not exclusively, due to NASA Glenn's operations. They include utilities, construction; information; professional and scientific services; administrative and waste services; and education services. The total increase in output due to indirect and induced economic impacts from the industries above in FY 2020 was $431.6 million or 36.8% of NASA Glenn's overall indirect and induced impact on Northeast Ohio.

Consumer-driven sectors increase sales, employment, and earnings primarily due to spending by Glenn employees and other workers who produce goods and services for NASA Glenn and their suppliers. These industries include other real estate; hospitals; monetary authorities and depository credit intermediation; insurance carriers, except direct life; offices of physicians, and other consumer-driven industries (see figure 6). The increase in output due to indirect and induced economic impacts for these industries in FY 2020 was $258.7 million or 22.0% of the total impact.

Other industries are driven by both NASA Glenn and consumer spending, and their impact is split between NASA Glenn and consumer spending, they should not be attributed to NASA Glenn operations only. These industries include: mining; manufacturing; agriculture; government enterprises; wholesale trade; and transportation and warehousing. The total increase in output due to indirect and induced economic impacts for these industries in FY 2020 was $484.0 million or 41.2% of the total impact.

The output distributions for select Glenn-and consumer-driven industries are shown in Figures 5 and 6, respectively. In figure 5, industries with additional sales of at least $19 million, or 4.0% of the total sale, were selected to be illustrated. Industries with additional sales of at least $9 million (4.0% of total) were selected to be presented in figure 6.

The scientific research and development services industry generated the largest output as a single industry in FY 2020, increasing by $145.6 million due to NASA Glenn's operations (Figure 5). This amount is the summation of the indirect and induced impacts generated primarily, but not exclusively, by NASA Glenn's spending on research services. The increase of $145.6 million represented 34% of the $431.6 million increase in output for all NASA Glenn-driven industries. Other industries shown in Figure 5 can be interpreted in a similar manner.

Figure 6 presents the consumer-driven industries of the economy that saw the largest increases in sales. Of these consumer-driven industries, the real estate industry saw the largest increase in sales (by $37.2 million). This amount is the summation of the indirect and induced impacts generated primarily by NASA Glenn employees and other workers for rental activities. The increase of $37.2 million accounted for 14% of the $258.7 million increase in output for all consumer-driven industries.

Figure 5. Increase in Sales for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2020

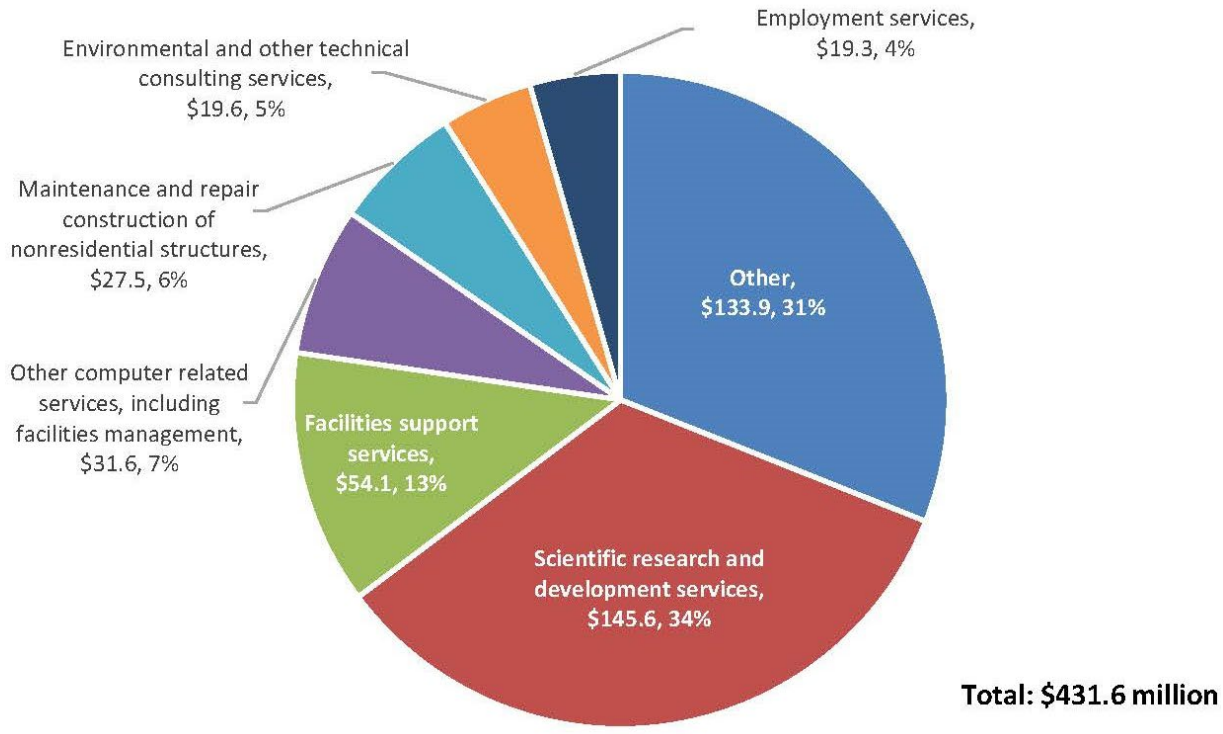
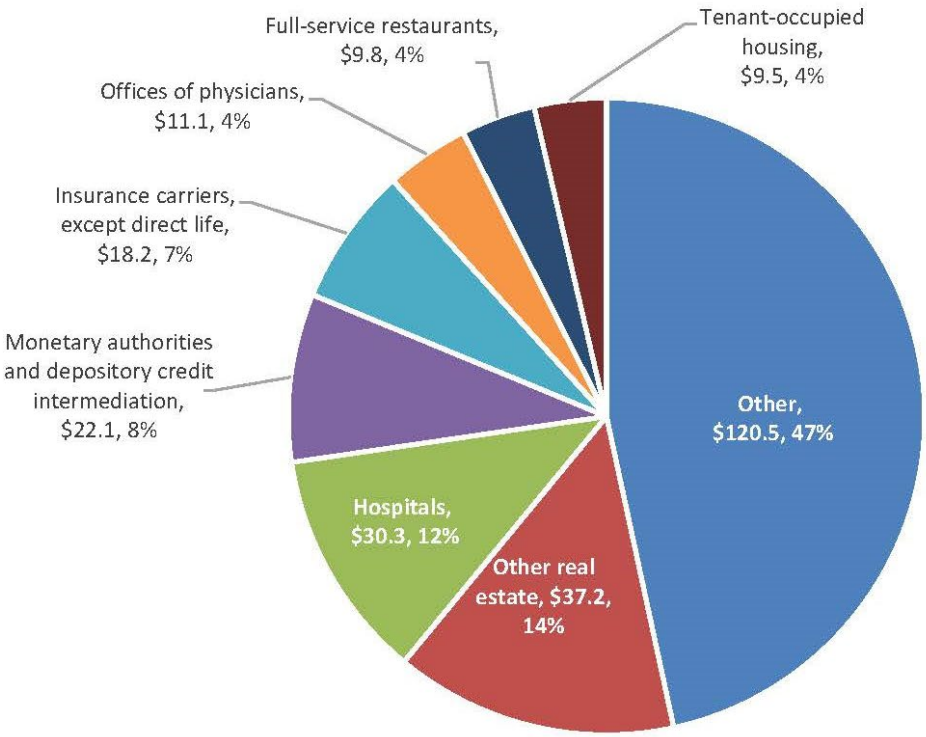


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2020



Total: $258.7 million

D.2.2. Employment Impact on Northeast Ohio, FY 2020

In addition to its employment (direct impact), NASA Glenn's presence in Northeast Ohio has supported and created new full-time and part-time jobs outside of NASA Glenn. FY 2020 spending resulted in retained workers in NASA Glenn directly and increased employment in its supplier industries (indirect impact).

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

Table 8. Employment Impact in Northeast Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		5	6	11
Mining		1	1	2
Utilities		12	6	18
Construction		146	15	161
Manufacturing		18	14	32
Wholesale Trade		23	52	75
Retail Trade		42	328	370
Transportation and Warehousing		48	84	132
Information		25	50	76
Finance and Insurance		28	157	185
Real Estate and Rental		124	117	241
Professional, Scientific, and Tech Services		1,200	104	1,304
Management of Companies		46	25	71
Administrative and Waste Services		775	130	905
Educational Services		160	90	251
Health and Social Services		15	531	546
Arts, Entertainment, and Recreation		9	73	82
Accommodation and Food Services		63	283	346
Other Services		34	224	259
Government & non-NAICs	1,581	1,847	20	3,448
Total Employment	**1,581**	**4,621**	**2,311**	**8,514**

Notes: For employment impact, the change in final demand (direct impact) equals the number of employees working for NASA Glenn. Sum to the total might have a slight error due to rounding.

Employment in Northeast Ohio increased by 8,514 employees in FY 2020 due to NASA Glenn's spending. Of these jobs, 1,581 (18.6%) were directly employed at NASA Glenn. New jobs were also created as a result of NASA Glenn's indirect economic impact. This spending on goods and services caused the creation and retention of additional 4,621 full-time and part-time jobs (53.3%) in NEO. The remaining 2,311 (27.1%) jobs were created as induced impact due to purchases made by NASA Glenn and suppliers' employees. These industries produce products that are typically within a consumer purchasing pattern of the region.

Of the 6,932 jobs created and supported in Northeast Ohio due to the indirect and induced impacts, 2,521 (36.4%) were found in the NASA Glenn-driven industries, 1,863 (26.9%) were in the consumer-driven industries, and 2,548 (36.8%) were in other industries. [34] The job distribution for select NASA Glenn and consumer-driven industries are shown in Figures 7 and 8, respectively. The industries illustrated in Figures 7 and 8 have the highest increases in employment, with a minimum of 120 employees (or over 5.0%) per sector in Figure 7 and a minimum of 70 (or over 4%) in Figure 8.

NASA Glenn's scientific research and development service industry generated the largest number of additional jobs among NASA Glenn-driven industries. Companies engaged in scientific R&D saw an increase of 664 jobs in FY 2020 due to NASA Glenn's operation in Northeast Ohio (Figure 7). These jobs equal the total of indirect and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in Northeast Ohio's R&D contractors' sector. The 664 R&D jobs accounted for 26% of the 2,521 NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted in a similar manner.

Of all consumer-driven industries, the real estate industry saw the largest increase in jobs; the industry grew by 192 jobs in FY 2020 as a result of NASA Glenn's spending (Figure 8). These jobs are the summation of the indirect and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in the Northeast Ohio real estate sector. The 192 jobs represent 10% of the 1,863 jobs created across all consumer-driven industries.

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

Figure 7. Increase in Jobs for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2020

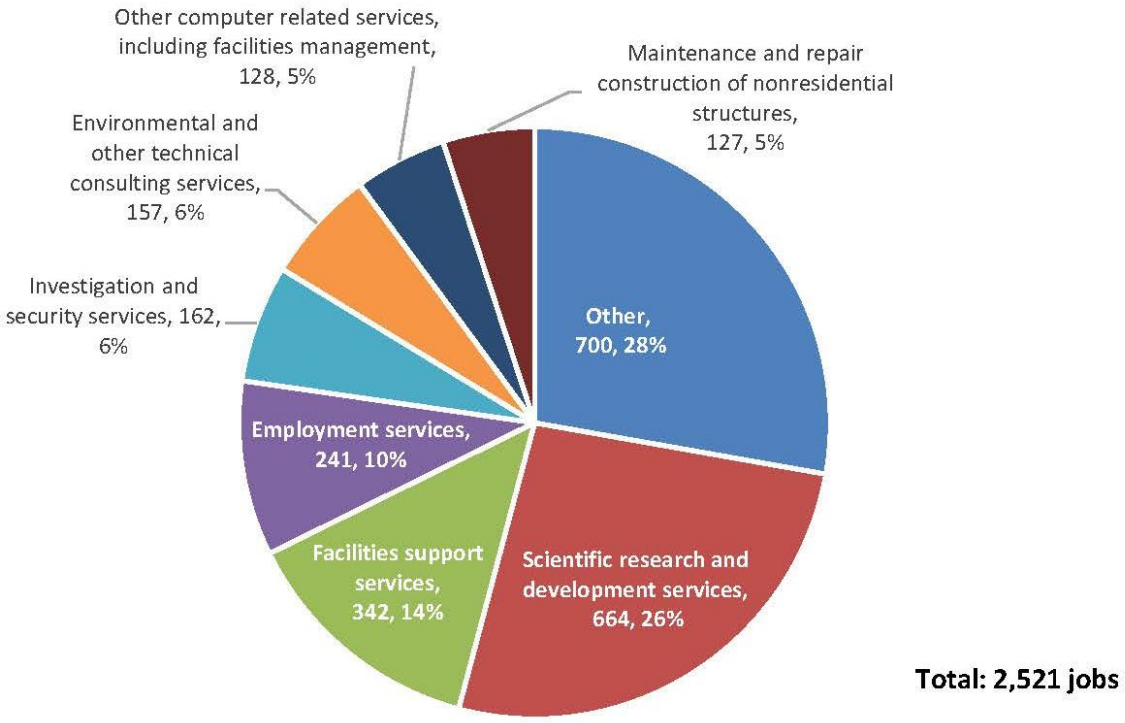
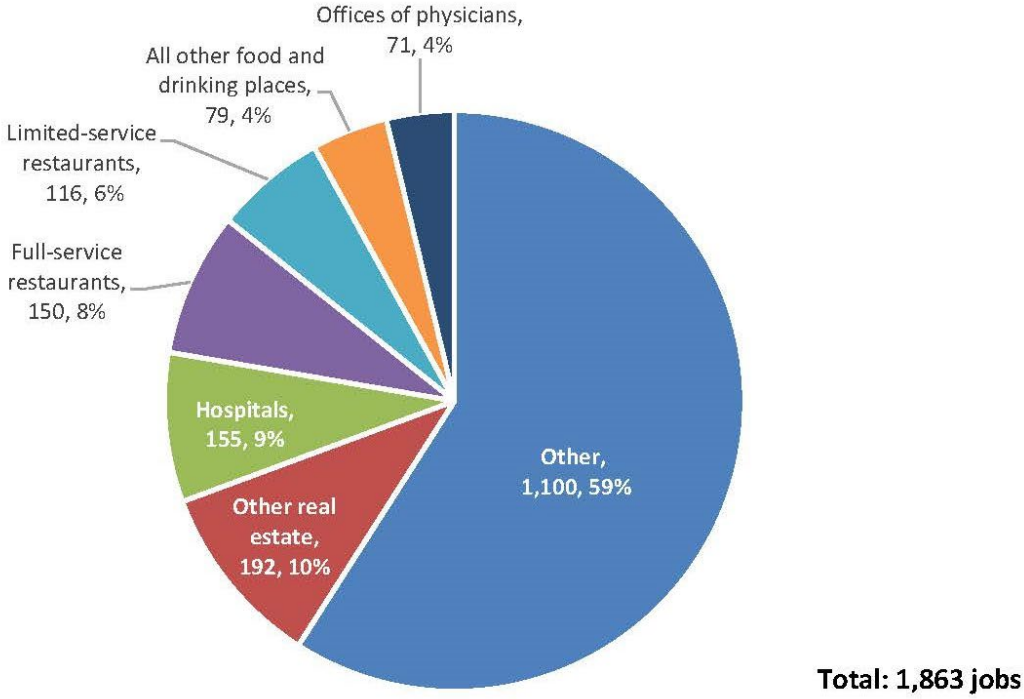


Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2020



D.2.3. Labor Income Impact on Northeast Ohio, FY 2020

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

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

Table 9. Labor Income Impact in Northeast Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing, and Hunting		$79,355	$109,475	$188,830
Mining		$522,003	$333,889	$855,892
Utilities		$4,145,375	$2,455,952	$6,601,327
Construction		$12,906,244	$1,351,581	$14,257,825
Manufacturing		$2,413,172	$1,707,508	$4,120,679
Wholesale Trade		$3,593,735	$7,912,975	$11,506,710
Retail Trade		$1,771,499	$14,116,474	$15,887,973
Transportation and Warehousing		$2,715,631	$4,484,294	$7,199,925
Information		$3,559,128	$6,360,440	$9,919,568
Finance and Insurance		$7,232,045	$26,852,148	$34,084,193
Real Estate and Rental		$9,596,587	$37,896,005	$47,492,592
Professional, Scientific, and Tech Services		$126,303,206	$11,312,106	$137,615,312
Management of Companies		$6,865,827	$3,837,573	$10,703,400
Administrative and Waste Services		$41,237,944	$6,263,543	$47,501,487
Educational Services		$6,292,206	$3,734,590	$10,026,796
Health and Social Services		$925,377	$38,035,572	$38,960,949
Arts, Entertainment, and Recreation		$452,004	$4,224,045	$4,676,048
Accommodation and Food Services		$2,126,584	$9,089,133	$11,215,717
Other Services		$2,259,071	$11,196,031	$13,455,102
Government & non-NAICs	$236,928,612	$104,944,516	$2,541,946	$344,415,074
Total Labor Income	**$236,928,612**	**$339,941,509**	**$193,815,278**	**$770,685,399**

Notes: Labor income constitutes economic impact through households of NASA employees and those affected by NASA operations throughout the economy.
The economic impact is shown in 2020 dollars.

Total labor income in Northeast Ohio increased by $770.7 million due to NASA Glenn spending in FY 2020. Of this total, $236.9 million (30.7%) was made up of wages and benefits paid directly to NASA Glenn employees (i.e., the direct effect measured in 2020 dollars). The indirect impact, or the wages and benefits paid to employees of companies in Northeast Ohio who supply goods and services to NASA Glenn, represented $339.9 million (44.1%) of the total amount. The remaining labor income impact is represented by the induced impact of $193.8 million (25.1%). This impact comes from the spending of both NASA Glenn and suppliers' employees in industries throughout the regional economy.

Of the $533.8 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, $218.1 million (41.0%) was reported in NASA Glenn-driven industries, $135.8 million (25.4%) was generated in consumer-driven industries, and $179.8 million (33.7%) was reported in other industries.[35]

The labor income distribution for select NASA Glenn-driven and consumer-driven industries is shown in Figures 9 and 10. Selected industries that added over $9 million (4%) are displayed in Figure 9, and industries that added over $4 million (4%) are displayed in Figure 10.

Within NASA Glenn-driven industries, those engaged in scientific research and development services saw their labor income increase by $70.2 million in FY 2020 (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 $70.2 million spent on scientific R&D represents 32% of the $218.1 million total increase in labor income reported by all the NASA Glenn-driven industries in FY 2020.

Of all consumer-driven industries, private hospitals saw the largest increase in earnings in FY 2020. Earnings in this industry totaled $15.9 million, making up 12% of the $135.8 million consumer-driven total. These earnings result from totaling the indirect and induced impacts generated by consumer spending on doctors' services.

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

Figure 9. Increase in Labor Income for NASA Glenn-Driven Industries in Northeast Ohio, FY 2020

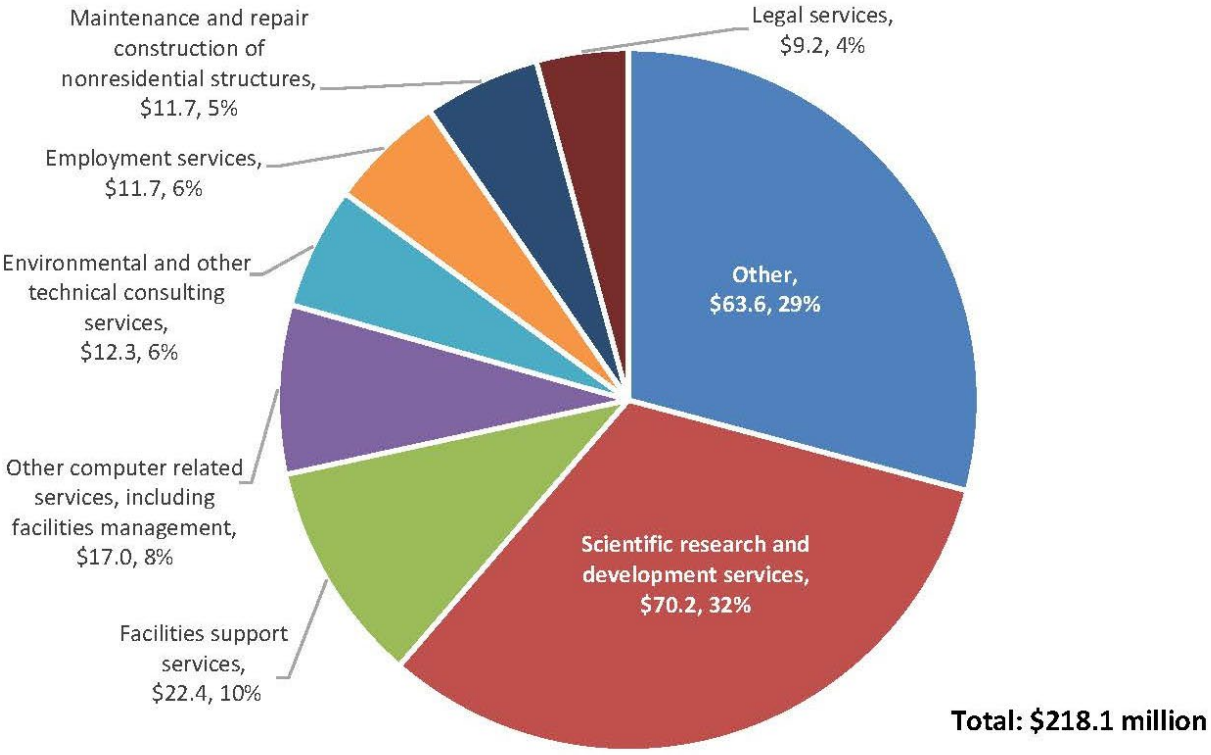
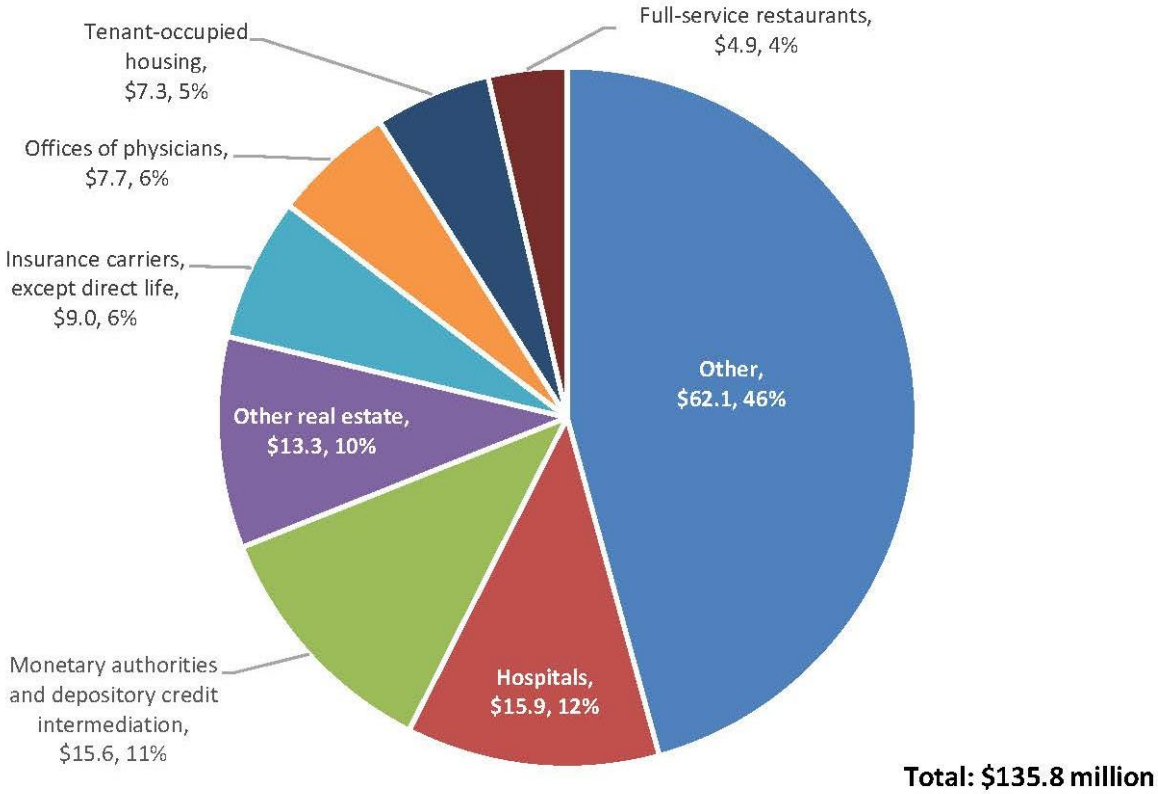


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2020



D.2.4. Value Added Impact on Northeast Ohio, FY 2020

The total value added [36] impact in Northeast Ohio was $1,063 million in FY 2020. This total resulted from NASA Glenn's regional spending on goods and services in Northeast Ohio. NASA Glenn's spending led to a $1,063 million increase in sales by all industries, excluding intermediary goods and services. The total output excluding intermediate expenditures constituted the change in final demand (or direct impact) for value added, $264.9 million in FY 2020. The sales from companies and other suppliers of goods and services to NASA Glenn, excluding the value for intermediary goods and services, represented the indirect value added impact.

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

Table 10. Value Added Impact in Northeast Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$82,969	$116,416	$199,385
Mining		$552,345	$343,996	$896,341
Utilities		$5,121,476	$3,072,484	$8,193,960
Construction		$13,106,402	$1,394,301	$14,500,703
Manufacturing		$2,484,352	$1,816,305	$4,300,657
Wholesale Trade		$4,340,599	$9,744,263	$14,084,862
Retail Trade		$2,388,197	$18,259,231	$20,647,428
Transportation and Warehousing		$2,907,222	$4,824,082	$7,731,304
Information		$3,946,554	$7,133,765	$11,080,319
Finance and Insurance		$7,435,810	$27,767,375	$35,203,185
Real Estate and Rental		$10,255,587	$43,123,681	$53,379,268
Professional, Scientific, and Tech Services		$128,970,366	$11,483,906	$140,454,273
Management of Companies		$7,002,425	$3,913,923	$10,916,348
Administrative and Waste Services		$42,910,203	$6,563,792	$49,473,995
Educational Services		$6,600,152	$3,856,192	$10,456,344
Health and Social Services		$937,946	$38,645,850	$39,583,796
Arts, Entertainment, and Recreation		$496,317	$4,615,286	$5,111,603
Accommodation and Food Services		$2,364,921	$10,315,781	$12,680,702
Other Services		$2,597,856	$12,594,973	$15,192,829
Government & non-NAICs	$264,932,975	$341,736,653	$2,234,147	$608,903,775
Total Value Added	**$264,932,975**	**$586,238,353**	**$211,819,749**	**$1,062,991,077**

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 any other research institution in Northeast Ohio. For an average research institution in Northeast Ohio, the intermediate expenditures accounted for 49% of total output.
The economic impact is shown in 2020 dollars.

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

Total value added in Northeast Ohio increased by $1,063 million in FY 2020 as a result of NASA Glenn's spending on goods and services. Of this total amount, $264.9 million (24.9%) represented the change in final demand (direct impact), calculated as total output less intermediate expenditures. In the case of NASA Glenn, a large portion of the value added are the wages and salaries paid to the employees. The indirect effect of $586.2 million (55.1%) represented the value of goods and services, excluding intermediary goods, of companies in Northeast Ohio that supply NASA Glenn. The remaining value added impact (the induced component) was estimated at $211.8 million (19.9%). This value occurred due to the ripple effects NASA Glenn's spending had on the Northeast Ohio economy.

Of the $798.0 million increase in value added attributed to Northeast Ohio due to the indirect and induced impacts, $226.0 million (28.3%) was observed in NASA Glenn-driven industries, $146.3 million (18.3%) has occurred in consumer-driven industries, and $425.6 million (53.3%) was reported in other industries.[37]

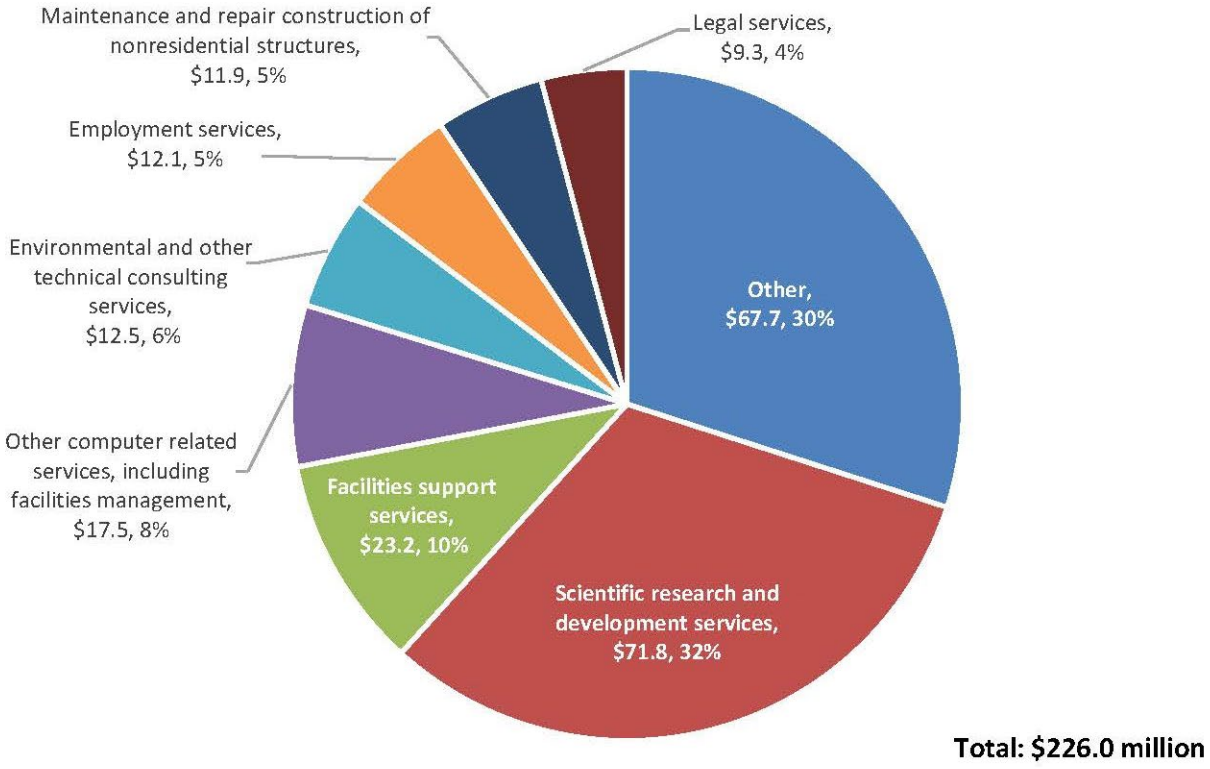
The value added distribution for select NASA Glenn-driven industries can be found in Figure 11. The value added distribution for select consumer-driven industries can be found in Figure 12. Each of the select industries shown in Figures 11 and 12 added at least $9 million (or 4%) and $7 million (or 5%), respectively.

Of the NASA Glenn-driven industries, the scientific research and development services industry saw the largest value added increase in FY 2020 ($71.8 million). This amount results from summing the indirect and induced impacts generated by NASA Glenn's spending. This $71.8 million increase in the scientific R&D industry represented a 32% share of the $226.0 million increase in value added across all NASA Glenn-driven industries. The other industries shown in Figure 11 can be interpreted similarly.

Within the consumer-driven industries, those who worked in the private hospital industry saw their value added increase by $16.2 million in FY 2020. This increase results from summing indirect and induced impacts that were generated primarily, though not exclusively, by NASA Glenn's spending at hospital establishments. This $16.2 million increase accounted for 11% of the $146.3 million value added growth that occurred across all consumer-driven industries.

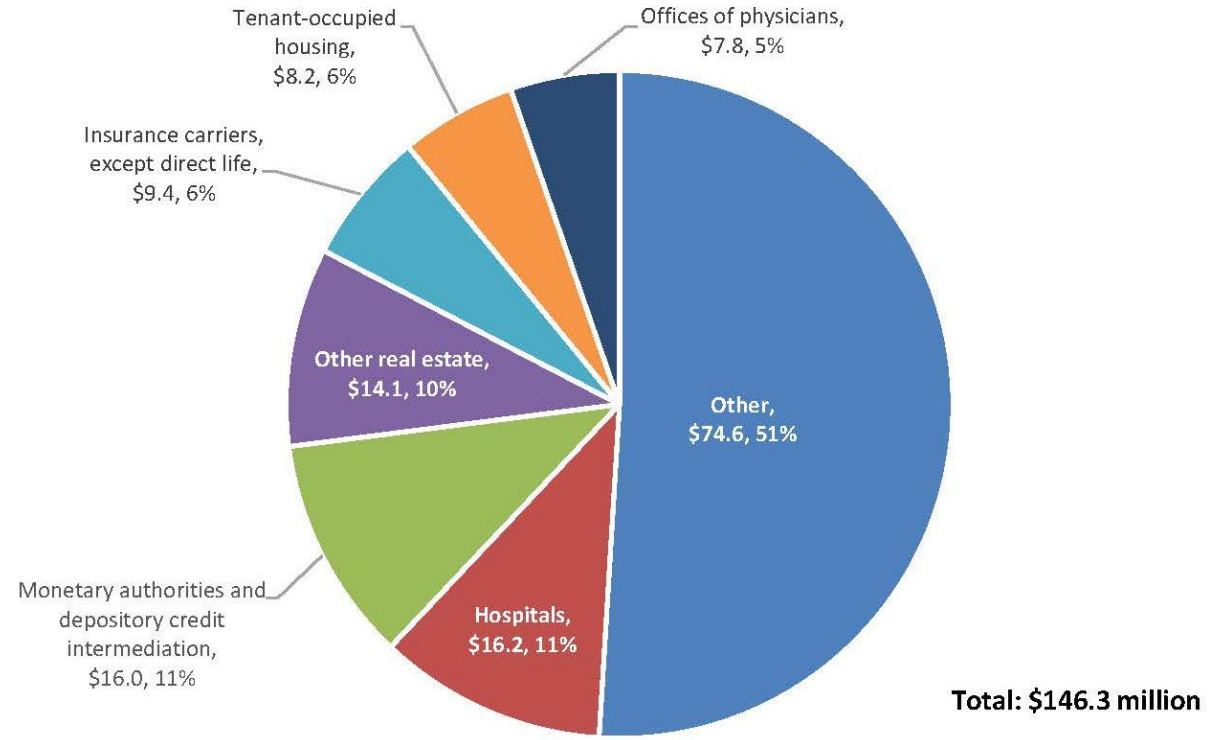
[37] See section D.2.1. Output Impact on Northeast Ohio for definitions of NASA Glenn-driven, consumer-driven, and other industries.

Figure 11. Increase in Value Added for NASA Glenn-Driven Industries in Northeast Ohio, FY 2020



Total: $226.0 million

Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2020



Total: $146.3 million

D.2.5. Tax Impact on Northeast Ohio, FY 2020

NASA Glenn's operations and economic impact on Northeast Ohio in FY 2020 increased the region's tax revenues by $148.1 million. Of this total, the direct tax impact paid by NASA Glenn's employees to all levels of government was $32.1 million in 2020 dollars. The local tax paid below the state level due to the NASA Glenn operations and employment (including county and sub-county taxes) was $20.3 million in FY 2020.

D.2.6. FY 2020 Northeast Ohio Impact Summary

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

- Total Output Impact: $1,714.9 M
- Total Employment Impact: 8,514 jobs
- Total Labor Income Impact: $770.7 M
- Total Value Added Impact: $1,063.0 M
- Total Tax Impact: $148.1 M

The impact of NASA Glenn's expenditures on Northeast Ohio reflects the benefits of total expenditures of $540.7 million. These expenditures include a total amount of $303.8 million spent on purchases in Northeast Ohio in FY 2020 and expenditures on labor income paid to employees living in or commuting to Northeast Ohio for $236.9 million.

Excluding expenditures on labor income, 63.0% (about $191.5 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 20.3% ($61.8 million) was spent on administrative and support services, and 5.1% ($27.8 million) was spent on construction – the three largest groups of NASA Glenn expenditures in Northeast Ohio.[38] Like in FY 2019, these three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio and, together, represented a 88.4% share ($281.1 million) of all NASA Glenn's FY 2020 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, educational service represented at 4.2% share and utilities at 1.8%. Other sectors' expenditures were less than 1%. Expenditures on labor income and benefits constituted 43.8% of the overall $540.7 million of NASA Glenn direct sending in Northeast Ohio in FY2020.

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

[38] Amounts in parentheses detailing percentage numbers are presented in 2020 dollars and correspond to Appendix Table A.3.

D.3. ECONOMIC IMPACT ON THE STATE OF OHIO, FY 2020

This section provides an assessment of the economic impact of NASA Glenn operations on the State of Ohio's economy in FY 2020. This economic impact analysis is based on the same methodology used to assess NASA Glenn's economic impact on Northeast Ohio, as described in Section D.2. The difference between the results in the two sections is based on the larger spending captured through Ohio vendors across the whole state (this section) in comparison to the purchases made from the companies located in only Northeast Ohio (section D.2).

D.3.1. Output Impact on the State of Ohio, FY 2020

This economic impact analysis used IMPLAN multipliers to identify the buy-sell relationship between industries in Ohio. The multipliers applied to the spending in the State of Ohio are generally larger than those that are applied to expenditures in Northeast Ohio due to the broader NASA Glenn's supply chain located in the state. The larger geographic area also results in less leakage from the economy.

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

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

Table 11. Output Impact in the State of Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$297,843	$445,000	$742,843
Mining		$1,418,734	$1,014,928	$2,433,662
Utilities		$11,366,511	$7,628,480	$18,994,990
Construction		$29,708,943	$3,658,167	$33,367,110
Manufacturing		$12,814,840	$9,889,659	$22,704,498
Wholesale Trade		$8,211,472	$18,597,739	$26,809,211
Retail Trade		$3,890,236	$33,937,328	$37,827,564
Transportation and Warehousing		$6,687,053	$11,206,141	$17,893,193
Information		$10,518,829	$17,339,926	$27,858,754
Finance and Insurance		$12,818,193	$58,837,859	$71,656,051
Real Estate and Rental		$26,051,865	$67,469,555	$93,521,420
Professional, Scientific, and Tech Services		$247,521,538	$19,280,078	$266,801,617
Management of Companies		$11,754,814	$6,899,215	$18,654,030
Administrative and Waste Services		$86,793,148	$12,820,660	$99,613,807
Educational Services		$13,299,081	$5,963,289	$19,262,371
Health and Social Services		$1,570,790	$69,840,308	$71,411,098
Arts, Entertainment, and Recreation		$775,028	$7,510,926	$8,285,954
Accommodation and Food Services		$4,276,145	$21,291,032	$25,567,178
Other Services		$4,159,652	$22,537,003	$26,696,655
Government & non-NAICs	$558,474,992	$346,784,927	$4,696,880	$909,956,799
Total Output	**$558,474,992**	**$840,719,642**	**$400,864,173**	**$1,800,058,807**

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 Ohio, including wages and benefits. The direct output is adjusted for inflation and shown in the table in 2020 dollars.

In FY 2020, the total output impact of NASA Glenn on the State of Ohio was $1.8 billion. NASA Glenn's expenditures of $869.5 million worth of overall expenditures, including $558.5 million of the spending in Ohio. This spending resulted in an output (sales) change of $1.8 billion across all industry sectors (Table 11). This economic impact included a $266.8 million increase in total sales in the Professional, Scientific, and Technical Services industry and a $99.6 million increased in sales in the Administrative and Waste Services.

Of the total output impact, 31.0% ($558.5 million) is the direct impact – total NASA Glenn's spending in Ohio. Indirect spending from NASA Glenn's purchases of goods and services within the State of Ohio made up $840.7 (46.7%) of the total output impact. The remaining $400.9 million (22.3%) of the total output impact is due to the induced impact of NASA Glenn's spending throughout the state.

A detailed analysis of the IMPLAN model shows that the $1.2 billion increase in sales generated by the indirect and induced impacts can be divided into three broad categories: NASA Glenn-driven ($462.9 million, 25.7%), consumer-driven ($438.1 million, 24.3%), and other industries ($899.0 million, 49.9%).[39]

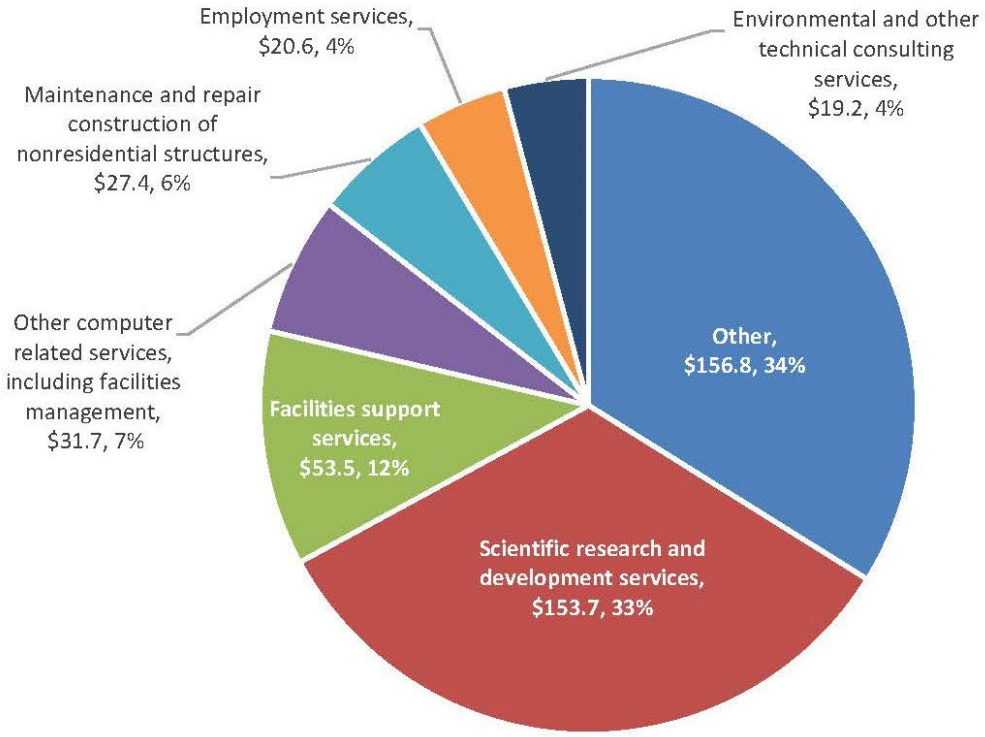
Figures 13 and 14 display the output distributions for select NASA Glenn- and consumer-driven industries, respectively. Selected industries illustrated in Figure 13 added over $19.0 million or 4.0%, and selected industries in Figure 14 added over $19.0 million or 5.0% each.

The scientific research and development industry generated the largest output impact as a single industry; it increased by $153.7 million in FY 2020 due to NASA Glenn's operations (Figure 13). This amount results from totaling the indirect and induced impacts generated primarily by NASA Glenn's spending on research services. This increase of $153.7 million accounted for 33% of the $462.9 million increase in output of all Glenn-driven industries. Other industries shown in Figure 13 can be interpreted similarly.

In consumer-driven industries (displayed in Figure 14), the real estate industry generated the largest output impact. This industry increased by $39.4 million in FY 2020 and represented a 14% share of the $281.1 million increase in output for all consumer-driven industries. Other industries shown in Figure 14 can be interpreted similarly.

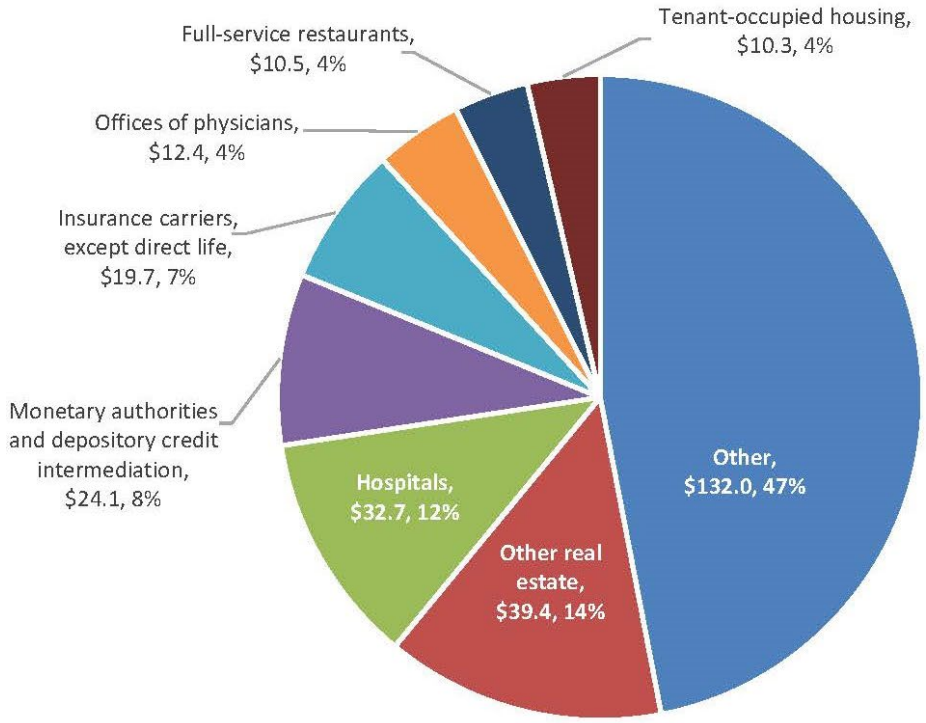
[39] NASA Glenn-driven industries are industries that increase sales, employment, and earnings primarily, but not exclusively, due to NASA Glenn's spending. Among these industries are utilities, construction, information, professional and scientific services, administrative and support services, and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

Figure 13. Increase in Sales for Select NASA Glenn-Driven Industries in Ohio, FY 2020



Total: $462.9 million

Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2020



Total: $281.1 million

D.3.2. Employment Impact on the State of Ohio, FY 2020

NASA Glenn's operations create jobs in Ohio beyond Glenn's hiring of its employees (change in final demand, or direct impact). Glenn's spending creates employment across the State of Ohio through its supply chain (indirect impact).

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

Table 12. Employment Impact in the State of Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		8	9	17
Mining		2	1	4
Utilities		13	7	20
Construction		146	18	164
Manufacturing		32	21	53
Wholesale Trade		25	58	83
Retail Trade		45	365	410
Transportation and Warehousing		53	98	151
Information		28	58	86
Finance and Insurance		31	176	207
Real Estate and Rental		131	129	260
Professional, Scientific, and Tech Services		1,263	115	1,378
Management of Companies		48	28	76
Administrative and Waste Services		795	148	943
Educational Services		166	97	263
Health and Social Services		15	588	603
Arts, Entertainment, and Recreation		9	81	90
Accommodation and Food Services		66	314	380
Other Services		37	251	287
Government & non-NAICs	1,581	1,894	22	3,498
Total Employment	**1,581**	**4,808**	**2,585**	**8,974**

Notes: For employment impact, the change in final demand (direct impact) equals the number of employees working for NASA Glenn. Sum to the total might have a slight error due to rounding.

NASA Glenn's spending in FY 2020 resulted in an increase of 8,974 jobs in the State of Ohio. Of the total employment, 1,581 people (17.6%) were directly employed at NASA Glenn Research Center. As a result of NASA Glenn's spending on goods and services purchased in Ohio through their supply chain industries, 4,808 full-time and part-time jobs (53.6%) were supported and created in the region as an indirect economic impact. The remaining 2,585 jobs (28.8%) were created as an induced impact due to consumer spending made by NASA Glenn and suppliers' employees. These industries produce products that are typically purchased by households in the region.

Of the 7,393 jobs created in the State of Ohio due to the indirect and induced effects, 2,823 (38.2%) were found in the NASA Glenn-driven sectors, 2,054 (27.8%) were created in consumer-driven sectors, and 2,517 (34.0%) were created in other sectors.[40]

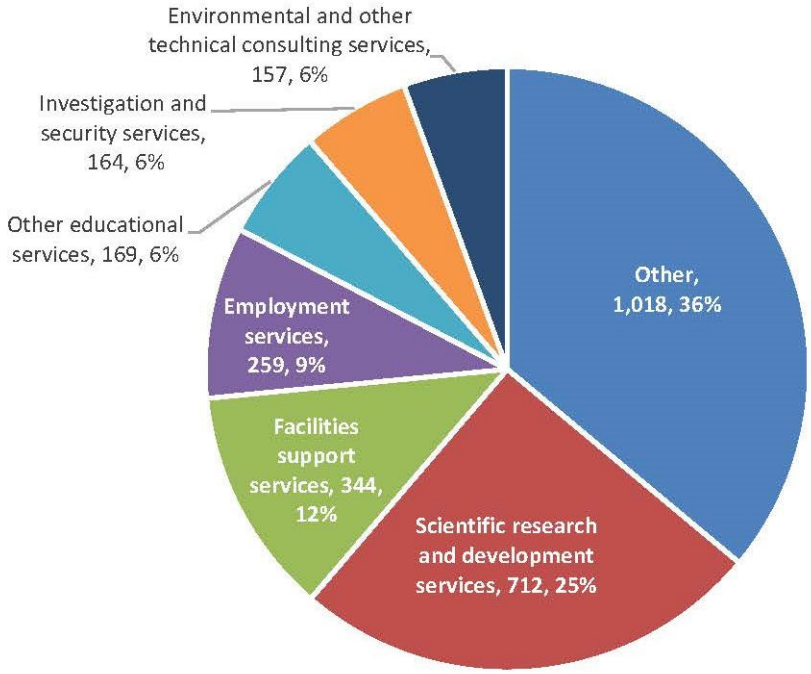
The job distribution by largest industrial sectors for select NASA Glenn-driven and consumer-driven sectors are shown in Figures 15 and 16, respectively. Each of the industries shown in Figure 15 supported or added over 150 jobs (6.0%). Each of the industries shown in Figure 16 supported or added over 80 jobs (4.0%).

Among all NASA Glenn-driven industries, the scientific research and development industry generated the highest number of additional jobs (Figure 15). Companies engaged in scientific R&D (professional, scientific, and technical services sector) increased their employment by 712 jobs and accounted for a 25% share of the 2,823 jobs created across all NASA Glenn-driven industries in FY 2020. This increase in jobs results from totaling the indirect and induced impacts generated primarily, though not exclusively, by NASA Glenn's use of scientific research and development services within the State of Ohio.

The real estate industry saw the largest increase of jobs as a single industry among consumer-driven industries in FY 2020; the increase of 206 jobs was due to NASA Glenn's spending generating jobs in regional supply industries (Figure 16). These jobs equal the total of the direct, indirect, and induced employment impacts generated primarily by NASA Glenn employees and other workers participating in the State of Ohio's real estate sector. These 206 jobs represent a 10% share of the 2,054 jobs created across all consumer-driven industries in the state.

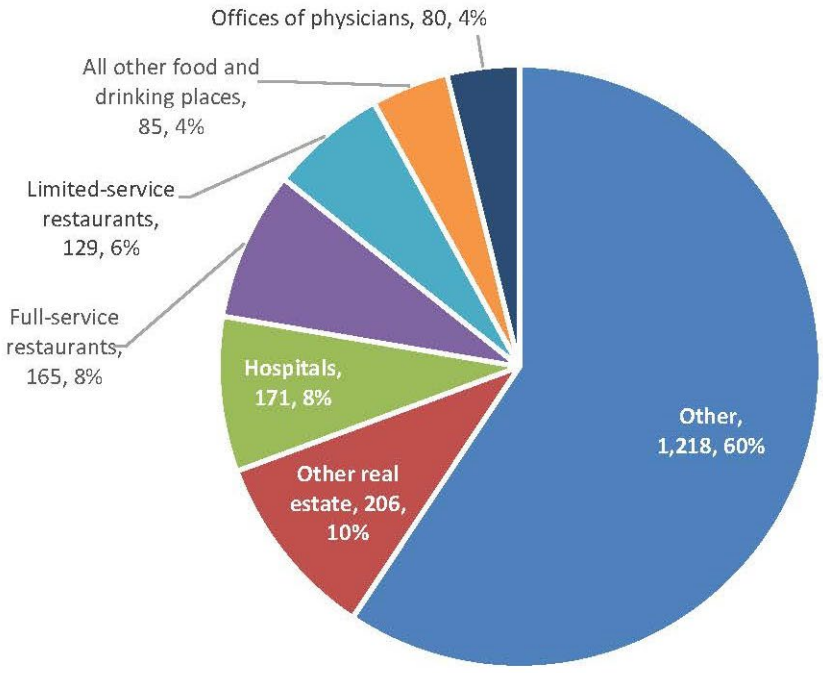
[40] Glenn-driven industries include utilities, construction, information, education, professional and scientific services, and administrative and support services. Consumer-driven industries include retail, healthcare, real estate, other services, owner-occupied buildings, finance and insurance, and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

Figure 15. Increase in Jobs for Select NASA Glenn-Driven Industries in Ohio, FY 2020



Total: 2,823 jobs

Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2020



Total: 2,054 jobs

D.3.3. Labor Income Impact on the State of Ohio, FY 2020

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

Wages and benefits paid to the employees of the companies from which NASA Glenn buys its supplies, and the suppliers of these companies make up the indirect earnings impact. The induced impact was generated through the spending of workers in all industries employed due to the increased demand for products and services created by NASA Glenn. The total earnings impact includes the wages and benefits received by NASA Glenn employees (the direct effect), employees of Glenn's supply chain companies (indirect effect), and employees working in consumer-driven industries (induced effect). The labor income impact by industry is illustrated in Table 13.

Table 13. Labor Income Impact in the State of Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$172,809	$185,338	$358,147
Mining		$802,838	$583,919	$1,386,757
Utilities		$4,469,040	$2,866,303	$7,335,343
Construction		$12,734,379	$1,538,846	$14,273,225
Manufacturing		$4,292,698	$2,913,035	$7,205,733
Wholesale Trade		$3,822,496	$8,703,634	$12,526,130
Retail Trade		$1,861,861	$15,499,025	$17,360,886
Transportation and Warehousing		$3,187,537	$5,332,589	$8,520,126
Information		$3,823,592	$7,175,261	$10,998,853
Finance and Insurance		$7,684,984	$29,874,978	$37,559,963
Real Estate and Rental		$10,055,408	$41,347,990	$51,403,398
Professional, Scientific, and Tech Services		$130,857,992	$12,189,392	$143,047,384
Management of Companies		$7,182,927	$4,216,985	$11,399,911
Administrative and Waste Services		$41,606,228	$7,068,863	$48,675,090
Educational Services		$6,479,029	$3,960,183	$10,439,212
Health and Social Services		$906,660	$41,461,537	$42,368,197
Arts, Entertainment, and Recreation		$471,693	$4,500,711	$4,972,403
Accommodation and Food Services		$2,197,101	$9,865,827	$12,062,928
Other Services		$2,454,318	$12,173,018	$14,627,337
Government & non-NAICs	$242,434,588	$96,676,516	$2,778,018	$349,191,264
Total Labor Income	**$242,434,588**	**$341,740,106**	**$214,235,451**	**$805,712,286**

Notes: For labor income impact, the change in final demand or direct impact equals the wages and benefits paid to NASA Glenn employees. The direct labor income is shown in 2020 dollars.

In FY 2020, the total labor income increased by $805.7 million in the State of Ohio due to NASA Glenn's spending on goods and services. Of this amount, $242.4 million (30.4%) originated from wages and benefits paid directly to NASA Glenn employees (change in final demand, or direct effect measured in 2020 dollars). Of the $805.7 million in total labor income, $341.7 million (42.8%) represented the compensations to employees of companies in the State of Ohio that supply goods and services to NASA Glenn (indirect impact). The remaining induced earnings, estimated to be $214.2 million (26.8%), resulted from NASA Glenn's spending rippling through the Ohio economy via the wages of Glenn's employees and wages of their supply companies.

Of the $556.0 million increase in labor income generated across the State of Ohio due to indirect and induced impacts, $233.3 million (41.9%) was paid in Glenn-driven industries, $147.5 million (26.5%) was paid in consumer-driven industries, and $175.2 million (31.6%) occurred in other industries.[41]

Figure 17 describes the labor income distribution by the industry for select NASA Glenn-driven sectors. The labor income distribution for select consumer-driven industries is shown in Figure 18. The select industries shown in Figures 17 and 18 each added over 4.0% ($9.5 million) and 5.0% ($ 7.9 million), respectively.

Of the NASA Glenn-driven industries, employees in the scientific research and development services industry saw the largest increase in labor income in FY 2020 (Figure 17). Labor income in this sector increased by $74.1 million and accounted for 32% of the $233.3 million total increase in labor income reported by all NASA Glenn-driven industries. These earnings result from totaling the indirect and induced impacts generated by NASA Glenn's purchases of computer-related services.

Private hospitals saw the largest increase in labor income across all consumer-driven industries in FY 2020 (Figure 18). Increasing by $17.0 million, labor income in the private hospitals' sector represented a 12% share of the $147.5 million labor income increase that occurred across all consumer-driven industries. These earnings are the summation of the indirect and induced impacts that occurred by consumer spending on doctors' services.

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

Figure 17. Increase in Labor Income for Select NASA Glenn-Driven Industries in Ohio, FY 2020

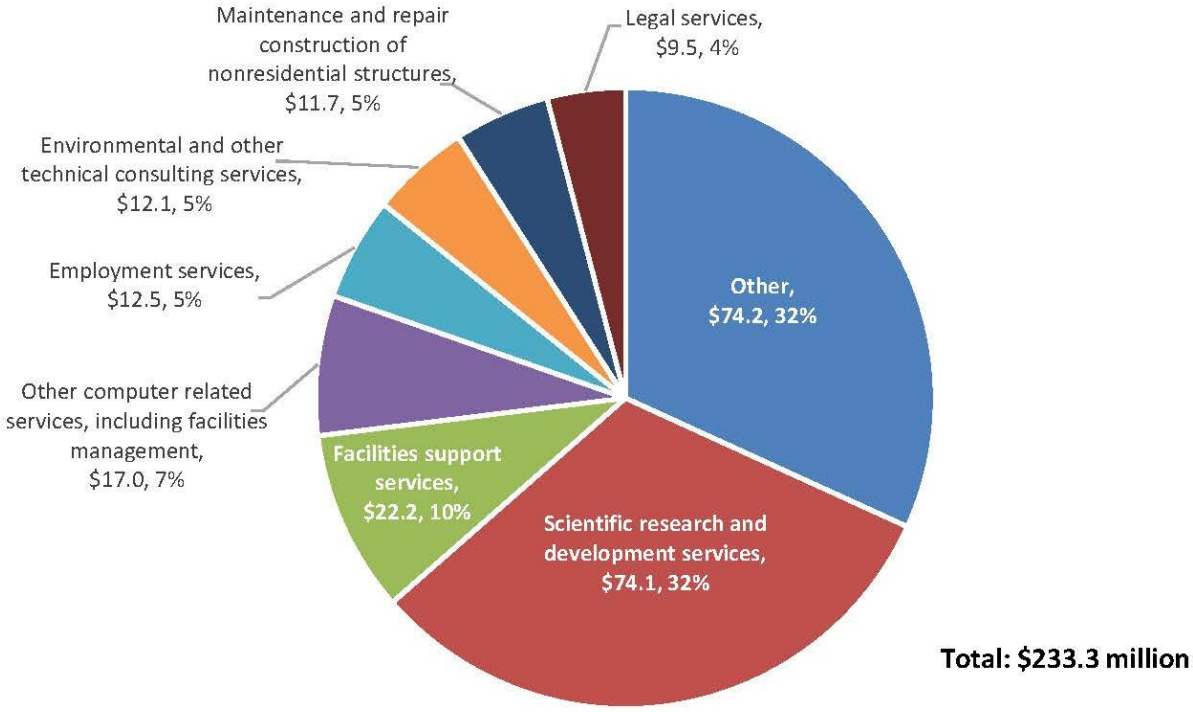
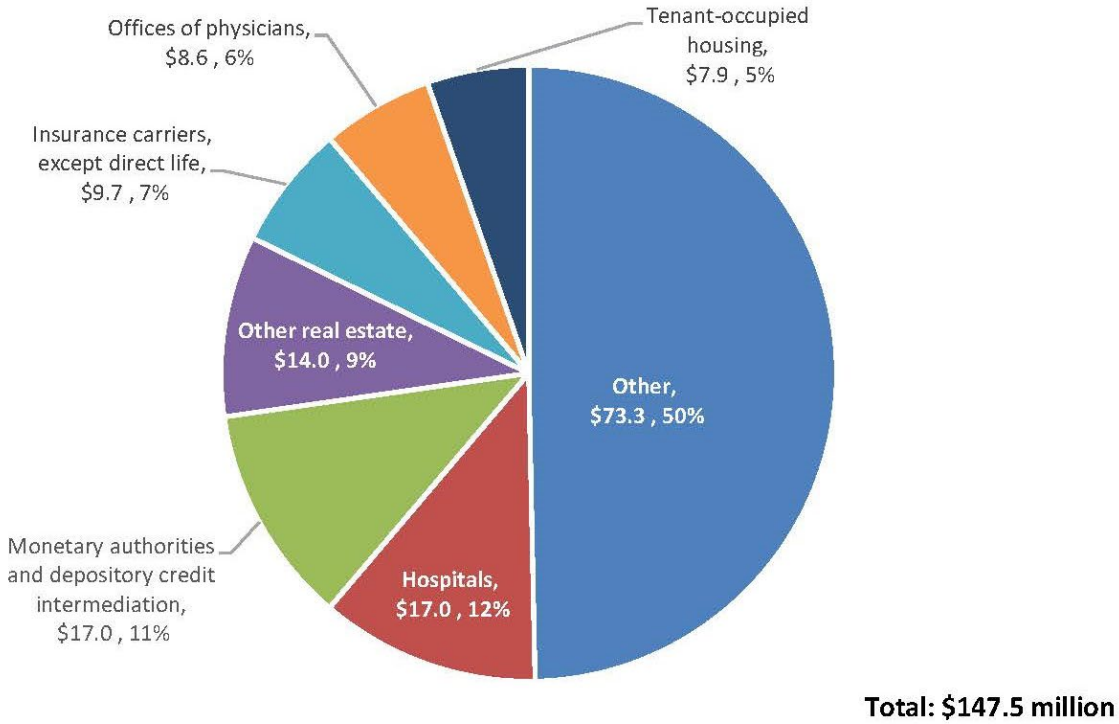


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2020



D.3.4. Value Added Impact on the State of Ohio, FY 2020

NASA Glenn's spending in FY 2020 created an increase of $1.1 billion in value added for all industries.[42] Of this total, $237.7 million (21.5%) was the change in final demand, or direct impact, calculated as total output less intermediate expenditures. Wages and salaries paid to NASA Glenn employees make up the largest portion of the total value added. Another $600.3 million (54.2%) represented the indirect impact – value of goods and services, less intermediary goods, of companies in Ohio that supply products and services to NASA Glenn. The remaining value added impact (the induced component) was estimated at $234.3 million (21.1%). It occurred as a result of NASA Glenn's spending rippling through the Ohio economy. The total value added impact is a result of totaling direct, indirect, and induced impacts (Table 14).[43]

Table 14. Value Added Impact in the State of Ohio, FY 2020

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing and Hunting		$172,128	$181,185	$353,313
Mining		$851,808	$600,431	$1,452,240
Utilities		$5,545,636	$3,605,405	$9,151,040
Construction		$12,931,934	$1,587,412	$14,519,346
Manufacturing		$4,425,100	$3,085,961	$7,511,062
Wholesale Trade		$4,732,600	$10,851,787	$15,584,387
Retail Trade		$2,509,813	$20,064,337	$22,574,151
Transportation and Warehousing		$3,402,716	$5,717,607	$9,120,323
Information		$4,237,395	$8,042,295	$12,279,691
Finance and Insurance		$7,903,470	$30,905,451	$38,808,920
Real Estate and Rental		$10,749,851	$47,054,837	$57,804,688
Professional, Scientific, and Tech Services		$133,628,034	$12,379,862	$146,007,896
Management of Companies		$7,325,715	$4,300,755	$11,626,470
Administrative and Waste Services		$43,293,672	$7,407,561	$50,701,233
Educational Services		$6,790,672	$4,089,512	$10,880,184
Health and Social Services		$918,973	$42,129,482	$43,048,455
Arts, Entertainment, and Recreation		$518,734	$4,926,809	$5,445,542
Accommodation and Food Services		$2,444,706	$11,200,544	$13,645,250
Other Services		$2,809,818	$13,700,628	$16,510,446
Government & non-NAICs	$273,652,746	$345,101,163	$2,439,354	$621,193,263
Total Value Added	**$273,652,746**	**$600,293,937**	**$234,271,215**	**$1,108,217,898**

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

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

Total value added in the State of Ohio increased by $1.1 billion as a result of NASA Glenn's spending for goods and services in FY 2020. Of this total amount, $273.7 million (21.5%) included the wages and benefits paid directly to NASA Glenn employees (change in final demand or direct impact). Another $600.3 million (54.2%) represented the value of goods and services (less intermediary goods) created by supply companies to NASA Glenn in Ohio (indirect impact). The remaining value added impact (induced component), estimated to be $234.3 million (21.1%), occurred as the effects of NASA Glenn's spending rippled through the Ohio economy.

Of the $834.6 million increase in value added generated across Ohio due to indirect and induced impacts, $240.9 million (28.9%) was reported in NASA Glenn-driven industries, $158.9 million (19.0%) was generated in consumer-driven industries, and $434.9 million (52.1%) was reported in other industries.

Figure 19 details the value added distribution for select NASA Glenn-driven industries, and Figure 20 shows the value added distribution for select consumer-driven industries. Select industries in Figure 19 and Figure 20 added at least $9 million (4%) and $8 million (6%), respectively.

The scientific research and development services industry saw the largest increase in value added of all NASA-Glenn driven industries, with its value added totaling $75.8 million (Figure 19). This increase in value added is the result of totaling indirect and induced impacts that are generated primarily, though not exclusively, by NASA Glenn's spending on facilities support services. The $75.8 million accounted for 32% of the $240.9 million value added increase that was reported across all NASA Glenn-driven industries.

In the consumer-driven industries, employees working in private hospitals and banks saw their value added increase by $17.4 million in each of these two sectors in FY 2020 (Figure 20). This value added increase is a result of totaling the indirect and induced impacts generated by consumer spending within each industry. The increase of $17.4 million accounted for 11% in each of these two industries of the $158.9 million value added increase that occurred across all consumer-driven industries.

Figure 19. Increase in Value Added for NASA Glenn-Driven Industries in Ohio, FY 2020

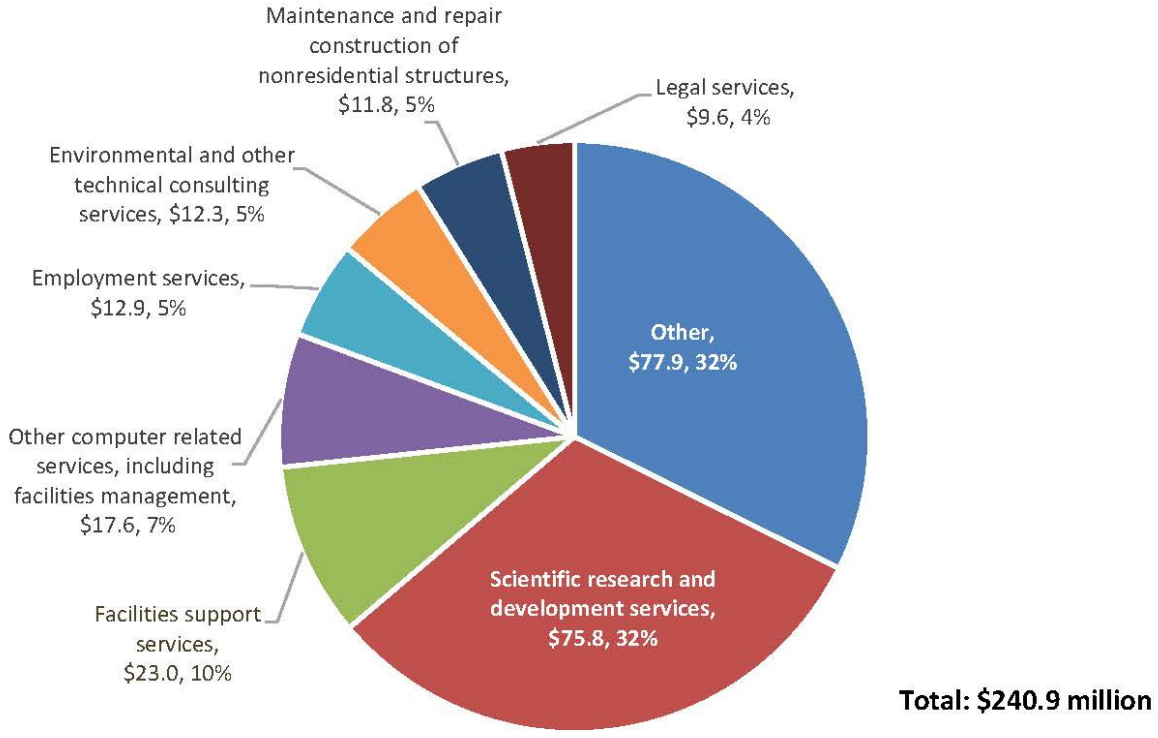
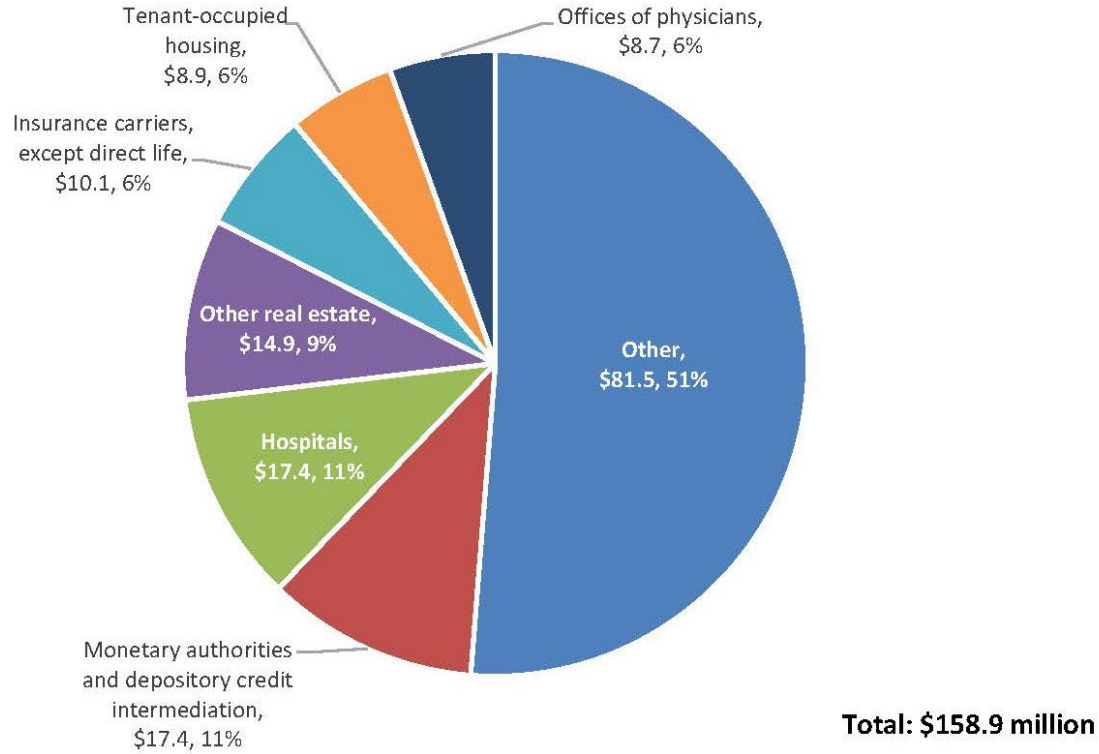


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2020



D.3.5. Tax Impact on the State of Ohio, FY 2020

NASA Glenn's operations and economic impact on the state of Ohio in FY 2020 increased tax revenues by a total of $154.6 million. Of this total amount, direct tax impact to all levels of government was $32.1 million in Glenn's employee taxes on wages. $44.1 million were paid in taxes to the state and local governments in the state of Ohio, including $23.0 million in state tax.

D.3.6. FY 2020 Ohio Impact Summary

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

- Total Output Impact: $1,800.1 M
- Total Employment Impact: 8,974 jobs
- Total Labor Income Impact: $805.7 M
- Total Value Added Impact: $1,108.2 M
- Total Tax Impact: $154.6 M

NASA Glenn's expenditures on the state of Ohio are slightly higher than the economic impact on Northeast Ohio because the models capture more buy-sell relationships in the larger geographic area and the modeling economic impact through the MRIO model allows capturing benefits across all areas of the state. The majority of NASA Glenn's expenditures in Ohio were spent in Northeast Ohio.

In FY 2020, NASA Glenn's expenditures in the State of Ohio totaled to $558.5 million, including $242.4 million (43.4%) in labor income. The total expenditures in all of Ohio were $17.8 million more than in the total expenditures in Northeast Ohio.

Similarly, to the expenditures made in Northeast Ohio in FY 2020, the largest share of the total payments, $201.1 was spent on professional, scientific, and technical services. Excluding labor income, this constitutes 63.6% of all expenditures. In addition, $61.8 million was paid for administrative and support and waste management and remediation services (19.6%), $27.8 (8.8%) for construction, $13.1 million (4.1%) for educational services, and $5.6 million (1.8%) for utilities. These five largest areas of spending accounted for $309.3 or 98% of all non-labor expenditures in FY 2020.[44]

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

[44] Amounts in parentheses detailing percentage numbers are presented in 2020 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2020

Region	Total	Share
Ohio	$316,040,404	50.7%
California	$129,855,274	20.9%
Alabama	$43,631,282	7.0%
Washington	$36,721,975	5.9%
Illinois	$14,564,074	2.3%
Maryland	$9,565,116	1.5%
Texas	$8,049,776	1.3%
New York	$7,703,798	1.2%
Colorado	$7,126,127	1.1%
Massachusetts	$6,797,087	1.1%
Connecticut	$5,717,103	0.9%
Florida	$4,978,953	0.8%
Virginia	$4,711,721	0.8%
New Jersey	$3,787,529	0.6%
Pennsylvania	$3,536,237	0.6%
Indiana	$2,895,018	0.5%
Missouri	$2,251,144	0.4%
Arizona	$1,841,836	0.3%
New Hampshire	$1,839,903	0.3%
Michigan	$1,707,722	0.3%
New Mexico	$1,414,814	0.2%
Wisconsin	$1,338,988	0.2%
Georgia	$1,081,115	0.2%
Oregon	$895,458	0.1%
Minnesota	$771,134	0.1%
District of Columbia	$754,863	0.1%
North Carolina	$569,250	0.1%
North Dakota	$557,009	0.1%
Iowa	$375,268	0.1%
Montana	$367,146	0.1%
Delaware	$196,026	0.0%
Kansas	$156,290	0.0%
Tennessee	$143,686	0.0%
Nevada	$123,672	0.0%
Rhode Island	$119,045	0.0%
Kentucky	$114,934	0.0%
Oklahoma	$100,972	0.0%
South Carolina	$92,839	0.0%
Mississippi	$78,135	0.0%

Region	Total	Share
South Dakota	$72,199	0.0%
Idaho	$29,383	0.0%
Utah	$29,126	0.0%
Vermont	$27,900	0.0%
Wyoming	$20,363	0.0%
West Virginia	$13,638	0.0%
Nebraska	$1,208	0.0%
Arkansas	$82	0.0%
Alaska	$0	0.0%
U.S. Total (No PR & LA)	**$622,766,620**	**99.9%**
Great Britain	$232,494	0.0%
Canada	$158,931	0.0%
Switzerland	$153,524	0.0%
Germany	$138,387	0.0%
Japan	$61,632	0.0%
South Korea	$28,254	0.0%
Australia	$21,142	0.0%
Denmark	$7,077	0.0%
France	-$226	0.0%
Foreign Total	**$801,215**	**0.1%**
Grand Total	**$623,567,835**	**100.0%**

Table A.2. NASA Glenn Grants Allocated to Academic Institutions by State, FY 2020

State	College / University	Share
California	$1,424,192	13.7%
Ohio	$1,089,134	10.5%
Maryland	$1,062,089	10.2%
Texas	$806,534	7.8%
Georgia	$755,688	7.3%
Florida	$587,135	5.7%
Michigan	$529,299	5.1%
Illinois	$520,789	5.0%
New York	$496,945	4.8%
Pennsylvania	$418,476	4.0%
Connecticut	$370,630	3.6%
Massachusetts	$318,926	3.1%
Colorado	$309,840	3.0%
Indiana	$226,596	2.2%
Arizona	$166,169	1.6%
North Carolina	$155,051	1.5%
Iowa	$149,223	1.4%
Virginia	$138,303	1.3%
Oregon	$137,075	1.3%
New Jersey	$134,552	1.3%
New Mexico	$106,703	1.0%
Missouri	$91,986	0.9%
Mississippi	$77,824	0.8%
Kansas	$70,956	0.7%
Washington	$67,189	0.6%
South Carolina	$44,262	0.4%
Kentucky	$39,678	0.4%
South Dakota	$34,820	0.3%
New Hampshire	$16,763	0.2%
Idaho	$5,207	0.1%
Minnesota	$2,001	0.0%
Outside US	$20,000	0.0%
Total	**$10,374,035**	**100%**

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2020

	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			**$5,468,166**
	Electric power transmission and distribution	47	$3,226,403
	Natural gas distribution	48	$407,896
	Water, sewage and other systems	49	$1,833,866
Construction			**$27,750,111**
	Construction of other new nonresidential structures	56	$4,044,226
	Maintenance and repair construction of nonresidential structures	60	$23,705,885
Manufacturing			**$696,215**
	Printing	152	$185
	Aluminum sheet, plate, and foil manufacturing	221	$12,607
	Nonferrous metal, except copper and aluminum, shaping	225	$49,015
	Sheet metal work manufacturing	239	$49,340
	Hardware manufacturing	245	$15,950
	Spring and wire product manufacturing	246	$14,801
	Machine shops	247	$337,631
	Turned product and screw, nut, and bolt manufacturing	248	$20,214
	Metal heat treating	249	$440
	Pump and pumping equipment manufacturing	285	$83,615
	Industrial process furnace and oven manufacturing	294	$3,000
	Audio and video equipment manufacturing	304	$10,849
	Semiconductor and related device manufacturing	307	$27,649
	Watch, clock, and other measuring and controlling device manufacturing	319	$70,919
Wholesale Trade & Retail Trade			**$2,277,617**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$567,353
	Retail - Miscellaneous store retailers	412	$1,710,264
Transportation and Warehousing			**$8,934**
	Truck transportation	417	$8,934
Information			**$2,692**
	News syndicates, libraries, archives and all other information services	437	$2,692
Real Estate and Rental and Leasing			**$9,809**
	Commercial and industrial machinery and equipment rental and leasing	453	$9,809
Professional, Scientific, and Technical Services			**$191,502,978**
	Legal services	455	$1,000
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,106,896
	Architectural, engineering, and related services	457	$7,162,726
	Other computer related services, including facilities management	461	$30,679,639
	Management consulting services	462	$3,186,445

	Description	IMPLAN Sector (a)	Expenditure (b)
	Environmental and other technical consulting services	463	$18,163,636
	Scientific research and development services	464	$128,029,217
	Marketing research and all other miscellaneous professional, scientific, and technical services	468	$173,418
Administrative and Support and Waste Management and Remediation Services			**$61,805,428**
	Facilities support services	471	$52,347,083
	Investigation and security services	475	$7,137,947
	Services to buildings	476	$2,148,822
	Other support services	478	$1
	Waste management and remediation services	479	$171,575
Educational Services			**$12,662,776**
	Junior colleges, colleges, universities, and professional schools	481	$694,352
	Other educational services	482	$11,968,424
Health Care and Social Assistance			**$1,566,205**
	Medical and diagnostic laboratories	487	$43,605
	Other ambulatory health care services	489	$1,522,600
Labor Income			**$236,928,612**
	Employee Compensation (c)		$236,928,612
TOTAL EXPENDITURES IN NEO			**$540,679,541**

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 2020. 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 paid in Northeast Ohio.

Table A.4. NASA Glenn Detailed Expenditures in the State of Ohio, FY 2020

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			**$5,574,423**
	Electric power transmission and distribution	47	$3,226,403
	Natural gas distribution	48	$407,896
	Water, sewage and other systems	49	$1,940,124
Construction			**$27,750,111**
	Construction of other new nonresidential structures	56	$4,044,226
	Maintenance and repair construction of nonresidential structures	60	$23,705,885
Manufacturing			**$2,039,661**
	Printing	152	$185
	Plastics material and resin manufacturing	164	$301,970
	Aluminum sheet, plate, and foil manufacturing	221	$12,607
	Nonferrous metal (exc aluminum) smelting and refining	223	$25,200
	Nonferrous metal, except copper and aluminum, shaping	225	$49,015
	Sheet metal work manufacturing	239	$49,340
	Metal tank (heavy gauge) manufacturing	242	$15,020
	Hardware manufacturing	245	$15,950
	Spring and wire product manufacturing	246	$14,801
	Machine shops	247	$373,274
	Turned product and screw, nut, and bolt manufacturing	248	$20,214
	Metal heat treating	249	$1,797
	Valve and fittings, other than plumbing, manufacturing	252	$270,098
	Machine tool manufacturing	279	$181,650
	Pump and pumping equipment manufacturing	285	$83,615
	Industrial process furnace and oven manufacturing	294	$375,258
	Scales, balances, and miscellaneous general purpose machinery manufacturing	297	$7,815
	Audio and video equipment manufacturing	304	$35,369
	Semiconductor and related device manufacturing	307	$27,649
	Industrial process variable instruments manufacturing	314	$62,354
	Watch, clock, and other measuring and controlling device manufacturing	319	$70,919
	Other aircraft parts and auxiliary equipment manufacturing	356	$45,562
Wholesale Trade & Retail Trade			**$2,562,882**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$567,353
	Retail - Building material and garden equipment and supplies stores	405	$106,164
	Retail - Miscellaneous store retailers	412	$1,889,365
Transportation and Warehousing			**$9,175**
	Truck transportation	417	$9,175
Information			**$31,790**

NAICS Sector	Description	IMPLAN Sector (a)	Expenditure (b)
	Software publishers	428	$17,350
	News syndicates, libraries, archives and all other information services	437	$2,692
	Internet publishing and broadcasting and web search portals	438	$11,748
Real Estate and Rental and Leasing			**$9,809**
	Commercial and industrial machinery and equipment rental and leasing	453	$9,809
Professional, Scientific, and Technical Services			**$201,079,070**
	Legal services	455	$1,000
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,106,896
	Architectural, engineering, and related services	457	$8,302,153
	Custom computer programming services	459	$16,615
	Other computer related services, including facilities management	461	$30,679,639
	Management consulting services	462	$3,186,445
	Environmental and other technical consulting services	463	$18,163,636
	Scientific research and development services	464	$136,432,178
	Marketing research & all other miscellaneous professional, scientific, & technical services	468	$190,506
Administrative & Support & Waste Management & Remediation Services			**$61,827,668**
	Facilities support services	471	$52,369,324
	Investigation and security services	475	$7,137,947
	Services to buildings	476	$2,148,822
	Other support services	478	$1
	Waste management and remediation services	479	$171,575
Educational Services			**$13,057,558**
	Junior colleges, colleges, universities, and professional schools	481	$1,089,134
	Other educational services	482	$11,968,424
Health Care and Social Assistance			**$1,566,205**
	Medical and diagnostic laboratories	487	$43,605
	Other ambulatory health care services	489	$1,522,600
Other Services (except Public Administration)			**$532,052**
	Grantmaking, giving, and social advocacy organizations	522	$173,114
	Other federal government enterprises	528	$358,938
Labor Income			**$242,434,588**
	Employee Compensation (c)		$242,434,588
TOTAL EXPENDITURES IN OHIO			**$558,474,992**

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 2020. 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 paid in Ohio.