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College of Urban Affairs

Prepared for:
NASA JOHN H. GLENN RESEARCH CENTER

Prepared by:
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The NASA John H. Glenn Research Center:

An Economic Impact Study Fiscal Year 2021

June 2022

CENTER FOR ECONOMIC DEVELOPMENT

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THE NASA JOHN H. GLENN RESEARCH CENTER: AN ECONOMIC IMPACT STUDY FISCAL YEAR 2021

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Acknowledgments

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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), located in 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 $4.15 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 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) 2021. 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

In FY 2021, the NASA Glenn Research Center continued creating the economic impacts on 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 to all levels of governments. This study uses Multi-Regional Input-Output model and methodology (MRIO) to measure NASA Glenn's impact on the economies of Northeast Ohio and Ohio based on the inter-relationships of two connected regions. This methodology is the same as was used to prepare the FY 2020 Economic Impact Study and is comparable with previous studies. The MRIO analysis better accounts for the Ohio regional supply chain, calculating the impact for the larger region as the economic impact of NASA Glenn on Northeast Ohio and on the remainder of Ohio.

This report illustrates complete economic impact on two regions using detailed economic sectors and illustrates the impact using five main indicators: output, employment, value added, labor income and taxes. Each indicator is detailed with direct, indirect, and induced components of economic impact. The table below summarizes NASA Glenn's economic impact on Northeast Ohio and the State of Ohio during FY 2021.

Economic Impact	Northeast Ohio	State of Ohio
Output	$1,769.6 million	$1,937.1 million
Value Added	$1,094.3 million	$1,182.9 million
Employment	8,393 jobs	9,095 jobs
Labor Income	$805.4 million	$853.4 million
Taxes	$167.7 million	$210.7 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. All values are in 2022 dollars.

- In FY 2021, NASA Glenn's $557.3 million of direct spending in Northeast Ohio (in 2021 dollars) created a total output economic impact of $1.77 billion across all industry sectors. The value added increased by $1.1 billion as a result of NASA Glenn's operations funded primarily by dollars external to the region. In addition, 8,393 jobs were created and supported in the region, and labor income in Northeast Ohio increased by $805.4 million. NASA Glenn's operations in Northeast Ohio also generated $167.7 million in local, state, and federal tax revenue.
- NASA Glenn's activities in Ohio in FY 2021 were stimulated by $595.6 million in direct spending in the state (in 2021 dollars). This funding was originating primarily from outside of the state and generated an increased demand in output (sales) for products and services valued at $1.9 billion.
- Ohio value added increased by $1.2 billion as a result of NASA Glenn's activities in the state. In addition, 9,095 jobs were created

and supported in Ohio, and labor income across the state increased by $853.4 million. NASA Glenn operations in Ohio also generated $210.7 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 2021, NASA Glenn had 1,537 civil service employees, including 323 Administrative Professionals (21%), 15 Clerical workers (1%), 1,137 Scientists & Engineers (74%), and 61 Technicians (4%). Compared to FY 2020, the total Glenn civil service employment has decreased by 44 workers, losing 25 employees in the Administrative Professional category, 17 in the Scientists & Engineers category, and 16 in the Technical occupation category.
- The civil service employees at NASA Glenn are highly educated and skilled. 90.4% of civil service employees had a bachelor's degree or higher in FY 2021. Specifically, of the total of NASA Glenn's civil service employees, 18.5% held doctoral degrees, 39.4% held master's degrees, and 32.4% held bachelor's degrees.[2]
- In FY 2021, the largest occupational category was Scientists & Engineers. This occupation has continued to be the largest occupation across all categories over the last five years, a historical trend that has sustained since before FY 2017. The Scientists & Engineers accounted for 74% of the civil service employees at NASA Glenn in FY 2021.
- The total number of NASA Glenn employees, including civil service employees and local contractors in FY 2021, was 3,282. This showed a decrease of 42 workers from FY 2020 to FY 2021. During the last five years, the highest total combined employment was 3,324 in FY 2019.
- The total compensation NASA Glenn civil service employees received was $255.7 million during FY 2021. Total compensation included both payroll, $189.9 million, and employee benefits, $65.9 million.
- Total compensation increased by $4.5 million (7.4%) between FY 2020 and FY 2021, in nominal dollars. In the same time period, NASA Glenn's nominal payroll has increased by $5.3 million (2.9%).
- From FY 2017 to FY 2021, total compensation increased by $23.4 million (10.1%) from $232.3 million in FY 2017 to $255.7 million in FY 2021, and the payroll increased by $12.1 million (6.8%) in nominal dollars.
- In FY 2021, vendors from 41 states, the District of Columbia, and ten foreign countries received a share of NASA Glenn expenditures, which totaled $570.5 million.

[2] These counts do not include Student Trainees.

These expenditures are 8.5% less than total expenditures in FY 2020 of $623.6 million, decreasing total spending by $53.1 million in nominal dollars. This translates to decrease of $84.4 million (12.6%) between FY 2020 and FY 2021 after adjusting for inflation.

- Once again, Ohio continues to receive the largest share of the total expenditures with $344.8 million going to state vendors in FY 2021. The expenditures made in Ohio accounted for 60.4% of NASA Glenn's total spending and reflecting a $28.7 million increase in nominal dollars from FY 2020. [3]
- Over 90% of NASA Glenn's total expenditures in the State of Ohio in FY 2021 went to Northeast Ohio, with the region's vendors receiving a total of $312.3 million. Cuyahoga County received the largest share of expenditures spent both within Northeast Ohio and in the State of Ohio, receiving 98.7% and 89.5%, respectively.
- After Ohio, California received the second largest share of NASA Glenn spending in FY 2021 receiving $100.9 million, 17.7% of total expenditures and a 22.3 percent drop from FY 2020. Alabama received the third-largest share of expenditures in FY 2021, 6.9% of total expenditure, or $39.6 million, despite experiencing a decline of $4 million, or 9.3% (in nominal dollars). Washington and Maryland received the fourth and fifth largest share of expenditures in FY 2021.
- NASA Glenn's expenditures in foreign countries decreased from $0.8 million to $0.25 million in nominal dollars between FY 2020 and FY 2021. Despite a 31% decrease in funding that totaled $0.55 million, Great Britain was the largest beneficiary of the foreign countries that received NASA Glenn's contracts.
- In FY 2021, NASA Glenn awarded $13.6 million to colleges and universities in 31 states. Grants accounted for $7.9 million in this total. Funding to academic institutions increased by $0.4 million (3.3%) between FY 2020 and FY 2021 in nominal dollars. NASA Glenn also awarded $5.7 million in contracts to Ohio academic institutions in FY 2021 through on-site contracts. The academic funding allocated to the top five states — Ohio, California, Georgia, Maryland, and Illinois — in FY 2021 accounted for 68% of the total awards, compared to 60.3% of total grants made to the top five states during FY 2020.
- Ohio experienced the largest nominal increase of $2.4 million (62%) in awards between FY 2020 and FY 2021, and Illinois had a nominal increase of $92 thousand (18%). Maryland and California saw large decreases in awards between FY 2020 and FY 2021, losing $0.4 million (38%) and $0.5 million (34%), respectively, while Georgia experiences a $7.7 thousand decrease (1%).
- Northeast Ohio received 48% of the $6.3 million awarded to all of Ohio, totaling $3 million. Northeast Ohio received 22% of all academic funding given by NASA Glenn in FY 2021. Northeast Ohio's share of awards decreased at the state level (66.7% of total Ohio awards in FY 2021), but the real amount in fact increased by 62% ($2.4 million).
- Of all Ohio universities that received funding, the University of Toledo and Case Western Reserve University (CWRU) continued receiving the most significant awards of all Ohio academic institutions in FY 2021. The two universities combined accounted for 80.2% of NASA Glenn Awards to Ohio academic institutions. The University of Toledo received $2.7 million (42.2% of the total), and CWRU received over $2.4 million

[3] Total expenditures increased by $28.7 million in nominal dollars and $13.9 million in real dollars adjusted for inflation between FY 2020 and FY 2021.

(38% of the total) in FY 2021. For CWRU, this was in fact a $0.16 million or 6.3% decrease in funding between FY 2017 and FY 2021. For the University of Toledo, this was a $0.63 million or 31% decrease during the last five years (adjusted to 2021 dollars).

- The University of Akron was awarded $557,750 (8.8% of the total) in FY 2021 and received the third-highest share of the total funding to Ohio academic institutions. The Ohio State University received $524,488 (8.3%) and ranked fourth. The remainder of the FY 2021 awards from NASA Glenn to Ohio academic institutions went to Ohio University ($97,032 or 1.5%), Kent State University ($40,664 or 0.6%), Cleveland State University ($32,280 or 0.5%) and the University of Cincinnati ($4,997 or 0.1%).
- In FY 2021, total revenue reached $829.8 million. Without adjusting for inflation, this is a 4.1% decrease from FY 2020. NASA Glenn's revenues have increased by 20.1% since FY 2017, ranging from $691.1 million in FY 2017 to $829.8 million in FY 2021 in nominal dollars. The largest share of revenue from reimbursable commitments came from Federal funding, accounting for 82.4%. The Department of Defense accounted for the largest share of total reimbursable commitment in FY 2021, contributing 56.7%.
- Total income tax paid by NASA Glenn employees totaled $33.1 million in FY 2021. This is a 3.1% increase from FY 2020. Excluding federal taxes, NASA Glenn employees paid $9.5 million in income taxes at the state and local levels in FY 2021, a 2.8% increase from FY 2020, in nominal dollars. The amount of taxes paid to local and state governments has increased steadily between FY 2017 and FY 2020, rising from $8.9 million in FY 2017 to $9.5 million in FY 2021.
- 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 the results of the economic impact analysis 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 2021.[4] 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.[5] Since NEO is a part of Ohio, this study is conducted using Multi-Regional Input-Output (MRIO) analysis, where economic impact is estimated on interconnected two regions, Northeast Ohio and the rest of the state of Ohio defined as Ohio less Northeast Ohio. 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 a descriptive analysis 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 2021. 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 2021 report is an update to previous studies published in 1996, 2000, 2005, and annually from 2007 through 2020.[6]

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

[5] 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.

[6] 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.[7]

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 $4.15 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.

[7] 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).
- Conducted Orion spacecraft qualification environmental testing at Glenn's Armstrong Test Facility of the fully integrated Orion ESM-CM in support of the Artemis I, Exploration Mission -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 (EUS) 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 Block 1B configuration of the SLS. The USA integrates the EUS to the Orion spacecraft and the comanifested payloads on the EUS while providing structural, electrical, and communication paths. The USA will also provide environmental control to payloads during integrated ground operations, launch, and ascent phases.
- 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 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 microgravity experiments and research apparatus in the physical science fields of combustion

science, fluid physics and transport phenomena, and soft matter dynamics, which are conducted on the International Space Station.

- 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 radio frequency 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 provided as NASA equipment to Space Science Missions, such as the Double Asteroid Redirection Test (DART).
- Contributions to the 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).
- Conducting airborne monitoring of harmful algal blooms, in fresh water such as Lake Erie, using hyperspectral sensors. This is 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 and Nuclear 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 lunar surface 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. GRC's T2X team conducted significant groundwork for the NASA Entrepreneurial Academy, FedTech, Tech Center, Parallel 18, and other similar programs, coordinating over 25 technology submissions with related inventor support. These efforts resulted in 16 patented technology selections, six licenses, and significant network growth. GRC's T2X also supported T2U programs with Youngstown State University, Baldwin Wallace University, and engaged in conversations with Northeast Ohio's National Institute of Standards and Technology Manufacturing Extension Partnership, MAGNET, Confluence Engineering LLC, and other local university and industry partners.
- The NASA Glenn Tech Transfer Office Licensing Team licensed 24 different NASA Glenn technologies through 18 new license agreements and two new Data Usage Agreements. The Glenn Tech Transfer Office hosted several webinars which featured a Glenn inventor presenting an overview of one of their patented technologies, and a brief discussion of licensing and partnering with Glenn presented by a Glenn Technology Manager. These webinars have resulted in numerous licensing leads for each of the technologies presented.

- 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 sustainability 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.
- Supporting the Aeronautics Evaluation and Test Capabilities Portfolio, 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.

- Conducting research in the Convergent Aeronautics Solutions Project, pursuing short duration activities to establish early-stage innovative concepts 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.
- Providing technical leadership for the Electrified Powertrain Flight Demonstrator Project to accelerate US industry technology readiness of integrated Mega Watt-class electrified powertrain for the next generation single aisle (150 – 200 passenger seat class) commercial transport aircraft. By increasing the power density of powertrain components, this demonstration will advance knowledge, technologies, and concepts enabling the next generation of sustainable commercial transports.

C. NASA GLENN RESEARCH CENTER: ECONOMIC OVERVIEW

This section presents an economic overview of the NASA Glenn Research Center during FY 2021. This analysis offers information on changes between FY 2017 and FY 2021 on 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 illustrate the large impact of NASA Glenn -- a large research enterprise that stimulates regional innovation and provides a significant economic impact on Northeast Ohio and Ohio.

C.1. EMPLOYMENT AND OCCUPATIONS

NASA Glenn Research Center's total employment has two components: Civil service employees and local contractors. This is a common practice among federal laboratories, since contracted employees allow for more flexibility and lower labor costs. The number of contracted employees can be adjusted to align with NASA Glenn's new projects and scope of work. Civil service employment is maintained in order to retain those workers with core expertise that are essential for the continuity of research and efficient operations. Civil Service employment distribution is made up of four main categories: (1) administrative professionals, (2) clerical staff, (3) scientists and engineers, and (4) technicians.

Table 1 shows the total number of NASA Glenn's service and their distribution among the four categories. Between FY 2017 and FY 2021, civil service workers average 1,560 annually. The number of civil service employees peaked in 2018 at 1,594 workers, this number has decreased by 57 in 2021, with the most significant decrease in Technicians (50), followed by Clerical (17), and Administrative Professionals (12), while there was an increase in the Scientists & Engineers category.

In FY 2021 NASA Glenn had 1,537 civil service employees and the overall distribution among all occupational categories has only changed slightly. It included 323 Administrative Professionals (21%), 15 Clerical workers (1%), 1,137 Scientists & Engineers (74%), and 61 Technicians (4%).

The total Glenn service employment decreased by 44 workers from FY 2020, losing 25 employees in the Administrative Professional category, 17 in the Scientists & Engineers category, and 2 in the Technicians category, while the Clerical category remained the same.

Table 1. NASA Glenn Civil Service Employment Distribution by Occupational Category, FY 2017-FY 2021

Fiscal Year	Total	Occupational Category			
		Administrative Professional	Clerical	Scientists & Engineers	Technician
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%
2021	1,537	21%	1%	74%	4%

Note: The table does not include local contractors.[8]

[8] 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 2021, the largest occupational category was Scientists & Engineers which has continued to be the largest occupation over the last five years and historically before FY 2017. The Scientists & Engineers account for 74% of the civil service employees at NASA Glenn in FY 2021.

The second largest occupational group was Administrative Professionals. They accounted for 21% of NASA Glenn employees in FY 2021. This category decreased by 1% from 22% in FY 2020 to 21% in FY 2021 but remains as the second largest category.

The share of technicians employed by NASA Glenn was maintained at 4% from FY 2020 to FY 2021 despite a decline (2) in the number of employees. Compared to FY 2018, the share of technicians in FY 2021 decreased by 3% (50 employees).

Over the last five years, the clerical category has continued to be the smallest occupational category among civil service employees, ranging from 1% to 2%, and between 15 and 32 employees. This category had 32 employees at its peak in 2018 and has continually dropped since, standing at 15 employees in 2021.

NASA Glenn's civil employees are highly educated and skilled. About 90% of civil service employees had a bachelor's degree or higher in FY 2021. Of the total NASA Glenn's civil service workforce, 18.5% held a doctorate degree, 39.4% held a master's degree, and 32.4% held a bachelor's degree. Compared to FY 2020 the level of educational attainment of NASA Glenn's civil employees has remained the same.[9]

In addition to its own employees, NASA Glenn also hires contractors. Table 2 shows NASA Glenn on- or near-site contractors' employment over the last five years. In FY 2021 NASA Glenn contracted work to 1,745 on- or near-site contractors. The number of contractors has grown 7% between FY 2017 and FY 2021. NASA Glenn contractor employment ranged from 1,626 to 1,745 over the last five years with an average of 1,695 contractors used per year.

The total number of NASA Glenn employees, including both civil service employees and local contractors in FY 2021, was 3,282. This showed a decrease of 42 workers from FY 2020 to FY 2021. During the last five years, the highest total combined employment was 3,324 in FY 2020, and the lowest was 3,134 in FY 2017.

Table 2. NASA Glenn On- or Near-Site Contractors Employment, FY 2017-FY 2021

Fiscal Year	Employment of On- or Near-Site Contractors
2017	1,626
2018	1,687
2019	1,676
2020	1,743
2021	1,745

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

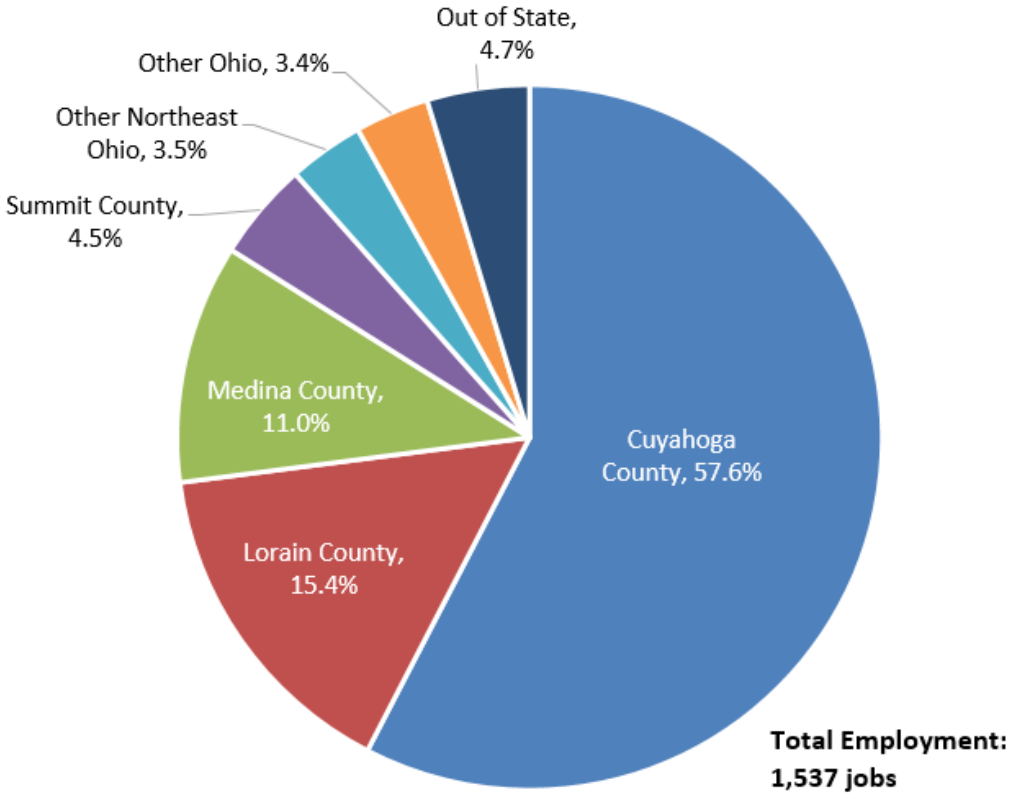
C.2. Place of Residence for Glenn Employees

NASA Glenn Lewis Field is located in Cuyahoga County near Cleveland Hopkins International Airport in Cuyahoga County, the heart of Northeast Ohio. NASA Glenn also operates the Armstrong Test Facility, located near Sandusky, Ohio, in Erie County to the west of Cleveland. Most civil service employees at NASA Glenn live in Cuyahoga County or the other surrounding counties that comprise Northeast Ohio.[10]

Figure 1 shows NASA Glenn civil service employees by employees' postal addresses by geographic region. In FY 2021, 92% (1,413 employees) of NASA Glenn's civil service employees resided in Northeast Ohio. Of the 1,537 total civil servants in FY 2021, 885 employees (57.6%) lived in Cuyahoga County. A significant number of NASA Glenn employees live in Lorain County (236 workers or 15.4%) and Medina County (169 workers or 11%). Summit County accounts for 4.5% (or 69 workers), and the other Northeast Ohio counties held 3.5% of NASA Glenn employee places of residence, and another 3.4% lived in Ohio Counties outside of Northeast Ohio. Only 4.7% of NASA Glenn employees resided outside Ohio.

Compared to FY 2020, the percentage of NASA Glenn employees who reside in Cuyahoga County has decreased by 4%. However, the distribution of NASA Glenn employment across Northeast Ohio and Ohio structurally changed very little between FY 2017 and FY 2021.

Figure 1. NASA Glenn Civil Service Employees by Place of Residence, FY 2021



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

The distribution of NASA Glenn civil service employees by their occupation is shown in Table 3. Cuyahoga County, the location of the NASA Glenn Lewis Field, was the place of residence for the highest share of employees in all occupational categories. In FY 2021, almost 92% of the employees in all four occupations resided in Northeast Ohio. All Clerical employees (100%) lived in Northeast Ohio Technicians and Technicians were second occupation likely to live in Northeast Ohio, at 98.4%. Approximately 7% and 9% of NASA Glenn's Administrative Professional and Scientist & Engineers lived outside of Northeast Ohio. Almost 53% of Administrative Professional, 77% of Clerical, 59% of Scientists & Engineers, and 47% of NASA Glenn's Technicians lived in Cuyahoga County in FY 2021. Of all of NASA Glenn civil service employees, Scientists & Engineers were the most likely to have postal addresses out of state, at 5.4%, while 100% of Technicians live in Ohio.

Table 3. NASA Glenn Civil Service Employees by Occupation and Place of Residence, FY 2021

Residence	Administrative Professional	Clerical	Scientists & Engineers	Technicians	Total
Northeast Ohio	93.0%	100.0%	91.2%	98.4%	91.9%
Cuyahoga County	52.9%	76.9%	59.4%	46.9%	57.6%
Lorain County	18.7%	23.1%	13.7%	26.6%	15.4%
Medina County	11.9%	0.0%	10.5%	17.2%	11.0%
Summit County	6.7%	0.0%	4.0%	3.1%	4.5%
Lake County	0.6%	0.0%	1.4%	1.6%	1.2%
Geauga County	0.0%	0.0%	1.4%	1.6%	1.1%
Portage County	1.5%	0.0%	0.8%	0.0%	0.9%
Ashtabula County	0.6%	0.0%	0.0%	1.6%	0.2%
Other Ohio	3.7%	0.0%	3.4%	1.6%	3.4%
Out of State	3.4%	0.0%	5.4%	0.0%	4.7%

Note: Northeast Ohio component counties sorted by total.

C.3. PAYROLL

Total compensation received by NASA Glenn civil service employees in FY 2021 amounted $255.8 million (in 2021 dollars). This includes $189.9 million in Payroll and $65.9 million in employee benefits. The total compensation increased by $9.8 million (4%) between FY 2020 and FY 2021, in nominal dollars.[11] In this same period, NASA Glenn's nominal payroll has increased by $5.3 million or 3%.[12] Since 2017, total compensation increased by $23.4 million (10.1%) from $232.3 million in FY 2017 to $255.7 million in FY 2021,[13] and payroll increased by $12.1 million (6.8%) in nominal dollars.[14]

Employee benefits have continually increased from FY 2017 to FY 2021. The percent of employee benefits in relation to the total compensation has been increasing every year since FY 2017. Benefits were 23.5% (or $54.6 million) of total compensation increasing to 25.8% (or $65.9 million) of total compensation in FY 2021 in nominal dollars.[15] The average wage per civil service employee increased 5.8% from $116,731 to $123,532 from FY 2020 to FY 2021.[16] There was a nominal increase of 4.8% (or $5,671) in total average wage per civil service employee during the last five years.[17]

[11] In real dollars adjusted for inflation, total compensation decreased by $2.7 million, or 1.1% between FY 2020 and FY 2021 (Constant or real dollar is an adjusted for inflation value of currencies to compare dollar values from one period to another. Inflation for payroll was adjusted using CPI for the Midwest region).

[12] Total real payroll has decreased by $4.1 million (or 2.1%) from FY 2020 and FY 2021.

[13] In real dollars adjusted for inflation, total compensation increased by $0.7 million (or 0.3%) between FY 2017 and FY 2021.

[14] The real payroll decreased by $5.2 million or 2.7% over the last five years.

[15] Real benefit was $59.9 million in FY 2017.

[16] The average wage per employee in real terms increased 0.7%, or $839 between FY 2020 and FY 2021.

[17] In real dollar adjusted for inflation, the average wage per employee decreased by 4.5%, or $5,828 between FY 2017 and FY 2021.

C.4. NASA GLENN EXPENDITURES, FY 2021

NASA Glenn allocated $570.5 million to vendors in 42 states, the District of Columbia, and nine foreign countries during FY 2021 (in 2021 dollars). This is an 8.5% or $53.1 million decrease (in nominal dollars) from FY 2020 expenditures of $623.5 million, which translates to an $82.4 million decrease (or 12.6%) between FY 2020 and FY 2021 after adjusting for inflation.[18] In the five-year period, expenditures increased $16.8%, or $81.9 million, between FY 2017 and FY 2021, in real 2021 dollars.

Figure 2 illustrates the geographic distribution of NASA Glenn's spending during FY 2021. Ohio continues to receive the largest share of the total expenditures with $344.7 million going to state vendors in 2021. These expenditures represent 60.4% of all of NASA Glenn expenditures and a $28.7 million increase from FY 2020 when Ohio received 58.7%, $316 million, in nominal dollars. [19]

Over 90% of NASA Glenn's total expenditures in Ohio in FY 2021 were spent in Northeast Ohio, a total of $312.3 million. Cuyahoga County received the largest share of expenditures spent both within Northeast Ohio and in the State of Ohio, receiving 98.8% and 89.5%, respectively. Cuyahoga county also received the largest share of spending across the entire geographic distribution of NASA Glenn's total expenditures in FY 2021 at 54.07%.

California and Alabama received the second and third largest shares of NASA Glenn spending in FY 2021. California received $100.1 million, the equivalent of 17.7% of total expenditures and Alabama received $39.6 million, or 6.9% of total expenditure. In California, expenditures decreased 22.3% ($29 million in nominal dollars), and $35.1 million (25.8%) in real dollars adjusted for inflation between FY 2020 and FY 2021. Alabama experienced a decrease of $4 million, or 9.3% in the nominal dollar, and $6 million or 13.4% in real dollars between FY 2020 and FY 2021.

Washington and Maryland received the fourth and fifth largest share of expenditures in FY 2021. However, Washington experienced a decrease of $9.4 million (25.7%) while Maryland experienced an increase of $2.7 million (28%), in nominal dollars. [20] (See Appendix Table A.1 for more information on NASA Glenn spending by state.)

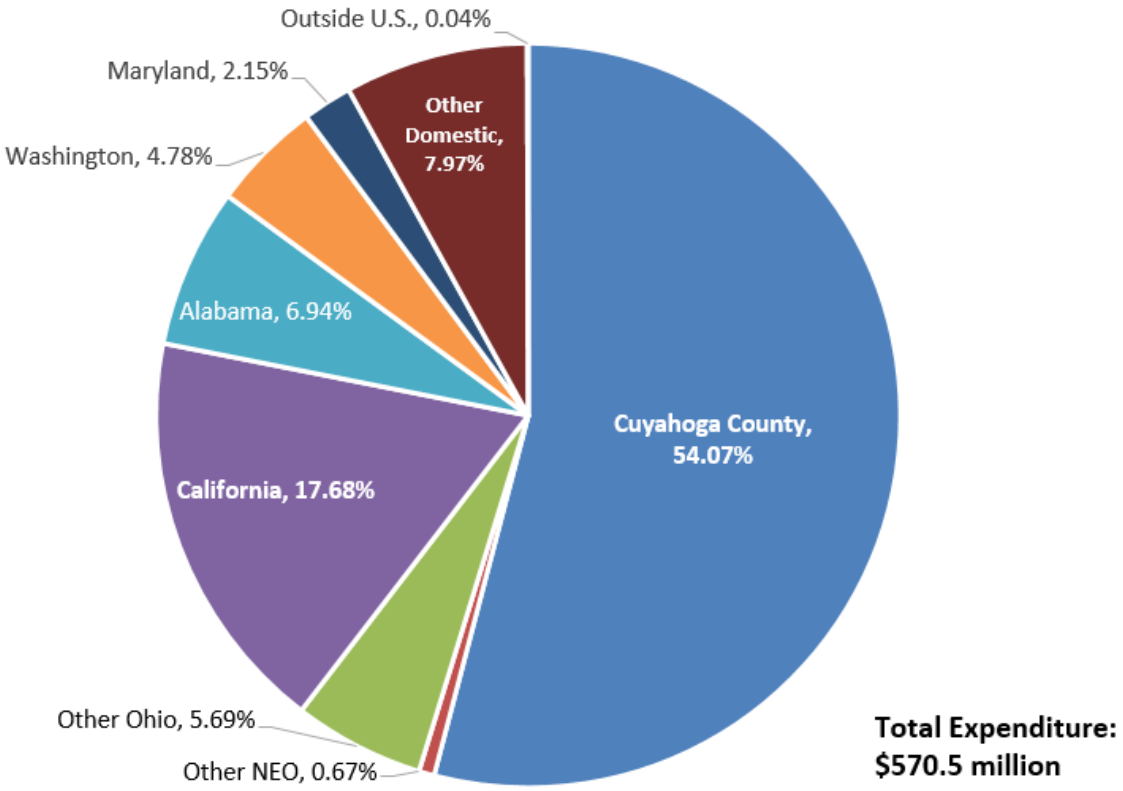
NASA Glenn's expenditures in foreign countries decreased by 31%, from $0.8 million to $0.25 million in nominal dollars between FY 2020 and FY 2021. Great Britain was the largest beneficiary of the foreign countries that received NASA Glenn's contracts, however, total expenditure in this country went down by 78% between FY 2020 and FY 2021. (See Appendix Table A.1 for more information on NASA Glenn foreign country expenditures).

[18] Inflation was adjusted using CPI-US, 271 for 2021.

[19] Total expenditures increased by $28.7 million in nominal dollars and $13.9 million in real dollars adjusted for inflation between FY 2020 and FY 2021.

[20] Washington experienced a decrease of 11.1 million (29%) and Maryland saw an increase of 2.2 million (22.5%) in real dollars.

Figure 2. NASA Glenn Spending in Selected Regions, FY 2021



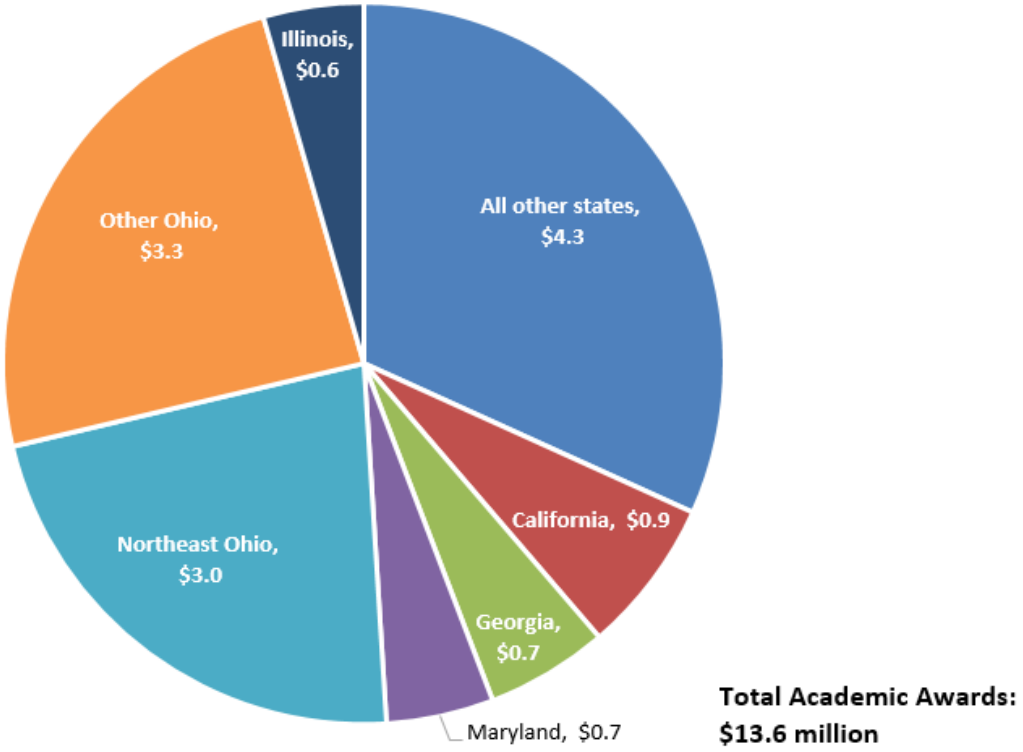
C.5. NASA Glenn Awards to Academic Institutions

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

In FY 2021, NASA Glenn awarded funding that totaled nearly $13.6 million to colleges and universities in 31 states. Grants accounted for $7.9 million of this total. Funding to academic institutions decreased by $0.4 million (3%) between FY 2020 and FY 2021, in nominal dollars. NASA Glenn also awarded $5.7 million in contracts to Ohio academic institutions in FY 2021 through on-site contracts.

Figure 3 displays the distribution of funding awarded to colleges and universities with emphasis on select states that received the largest share of funding. The academic funding awarded in the top five states – California, Georgia, Maryland, Ohio and Illinois – in FY 2021 accounted for 68% of the total awards, compared to 65.4% of total awards made to the top five states during FY 2020. Ohio experienced the largest nominal increase of $2.4 million (62%) in awards between FY 2020 and FY 2021, and Illinois had a nominal increase of $92 thousand (18%). Maryland and California saw large decreases in awards between FY 2020 and FY 2021, losing $0.4 million (38%) and $0.5 million (34%, respectively, while Georgia experiences a $7.7 thousand decrease (1%). (See Appendix Table A.2. for more information).

Figure 3. NASA Glenn Academic Awards to Colleges and Universities, FY 2021 (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 $6.3 million in FY 2021, which accounted for the largest share (47%) of NASA Glenn's academic awards for the year. NASA Glenn's academic awards to Ohio increased by 16.8 percent points between FY 2020 and FY 2021. Northeast Ohio received 48% of the $6.3 million awarded to all of Ohio, totaling $3 million. Northeast Ohio received 22% of all academic funding given by NASA Glenn in FY 2021. In FY 2021, California received $0.95 million of NASA Glenn's academic awards. The second only to Ohio, California received 7% of the total share. Georgia and Maryland were awarded the third and fourth largest shares overall, receiving $0.75 million (5.5%) and $0.65 million (4.8%), respectively, in funding to colleges and universities.

Table 4 presents the distribution of NASA Glenn awards to academic institutions in the State of Ohio from FY 2017 to FY 2021 (inflated to 2021 dollars).[21] The total amount of funding to Ohio academic institutions increased by 1% between 2017 and 2021, from $6.28 million in FY 2017 to $6.4 million in FY 2021, after adjusting for inflation.[22] Total academic funding awarded in Ohio also increased between FY 2020 and FY 2021, increasing by $2.4 million (62%).

Of all Ohio academic institutions that received funding, Case Western Reserve University (CWRU) and the University of Toledo were awarded the most in FY 2021. The two universities combined accounted for 80.2% of NASA Glenn awards to Ohio academic institutions in FY 2021. The University of Toledo

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

[22] NASA Glenn increased its total academic funding in Ohio by 10.9%, from $5.7 million in FY 2017 to 6.4 million in FY 2021 in nominal dollars.

received $2.7 million (42.2% of the total), and CWRU received over $2.4 million (38% of the total) in FY 2021. For CWRU, this was in fact a $0.16 million or 6.3% decrease in funding between FY 2017 and FY 2021. For the University of Toledo, this was a $0.63 million or 31% increase during the last five years (adjusted to 2021 dollars).

The University of Akron was awarded $557,750 (8.8% of the total) in FY 2021 and received the third-highest share of the total funding to Ohio academic institutions. The Ohio State University received $524,488 (8.3%) and ranked fourth. The remainder of the FY 2021 awards from NASA Glenn to Ohio academic institutions went to the Ohio University ($97,032 or 1.5%), Kent State University ($40,664 or 0.6%), Cleveland State University ($32,280 or 0.5%) and University of Cincinnati ($4,997 or 0.1%).

Table 4. NASA Glenn Educational Awards in Ohio by Academic Institution, FY 2017-FY 2021

Ohio Colleges and Universities	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2021 Share
University of Toledo	$2,041,449	$2,007,534	$1,865,570	$1,063,557	$2,673,566	42.2%
Case Western Reserve University	$2,572,588	$2,521,313	$2,368,769	$2,293,104	$2,409,972	38.0%
The University of Akron	$482,903	$475,161	$457,767	$252,855	$557,750	8.8%
Ohio State University	$352,335	$398,424	$510,037	$210,113	$524,488	8.3%
Ohio University	$140,556	$81,658	$80,495	$81,711	$97,032	1.5%
Kent State University	$100,573	$143,854	$187,892	$73,800	$40,664	0.6%
Cleveland State University	$187,633	$175,785	$172,741	$128,486	$32,280	0.5%
University of Cincinnati	$252,622	$144,150	$40,710	$15,737	$4,997	0.1%
Cuyahoga Community College	$146,650	$115,480	$16,980	$0	$0	0.0%
TOTAL	$6,277,308	$6,063,361	$5,700,962	$4,119,362	$6,340,750	100.0%

Notes: The table is sorted by FY 2021 column.
Data are inflated to 2021 dollars (Inflation coefficient of 252.3 is based on CPI Midwest region).

C.6. NASA Glenn Revenues

In FY 2021, NASA Glenn's Total Revenue reached $829.8 million which is a 4.1% decrease from FY 2020, in real dollars. In the last five years, revenue has increasing 20.1%, ranging from $691.1 million in FY 2017 to $829.8 million in FY 2021, in nominal dollars.

Table 5 illustrates NASA Glenn's revenue from FY 2017 to FY 2021 by source: NASA direct authority and reimbursable commitments. Revenue from NASA's direct authority decreased by 3% from FY 2020 to FY 2021. Overall in the past five years, there was a 21.6% increase in NASA's direct authority in nominal dollars, peaking in FY 2019 at $928.3 million and declining slightly for the past two years. In addition to the $797.7 million in direct authority revenue in FY 2021, NASA Glenn also received $32.1 million in reimbursable commitments.

As shown in Table 5 below, reimbursable funding has fluctuated since FY 2017, reflecting the change in non-NASA customers doing business with NASA Glenn in recent years. Revenues from reimbursable commitments have decreased by 25.3% within the past year, dropping nearly $10.9 million from FY 2020, after peaking at $67.9 million in FY 2019.

In FY 2021, the largest share of the revenue for reimbursable commitment came from federal funding which accounted for 82.4%. The largest share of federal funding came from the Department of Defense that contributed 56.7%. "Other Federal Agency" accounted for the second largest share (25.6%). There was a 9.1 percent point decrease in reimbursable commitments from the Department of Defense between FY 2020 and FY 2021 than can be attributed from an equally large decrease in funding from the U.S. Air Force, despite a modest 1.1% increase in funding from the U.S Navy.

Table 5. NASA Glenn Revenues, FY 2017-FY 2021 (in millions of nominal dollars)

Description	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
NASA Direct Authority	$655.9	$697.4	$928.3	$822.2	$797.7
Total Reimbursable Commitments	$35.2	$47.9	$67.9	$43.0	$32.1
Total FY Authority	$691.1	$745.3	$996.2	$865.3	$829.8
NASA Budget %	94.9%	93.6%	93.2%	95.0%	96.1%

Note: Data in millions of nominal dollars.

C.7. TAXES PAID BY NASA GLENN EMPLOYEES

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

Table 6 shows the amount of income taxes paid by NASA Glenn employees at the federal, state, and local level. The table excludes income taxes paid by NASA Glenn employees residing outside the respective regions. In FY 2021, the total income tax paid by NASA Glenn employees totaled $33 million. This is a slight increase of 3.1%, or $1 million compared to FY 2020, in nominal dollars.

NASA Glenn employees paid $9.5 million in income taxes at the state and local levels in FY 2021. This is a 2.6% increase from FY 2020, without adjusting for inflation. The amount of taxes paid to local and state governments has increased steadily over the past five years, rising from $8.9 million in FY 2017 to $9.5 million in FY 2021.

The city of Brook Park and the state of Ohio received the largest share of the income taxes paid by NASA Glenn's employees. Combined, they accounted for 99.5% of the total state and local income taxes paid in FY 2021. In FY 2021, 61.6% ($5.8 million) of the income taxes paid at the state and local levels went to the State of Ohio. Since 2017, 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 $3.6 million in income tax revenue from NASA Glenn employees in FY 2021, representing a marginal increase of 2.6% (or $90,323) compared to FY 2020. 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 2021, at a total of $3.6 million. In the past five years, the city of Cleveland saw a notable increase in income tax of 53.3%, while the city of Fairview Park experienced a 10.5% increase, but the dollar amounts received remain low compared to that of the city of Brook Park.

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
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**
2021	$3,587,596	$15,512	$27,079	$5,826,093	$23,613,701	**$33,069,982**
5-Year Total	**$17,288,249**	**$66,458**	**$127,427**	**$28,694,635**	**$116,133,055**	**$162,309,822**

D. ECONOMIC IMPACT OF NASA GLENN

This section describes the methodology and illustrates the results of research estimating the economic impact NASA Glenn created on Northeast Ohio and the State of Ohio in FY 2021.[23] 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.[24] 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 2021 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 of each region.[25] The initial NASA expenditures (i.e., change in final demand) in the region result in economic impacts on Northeast Ohio and Ohio. The economic impact is born via the inter-relation of industries buying goods and services from each other within the region of study. This study uses an input-output model that reflects the buy-sell relationships among all industry sectors.

NASA Glenn purchases goods and services as inputs in its research and development activities, which creates a direct impact. The assessment of intermediate goods purchasing from the NASA suppliers within the region of study 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 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 and not as a federal government industry. This makes the intermediate expenditure pattern of NASA Glenn

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

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

[25] 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.

similar to that of other comparable research institutions in the area.

Economic impact analysis accounts for inter-industry buy-sell relationships within the respective economies of the research areas of 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.[26]

This study utilizes regional I-O multipliers from the IMPLAN online application model.[27] Specifically, SAM multipliers estimate the ripple effect that an initial expenditure made by NASA Glenn has on the regional economy.[28] The data on industry buy-sell relationships within the respective economy of the research areas of Northeast Ohio or Ohio are updated annually.

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 or Ohio) affect the production of all 536 Industries and household spending in these regions.[29]

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 are addressed: (1) the exclusion of NASA Glenn 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 accounts for the purchases of goods produced by companies located in Northeast Ohio and 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

[26] 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.

[27] 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.

[28] 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.

[29] MRIO: Considerations when using Multi-Regional Input-Output Analysis. https://support.implan.com/hc/en-us/articles/115009713448-MRIO-Introduction-to-Multi-Regional-Input-Output-Analysis.

produced only by companies located in Ohio. All goods and services purchased from 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 made for its operations.
- Labor income impact measures the additional labor earnings created in the region due to NASA Glenn expenditures made for its operations.
- Value added impact measures the additional value added created in the region due to NASA Glenn expenditures made for its operations. Value added is calculated as output less the value of intermediary goods.[30]
- Output impact measures the additional value of all goods and services produced in the region due to NASA Glenn expenditures made for its operations.
- Tax impact measures the additional federal, state, and local tax revenues collected in the region due to NASA Glenn expenditures made for its operations.

The employment, labor income, value added impact, and output impacts are each a summation of three components: direct impact, indirect impact, and induced impact.[31] Unlike in the previous studies, throughout this report, the NASA Glenn FY 2021 expenditures and their comparison to FY 2020 are analyzed in 2021 dollars, according directly to the data received from the NASA Glenn. To illustrate economic impact in real terms, the results of the economic impact for Northeast Ohio and Ohio are expressed in 2022 dollars. Appropriate footnotes are included to each table.

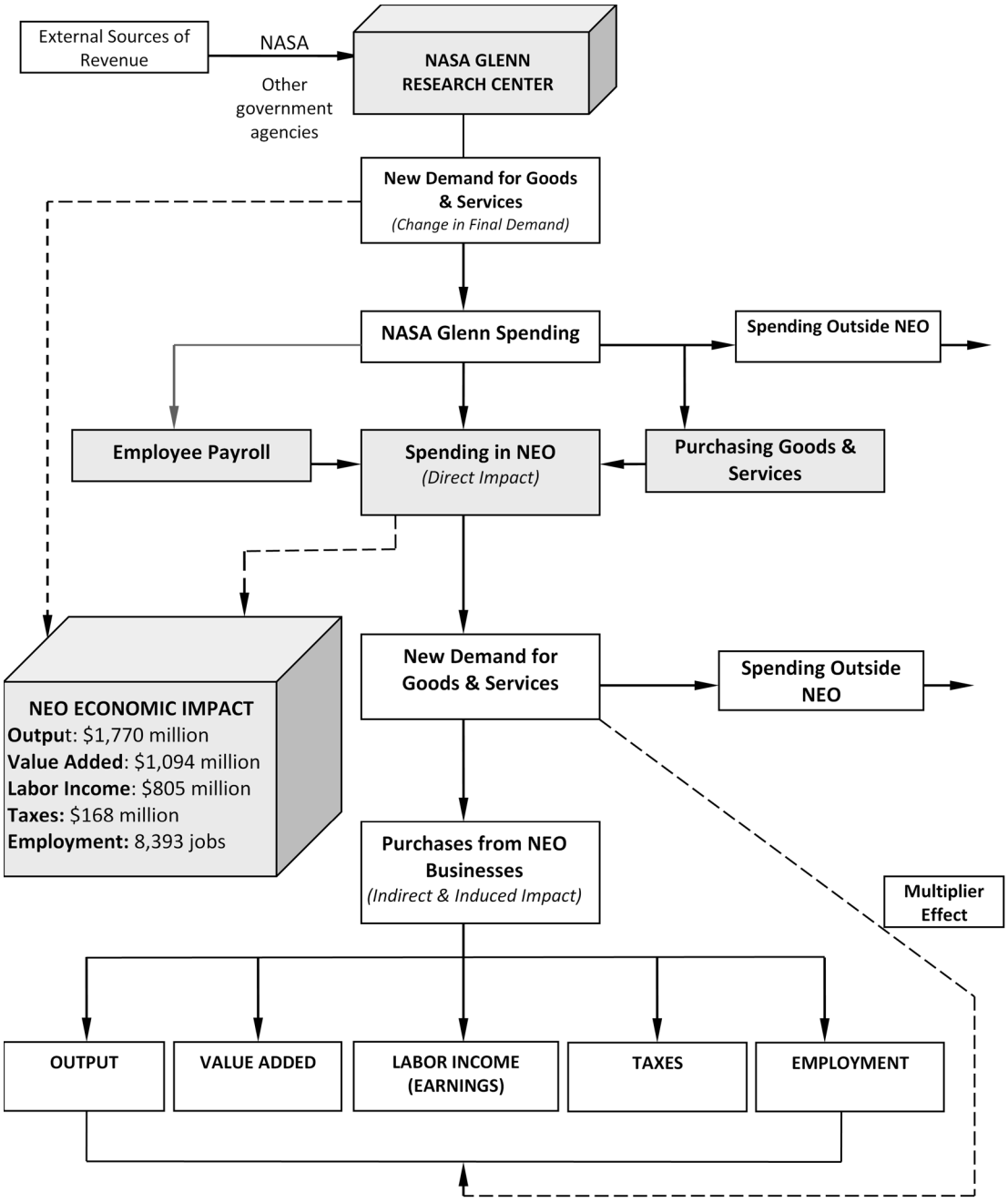
Figure 4 illustrates the process by which NASA Glenn impacted Northeast Ohio's economy through its spending in the region in FY 2021.

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

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

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

Figure 4. Economic Impact of NASA Glenn Research Center on Northeast Ohio, FY 2021



D.2. Economic Impact on Northeast Ohio, FY 2021

The following section of the report analyzes the economic impact of NASA Glenn on the economy of Northeast Ohio in FY 2021. The economic impact is triggered by the changes in the final demand in Northeast Ohio, i.e. purchases from the companies within this region and companies in the rest of Ohio that have supply chain in the region of study. 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 2021

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 NASA Glenn-supplier 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 2021.

About 44% of NASA Glenn's total expenditures in Northeast Ohio went towards employee compensation, which is typical for labor-intense industries conducting research and development activities. NASA Glenn's largest expenditures on goods and services in Northeast Ohio in FY 2021 were made on professional, scientific, and technical services (32%), including about 20.9% 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 contains direct, indirect, 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 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 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$127,333	$271,872	$399,205
Mining		$708,242	$209,654	$917,896
Utilities		$11,044,118	$5,865,936	$16,910,054
Construction		$52,031,396	$3,127,562	$55,158,958
Manufacturing		$9,727,943	$5,584,247	$15,312,190
Wholesale Trade		$9,977,853	$17,182,631	$27,160,483
Retail trade		$4,599,324	$30,976,153	$35,575,477
Transportation & Warehousing		$6,107,033	$8,907,455	$15,014,488
Information		$10,617,078	$14,429,446	$25,046,524
Finance & insurance		$12,751,144	$56,249,399	$69,000,543
Real estate & rental		$25,042,097	$59,318,920	$84,361,017
Professional- scientific & tech services		$223,793,900	$16,976,028	$240,769,928
Management of companies		$11,725,101	$6,152,261	$17,877,362
Administrative & waste services		$84,348,478	$10,937,569	$95,286,047
Educational services		$14,034,361	$5,188,654	$19,223,015
Health & social services		$1,328,829	$61,240,967	$62,569,796
Arts- entertainment & recreation		$405,758	$4,532,763	$4,938,522
Accommodation & food services		$3,302,186	$16,083,177	$19,385,362
Other services		$3,800,047	$17,888,997	$21,689,043
Government & non-NAICs	$583,851,299	$355,549,915	$3,630,612	$943,031,826
Total Output	**$583,851,299**	**$841,022,136**	**$344,754,303**	**$1,769,627,737**

Notes: For output impact, the change in final demand or direct impact ($583,851,299) 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 2022 dollars.

The total output impact of NASA Glenn on Northeast Ohio was $1.77 billion in FY 2021.

NASA Glenn's spending of $583.9 million in Northeast Ohio resulted in an output (sales) change of $1.77 billion across all industry sectors (Table 7, in 2022 dollars). Glenn's initial spending triggered a $240.8 million increase in total sales (direct, indirect, and induced) by the Professional, Scientific, and Technical Services industry and a $25.1 million increase in sales by the Information industry. NASA Glenn was also responsible for a $95.3 million increase in total sales by the Administrative and Waste services industry, $84.4 million increase by the Real Estate and Rental Industry, and $69.0 by the Finance and Insurance industry. If NASA Glenn did not exist in Northeast Ohio, the region would lose the output generated by its spending. The above 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, 33.0% ($583.9 million in 2022 dollars) is accounted for by NASA Glenn's direct spending in Northeast Ohio, which creates the direct economic impact to Northeast Ohio. Approximately $841.0 million (47.5%) of the total output impact results from indirect spending by NASA Glenn (purchasing from its suppliers). The remaining output impact of $344.8 million (19.5%) is attributed to the induced impact from NASA Glenn purchases rippling through the regional economy.

The following analysis of the economic impact results illustrates that the indirect and induced portions of the economic impact (totaling $1.19 billion, or 67.0% 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 these industries in FY 2021 was $452.4 million or 38.1% 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 2021 was $248.4 million or 21.0% of the total impact.

Other industries are driven by both NASA Glenn and consumer spending, and their impact could not be attributed to either group. It 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 2021 was $485.0 million or 40.9% of the total impact.

The output distributions featuring the largest Glenn- and consumer-driven industries are shown in Figures 5 and 6, respectively. In figure 5, industries with additional sales of at least $18 million, or 4.0% of the total sale, were selected to be illustrated. Industries with additional sales of at least $10 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 2021; it created the output increase of $134.0 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 $134.0 million represented 30% of the $452.4 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 other real estate industry saw the largest increase in sales (by $36.4 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 $36.5 million accounted for 15% of the $248.4 million increase in output for all consumer-driven industries.

Figure 5. Increase in Sales for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2021

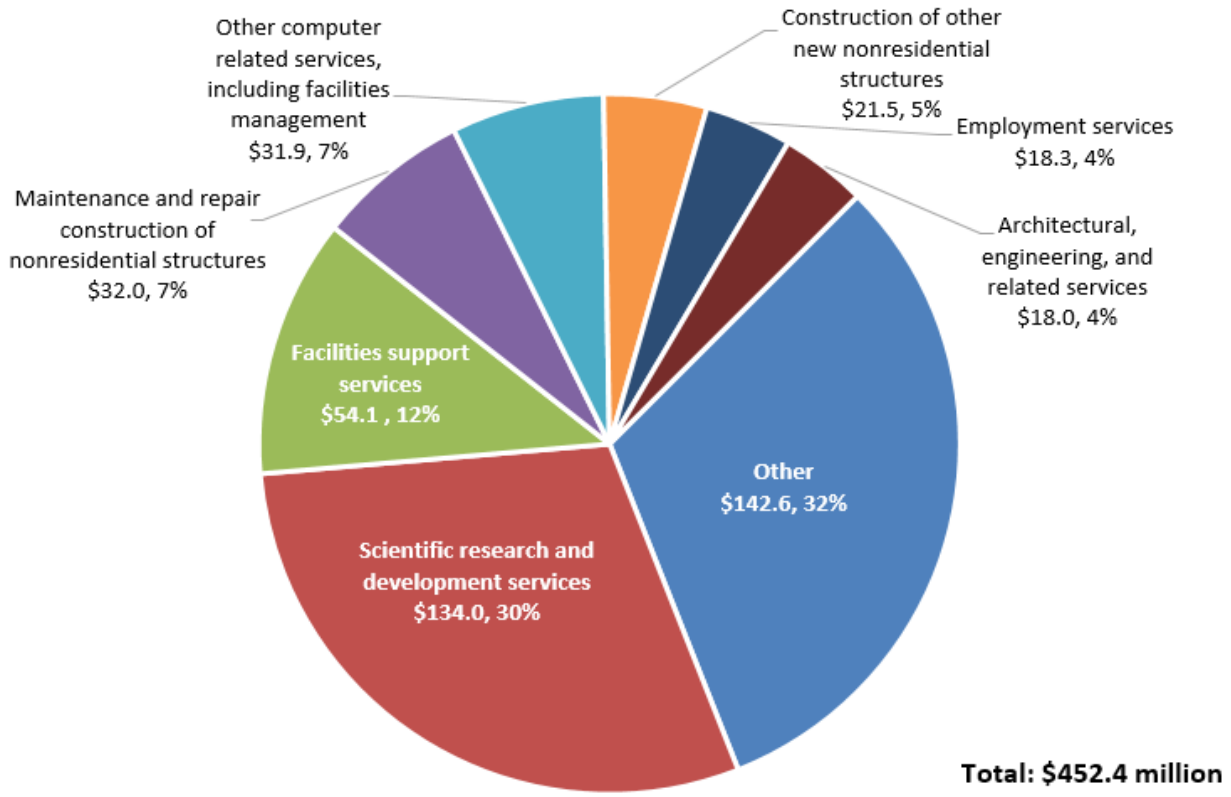
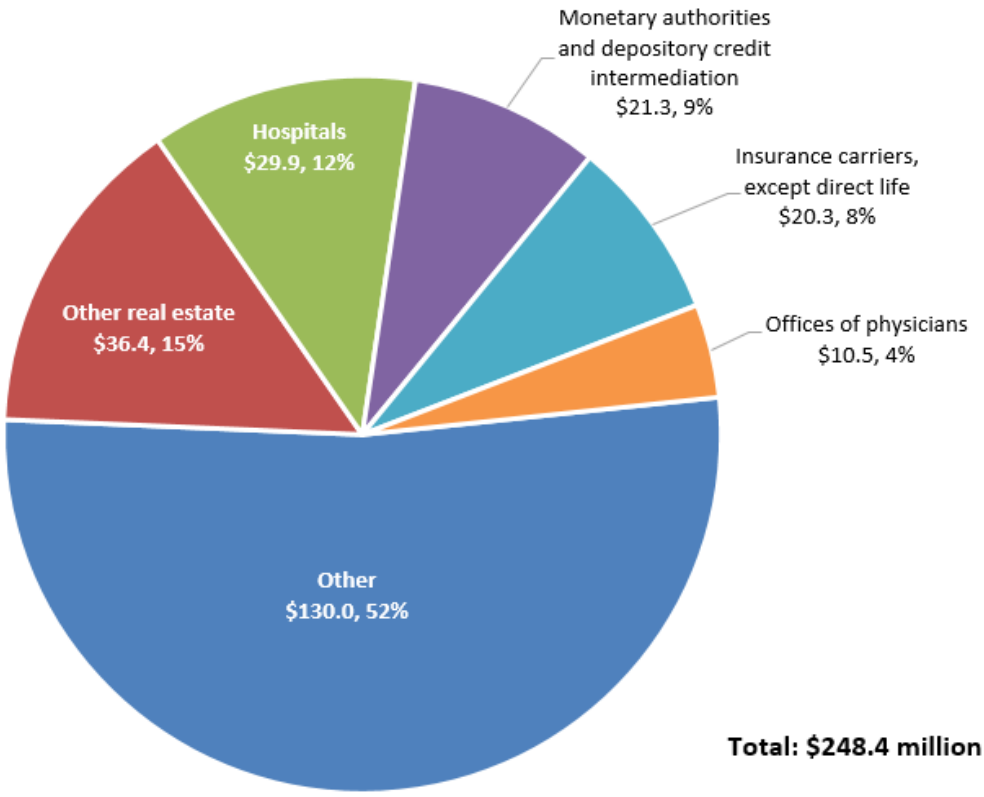


Figure 6. Increase in Sales for Select Consumer-Driven Industries in Northeast Ohio, FY 2021



D.2.2. Employment Impact on Northeast Ohio, FY 2021

In addition to its direct employment, NASA Glenn's presence in Northeast Ohio has supported and created new full-time and part-time jobs outside of NASA Glenn. Spending in FY 2021 resulted in retained workers in NASA Glenn (direct impact) 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), employment in the supply chain companies, and employment across many consumer goods and services industries (the indirect and induced components). Table 8 shows the number of jobs supported and created by industry sector.

Table 8. Employment Impact in Northeast Ohio, FY 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		3	5	8
Mining		1	0	1
Utilities		14	5	20
Construction		275	14	289
Manufacturing		27	14	40
Wholesale Trade		32	54	86
Retail trade		41	316	358
Transportation & Warehousing		54	83	138
Information		20	30	50
Finance and Insurance		29	164	193
Real estate and Rental		125	113	238
Professional- scientific & Tech Services		1,172	104	1,276
Management of companies		47	25	71
Administrative and waste services		706	119	825
Educational services		167	81	248
Health & social services		12	502	514
Arts- entertainment & recreation		7	60	67
Accommodation & food services		51	226	277
Other services		35	210	246
Government & non-NAICs	1,537	1,890	20	3,447
Total Employment	**1,537**	**4,709**	**2,147**	**8,393**

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 8,393 employees in FY 2021 due to NASA Glenn's spending. Of these jobs, 1,537 (18.3%) were directly employed at NASA Glenn. New and retained jobs were also created as a result of NASA Glenn's indirect economic impact in the supplier companies. This spending on goods and services caused the creation and retention of additional 4,709 full-time and part-time jobs (56.1%) in NEO. The remaining 2,147 (25.6%) 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. All these jobs are called new and retained based on the assumption that these jobs would not exist in the region if hypothetically NASA Glenn were not present in the NEO economy and had not spent its budget for regional purchases in FY 2021.

Of the 6,856 jobs created and supported in Northeast Ohio due to the indirect and induced impacts, 2,708 (39.5%) were found in the NASA Glenn-driven industries, 1,743 (25.4%) were in the consumer-driven industries, and 2,405 (35.1%) were in other industries.[32] The job distribution across the largest sectors 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 115 employees (or over 4%) per sector in Figure 7 and a minimum of 70 (or over 4%) in Figure 8.

Besides the federal government sector where NASA Glenn's direct employment is accounted for, the 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 617 jobs in FY 2021 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 617 R&D jobs accounted for 23% of the 2,708 NASA Glenn-driven industries. Other industries shown in Figure 7 can be interpreted in a similar manner.

Of all consumer-driven industries, the other real estate industry saw the largest increase in jobs; it grew by 188 jobs in FY 2021 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 188 jobs represent 11% of the 1,743 jobs created across all consumer-driven industries.

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

Figure 7. Increase in Jobs for Select NASA Glenn-Driven Industries in Northeast Ohio, FY 2021

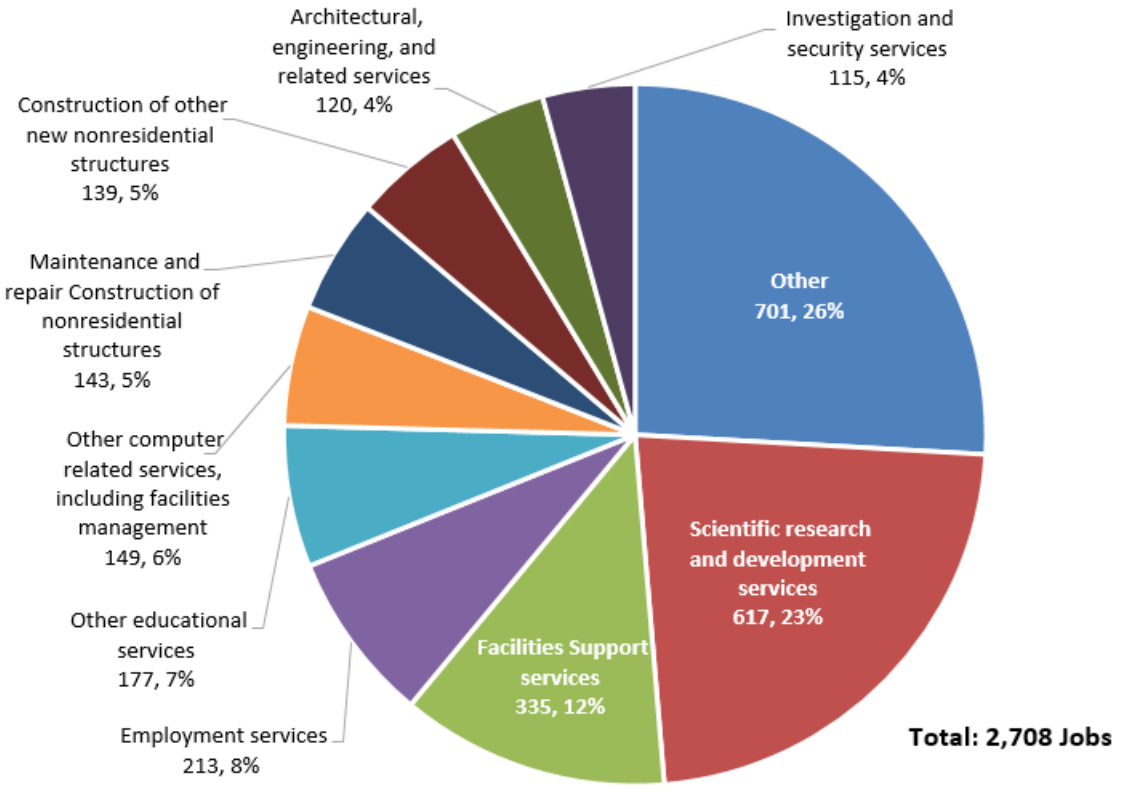
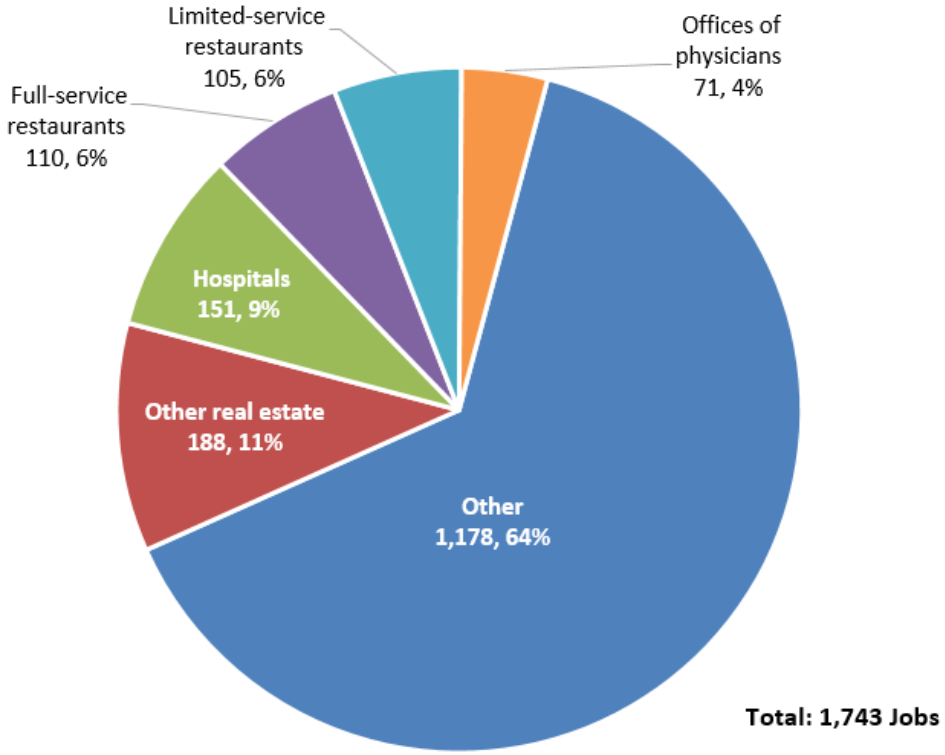


Figure 8. Increase in Jobs for Select Consumer-Driven Industries in Northeast Ohio, FY 2021



D.2.3. Labor Income Impact on Northeast Ohio, FY 2021

Labor income impact includes the earnings received by NASA Glenn employees, the change in earnings of employees of its supply chain companies, and the labor income of employees in the consumer driven industries in Northeast Ohio. All these earnings are received by employees due to NASA Glenn's spending on goods and services in the region. Wages and benefits paid to NASA Glenn employees represent the direct economic impact. The indirect impact is estimated by summing 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 in 2022 dollars.

Table 9. Labor Income Impact in Northeast Ohio, FY 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$94,449	$114,137	$208,586
Mining		$65,581	$5,698	$71,279
Utilities		$1,855,429	$855,227	$2,710,656
Construction		$12,354,110	$623,842	$12,977,952
Manufacturing		$2,078,642	$1,117,595	$3,196,237
Wholesale Trade		$3,060,240	$6,279,196	$9,339,436
Retail trade		$1,941,382	$10,959,688	$12,901,071
Transportation & Warehousing		$2,773,246	$3,870,737	$6,643,983
Information		$2,147,226	$4,403,237	$6,550,463
Finance & insurance		$4,017,486	$11,561,981	$15,579,467
Real estate & rental		$4,180,963	$3,265,286	$7,446,248
Professional- scientific & tech services		$106,819,031	$10,367,744	$117,186,775
Management of companies		$1,321,844	$587,875	$1,909,719
Administrative & waste services		$28,756,739	$6,013,267	$34,770,006
Educational svcs		$6,924,085	$9,596,285	$16,520,370
Health & social services		$678,356	$26,584,535	$27,262,892
Arts- entertainment & recreation		$232,089	$2,142,615	$2,374,704
Accommodation & food services		$1,841,195	$7,939,901	$9,781,096
Other services		$2,146,473	$8,513,683	$10,660,156
Government & non-NAICs	$256,656,487	$249,452,270	$1,233,484	$507,342,242
Total Employment	**$256,656,487**	**$432,740,838**	**$116,036,012**	**$805,433,337**

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 2022 dollars.

Due to NASA Glenn spending in FY 2021, the total labor income in Northeast Ohio increased by $805.4 million. Of this total, $256.7 million (31.9%) was due to wages and benefits paid directly to NASA Glenn employees (i.e., the direct effect measured in 2022 dollars). The indirect impact, or the wages and benefits paid to employees of companies who supply goods and services to NASA Glenn, represented $432.7 million (53.7%) of the total amount. The remaining economic impact is represented by the induced effect totaling to $116.0 million (14.4%). This impact comes from the spending of both NASA Glenn and suppliers' employees in consumer goods and services industries throughout the regional economy.

Of the $547.8 million increase in labor income generated across Northeast Ohio due to the indirect and induced impacts, $179.0 million (32.6%) was reported in NASA Glenn-driven industries, $84.7 million (15.4%) was generated in consumer-driven industries, and $285.1 million (52.0%) was reported in other industries.[33]

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 $7 million (4%) are displayed in Figure 9, and industries that added over $3 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 $53.9 million in FY 2021 (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 $53.9 million spent on scientific R&D represents 30% of the $179.0 million total increase in labor income reported by all the NASA Glenn-driven industries in FY 2021.

Of all consumer-driven industries, private hospitals saw the largest increase in earnings in FY 2021. Earnings in this industry totaled $13.8 million, making up 16% of the $84.7 million consumer-driven total. These earnings result from totaling the indirect and induced impacts generated by consumer spending on doctors' services.

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

Figure 9. Increase in Labor Income for NASA Glenn-Driven Industries in Northeast Ohio, FY 2021

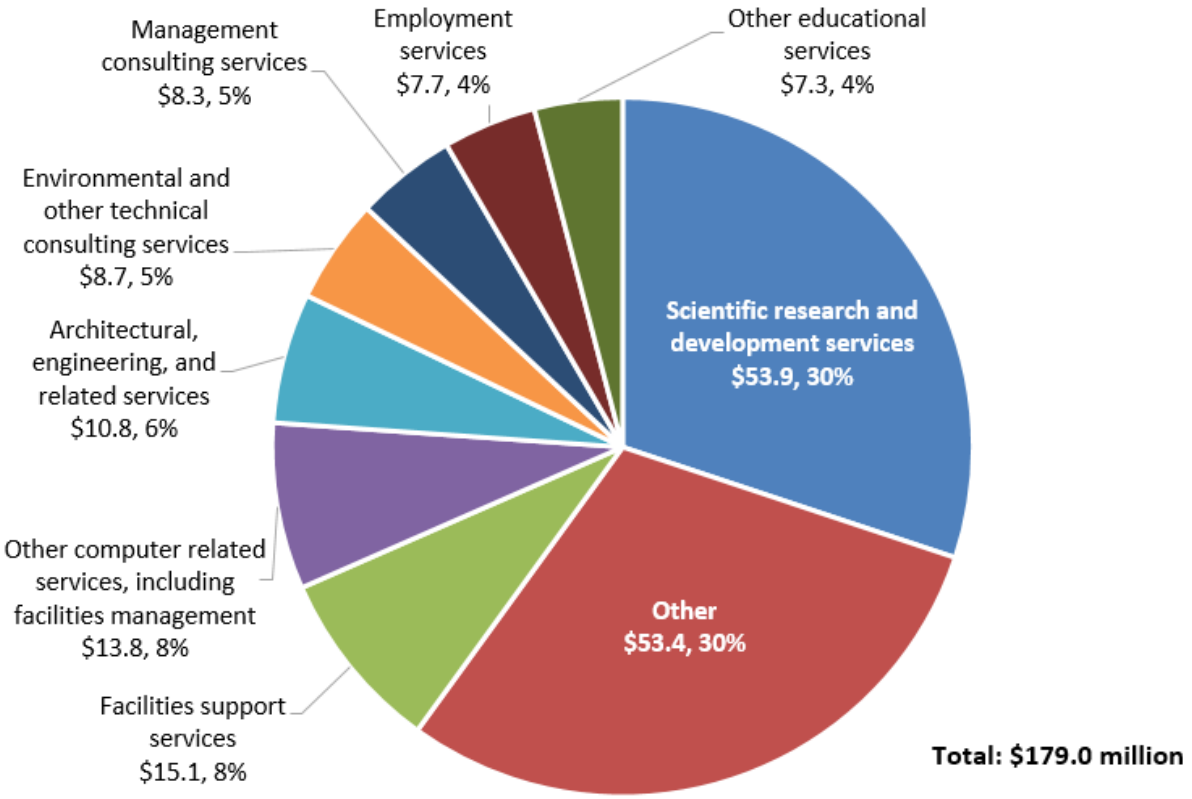
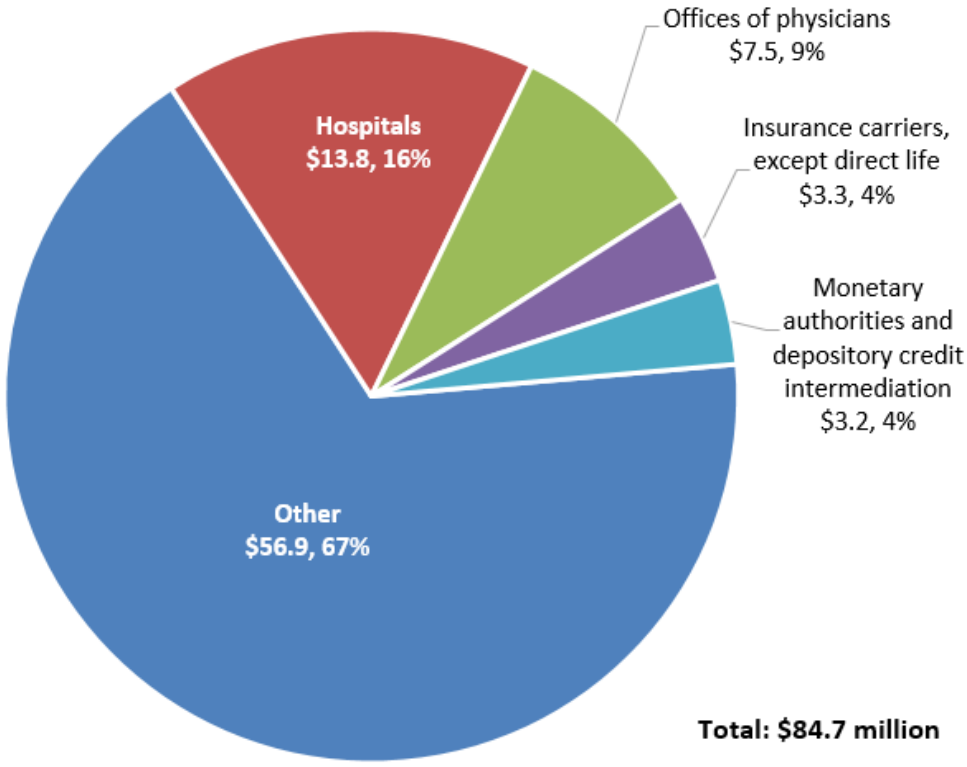


Figure 10. Increase in Labor Income for Consumer-Driven Industries in Northeast Ohio, FY 2021



D.2.4. Value Added Impact on Northeast Ohio, FY 2021

The total value added[34] impact in Northeast Ohio was $1,094.3 million in FY 2021. The direct impact of $286.1 million was created by excluding intermediate expenditures from the total output.[35] The sales from companies to NASA Glenn, excluding the value for intermediary goods and services, represented the indirect impact of $603.4 million.

Induced value-added economic impact of $204.8 million 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 economic impact is a summation of the direct, indirect, and induced impacts. Table 10 displays the value-added impact by the industry sector in 2022 dollars.

Table 10. Value Added Impact in Northeast Ohio, FY 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$170,667	$219,038	$389,705
Mining		$350,388	$27,845	$378,233
Utilities		$5,636,675	$2,915,127	$8,551,802
Construction		$20,534,860	$1,197,771	$21,732,631
Manufacturing		$3,880,612	$2,335,634	$6,216,246
Wholesale Trade		$5,735,480	$11,344,368	$17,079,848
Retail trade		$3,244,218	$17,295,733	$20,539,951
Transportation & Warehousing		$3,025,899	$4,265,994	$7,291,893
Information		$4,500,738	$9,455,507	$13,956,245
Finance & insurance		$16,731,324	$33,309,151	$50,040,475
Real estate & rental		$7,760,118	$39,402,105	$47,162,222
Professional- scientific & tech svcs		$123,261,418	$11,835,124	$135,096,542
Management of companies		$625,087	$278,001	$903,088
Administrative & waste services		$40,945,796	$6,942,884	$47,888,680
Educational services		$6,743,072	$9,211,509	$15,954,580
Health & social services		$829,330	$30,244,733	$31,074,064
Arts- entertainment & recreation		$289,480	$3,107,382	$3,396,862
Accommodation & food services		$2,315,390	$10,441,796	$12,757,187
Other services		$2,573,994	$9,756,739	$12,330,733
Government & non-NAICs	$286,087,078	$354,289,573	$1,222,417	$641,599,069
Total Employment	**$286,087,078**	**$603,444,120**	**$204,808,858**	**$1,094,340,056**

Notes: The economic impact is shown in 2022 dollars.

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

[35] 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.

Total value added in Northeast Ohio increased by $1,094.3 million in FY 2021 as a result of NASA Glenn's spending on goods and services. Of this total amount, $286.1 million (26.1%) 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, which is typical for any organization or company in the research and development industry. The indirect effect of $603.4 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 induced impact was estimated at $204.8 million (18.7%). This value arose due to the ripple effects that NASA Glenn's spending had on the Northeast Ohio economy.

Of the $808.3 million increase in value added attributed to Northeast Ohio due to the indirect and induced impacts, $231.8 million (28.7%) was observed in NASA Glenn-driven industries, $142.5 million (17.6%) has occurred in consumer-driven industries, and $434.0 million (53.7%) was reported in other industries.[36]

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 $6 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 2021 ($66.7 million). This amount results from summing the indirect and induced impacts generated by NASA Glenn's spending. This $66.7 million increase in the scientific R&D industry represented a 29% share of the $231.8 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 monetary authorities and depository credit intermediation industry saw their value-added increase by $17.3 million in FY 2021. This increase results from summing indirect and induced impacts that were generated primarily, though not exclusively, by NASA Glenn's spending at the banking industry. This $17.3 million increase accounted for 12% of the $142.5 million value added growth that occurred across all consumer-driven industries.

[36] 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 2021

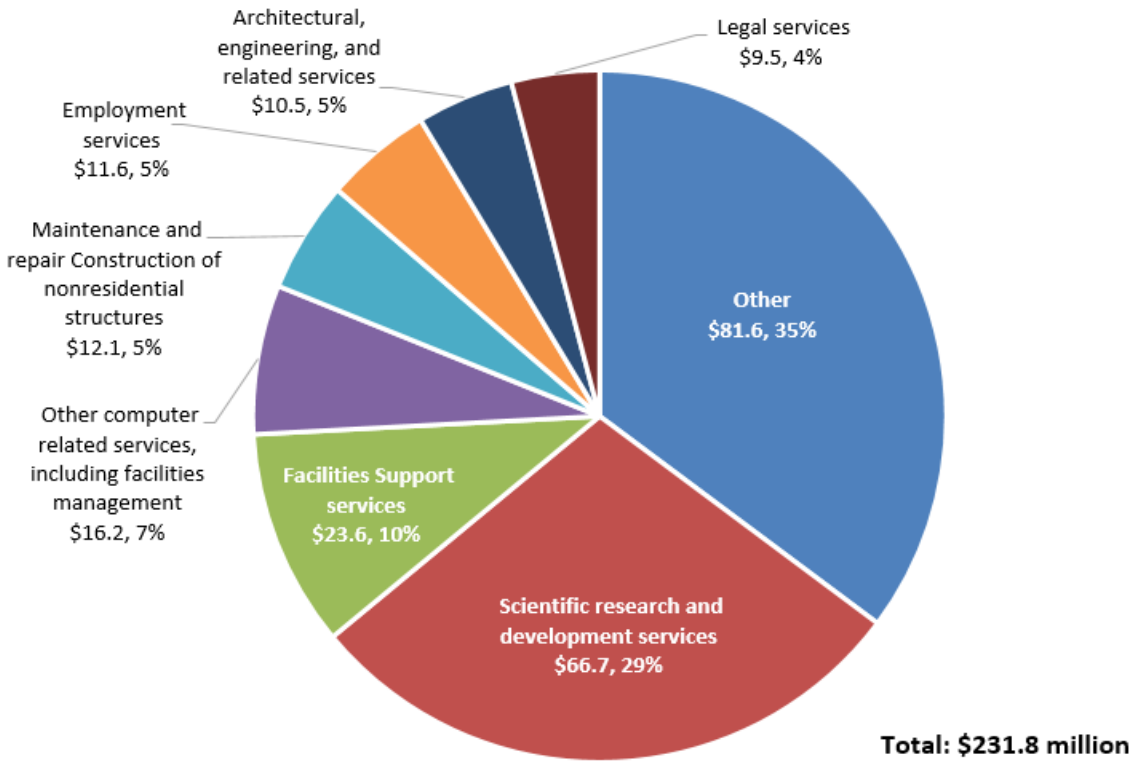
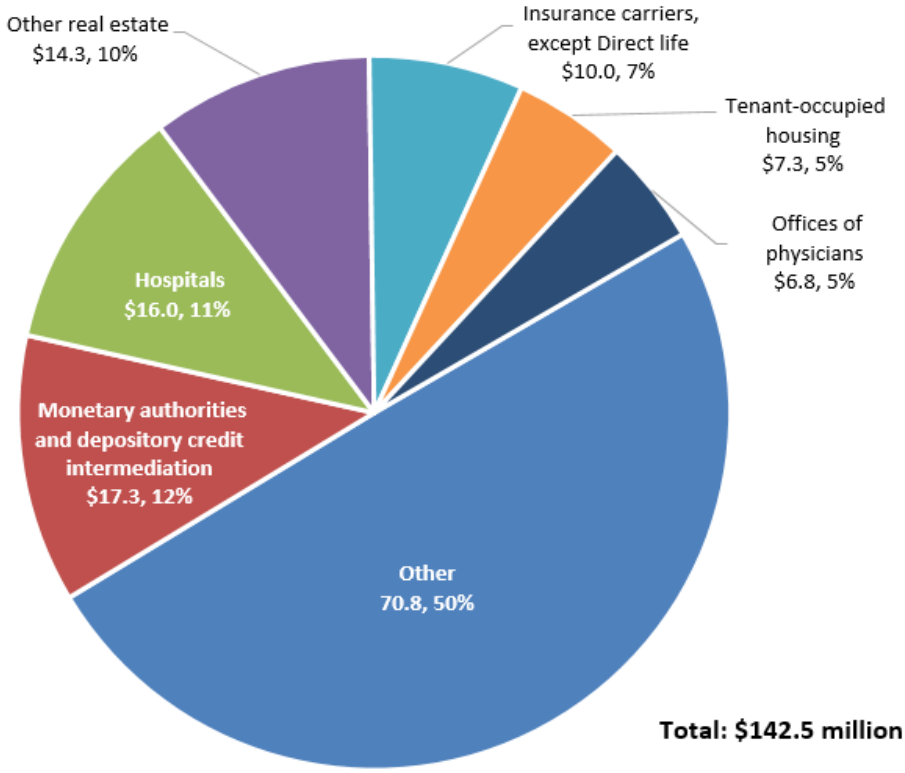


Figure 12. Increase in Value Added for Consumer-Driven Industries in Northeast Ohio, FY 2021



D.2.5. Tax Impact on Northeast Ohio, FY 2021

NASA Glenn's operations and economic impact on Northeast Ohio in FY 2021 increased the region's tax revenues by $167.7 million (in 2022 dollars). Of this total, the direct tax impact paid by NASA Glenn's employees to all levels of government was $34.5 million in 2022 dollars. The local tax paid below the state level due to the NASA Glenn operations and employment (including county and sub-county taxes) was $19.4 million in FY 2021.

D.2.6. FY 2021 Northeast Ohio Impact Summary

The economic activity in FY 2021 generated by NASA Glenn Research Center created the following economic impact on Northeast Ohio:

- Total Output Impact: $1,769.6 M
- Total Employment Impact: 8,393 jobs
- Total Labor Income Impact: $805.4 M
- Total Value Added Impact: $1,094.3 M
- Total Tax Impact: $167.7 M

The impact of NASA Glenn's expenditures on Northeast Ohio reflects the benefits of total expenditures of $557.3 million (which is equal to $583.9 million in 2022 dollars). These expenditures include a total amount of $312.3 million spent on purchases in Northeast Ohio in FY 2021 and expenditures on labor income paid to employees living in Northeast Ohio for $245.0 million.

Excluding expenditures on labor income, 57.0% (about $178.1 million) of NASA Glenn's expenditures were allocated to professional, scientific and technical services; 19.4% ($60.6 million) was spent on administrative and support services, and 15.8% ($49.4 million) was spent on construction – the three largest groups of NASA Glenn expenditures in Northeast Ohio.[37] These three sectors constituted the largest categories of NASA Glenn spending in Northeast Ohio in FY 2021 and together represented 92.3% ($288.2 million) of all NASA Glenn's FY 2021 expenditures in Northeast Ohio, excluding labor income. Among other expenditures, educational service represented at 4.3% share and utilities at 2.1%. Other sectors' expenditures were less than 1%. Expenditures on labor income and benefits constituted 44.0% of the overall $557.3 million of NASA Glenn direct spending in Northeast Ohio in FY 2021.

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.

[37] Amounts in parentheses detailing percentage numbers are presented in 2021 dollars and correspond to Appendix Table A.3.

D.3. Economic Impact on the State of Ohio, FY 2021

This section illustrates an assessment of the economic impact of NASA Glenn operations on the State of Ohio's economy in FY 2021. This economic impact analysis is based on the same methodology used to estimate 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 2021

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 NASA Glenn's broader supply chain located in the state. The larger geographic area also results in less leakage (money spent outside of the region of study) 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. Only expenditures made in Ohio created the economic impact described in this section. This spending within the state 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 on the state of Ohio 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 estimated by measuring the spending of the employees of NASA Glenn and supplying industries due to Glenn's increased demand for products and services. Adding the direct, indirect, and induced impacts resulted in the total output impact. Table 11 also 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 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$312,047	$549,522	$861,569
Mining		$1,610,324	$529,345	$2,139,669
Utilities		$12,806,787	$7,519,688	$20,326,475
Construction		$54,237,047	$3,802,375	$58,039,423
Manufacturing		$17,410,315	$9,646,472	$27,056,787
Wholesale Trade		$11,249,583	$19,865,166	$31,114,749
Retail trade		$5,052,722	$35,634,091	$40,686,813
Transportation & Warehousing		$7,590,678	$10,720,559	$18,311,237
Information		$11,976,420	$16,422,496	$28,398,915
Finance & insurance		$14,762,676	$63,997,847	$78,760,523
Real estate & rental		$28,412,264	$67,571,719	$95,983,983
Professional- scientific & tech svcs		$256,263,857	$19,029,122	$275,292,979
Management of companies		$13,200,999	$6,991,125	$20,192,123
Administrative & waste services		$89,504,737	$12,863,938	$102,368,675
Educational services		$14,243,128	$5,724,313	$19,967,440
Health & social services		$1,329,250	$69,843,627	$71,172,877
Arts- entertainment & recreation		$458,014	$5,066,398	$5,524,412
Accommodation & food services		$3,650,442	$18,414,772	$22,065,214
Other services		$5,006,713	$20,537,114	$25,543,827
Government & non-NAICs	$623,990,698	$365,060,163	$4,248,452	$993,299,313
Total Output	**$623,990,698**	**$914,138,165**	**$398,978,141**	**$1,937,107,004**

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 output impact is adjusted for inflation and shown in 2022 dollars.

In FY 2021, the total output impact of NASA Glenn on the State of Ohio was $1.94 billion. NASA Glenn's expenditures of $826.3 million worth of overall expenditures, including $624 million of the spending in Ohio. This spending resulted in an output (sales) change of $1.94 billion across all industry sectors (Table 11, in 2022 dollars). This economic impact included a $275.3 million increase in total sales in the Professional, Scientific, and Technical Services industry and a $102.4 million increased in sales in the Administrative and Waste Services.

Of the total output impact, 32.2% ($624.0 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 $914.1 (47.2%) of the total output impact. The remaining $399 million (20.6%) 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 $1.31 billion increase in sales generated by the indirect and induced impacts can be divided into three broad categories: NASA Glenn-driven ($504.4 million, 38.4%), consumer-driven ($283.2 million, 21.5%), and other industries ($526.7 million, 40.1%).[38]

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 $9.0 million or 3.0% each.

The scientific research and development industry generated the largest output impact as a single industry; it increased by $163.4 million in FY 2021 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 and development services. This increase of $163.4 million accounted for 32% of the $504.4 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 other real estate industry generated the largest output impact as an individual industry. This industry increased by $41.2 million in FY 2021 and represented a 15% share of the $283.2 million increase in output for all consumer-driven industries. Other industries shown in Figure 14 can be interpreted similarly.

[38] 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 2021

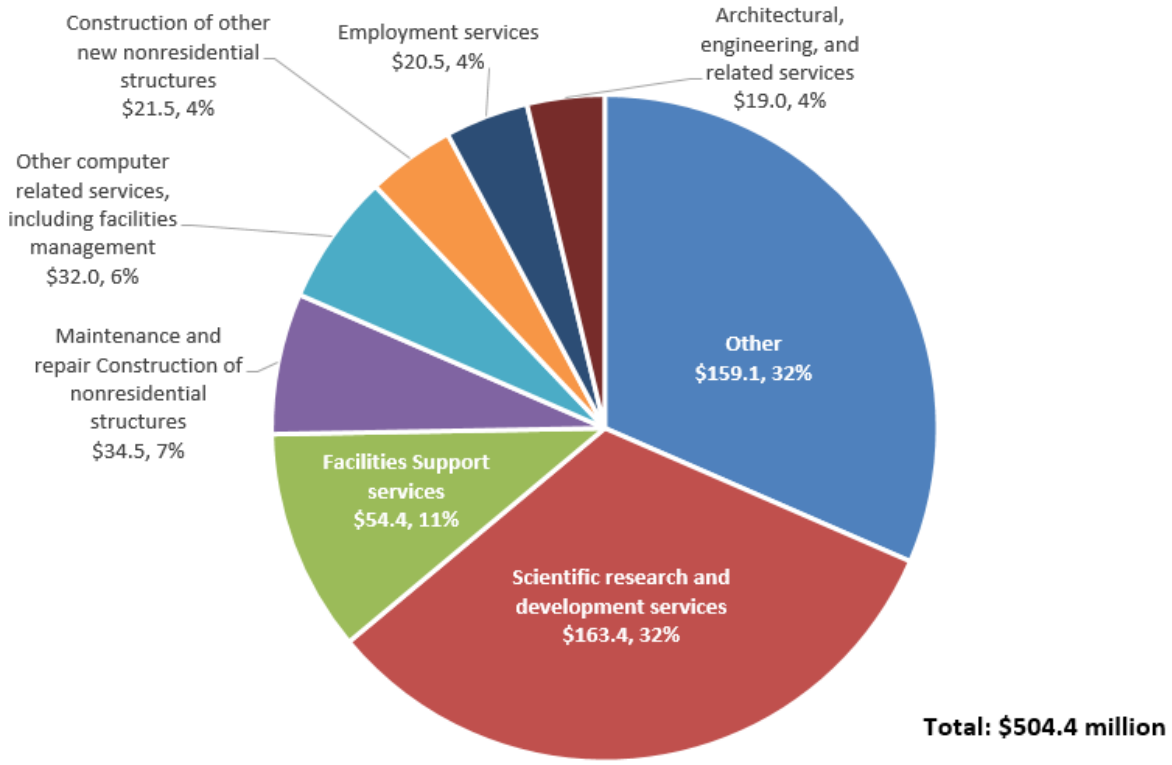
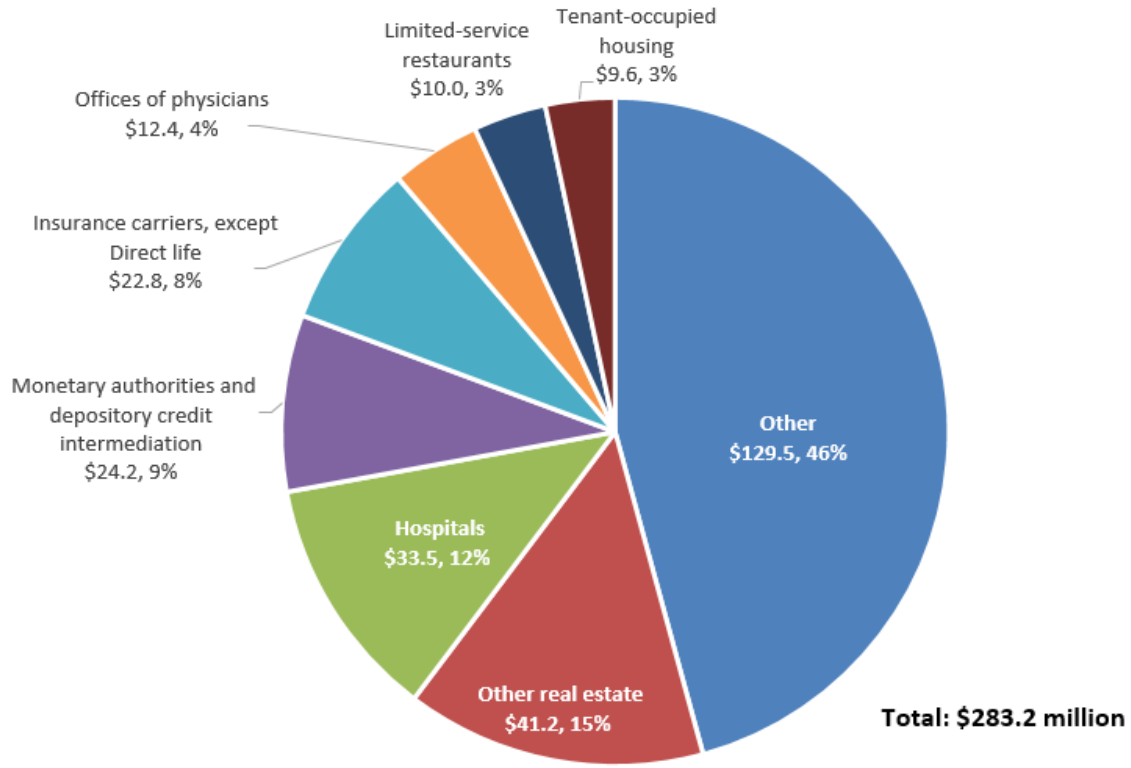


Figure 14. Increase in Sales for Select Consumer-Driven Industries in Ohio, FY 2021



D.3.2. Employment Impact on the State of Ohio, FY 2021

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).

In addition, money spent by NASA Glenn employees and employees of supply chain companies create 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 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		6	8	14
Mining		3	1	4
Utilities		16	7	23
Construction		285	17	302
Manufacturing		44	21	66
Wholesale Trade		36	62	98
Retail trade		46	363	409
Transportation & Warehousing		64	98	163
Information		23	35	57
Finance & insurance		35	187	221
Real estate & rental		141	128	269
Professional- scientific & tech svcs		1,331	118	1,449
Management of companies		53	28	81
Administrative & waste services		773	139	912
Educational services		170	90	260
Health & social services		12	574	586
Arts- entertainment & recreation		8	68	76
Accommodation & food services		56	259	316
Other services		42	242	284
Government & non-NAICs	1,537	1,947	23	3,507
Total Employment	**1,537**	**5,090**	**2,467**	**9,095**

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 2021 resulted in a total increase of 9,095 jobs in the State of Ohio. Of the total employment, 1,537 people (16.9%) 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, 5,090 full-time and part-time jobs (56.0%) were supported and created in the region as an indirect economic impact. The remaining 2,467 jobs (27.1%) 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 7,557 jobs created in the State of Ohio due to the indirect and induced effects, 3,003 (39.7%) were found in the NASA Glenn-driven sectors, 1,987 (26.3%) were created in consumer-driven sectors, and 2,567 (34.0%) were created in other sectors.[39]

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 140 jobs (5.0%). Each of the industries shown in Figure 16 supported or added over 60 jobs (3.0%).

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 754 jobs and accounted for a 25% share of the 3,003 jobs created across all NASA Glenn-driven industries in FY 2021. 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 other real estate industry saw the largest increase of jobs as a single industry among consumer-driven industries in FY 2021; the increase of 213 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 213 jobs represent an 11% share of the 1,987 jobs created across all consumer-driven industries in the state.

[39] 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 2021

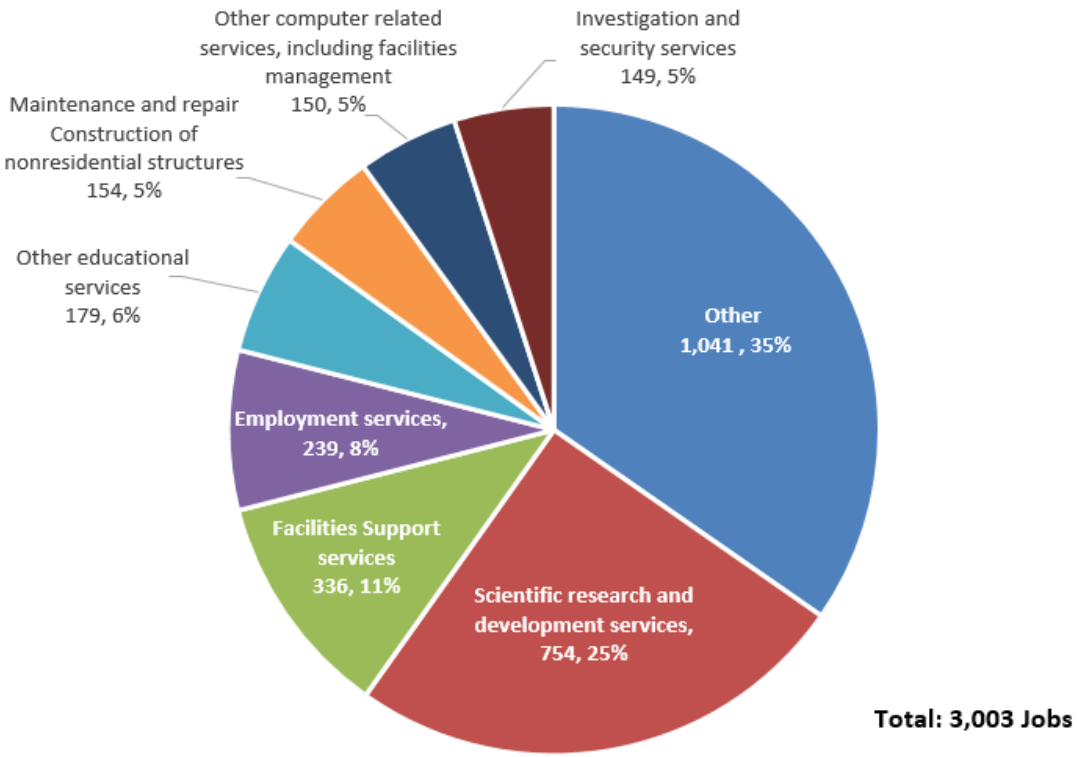
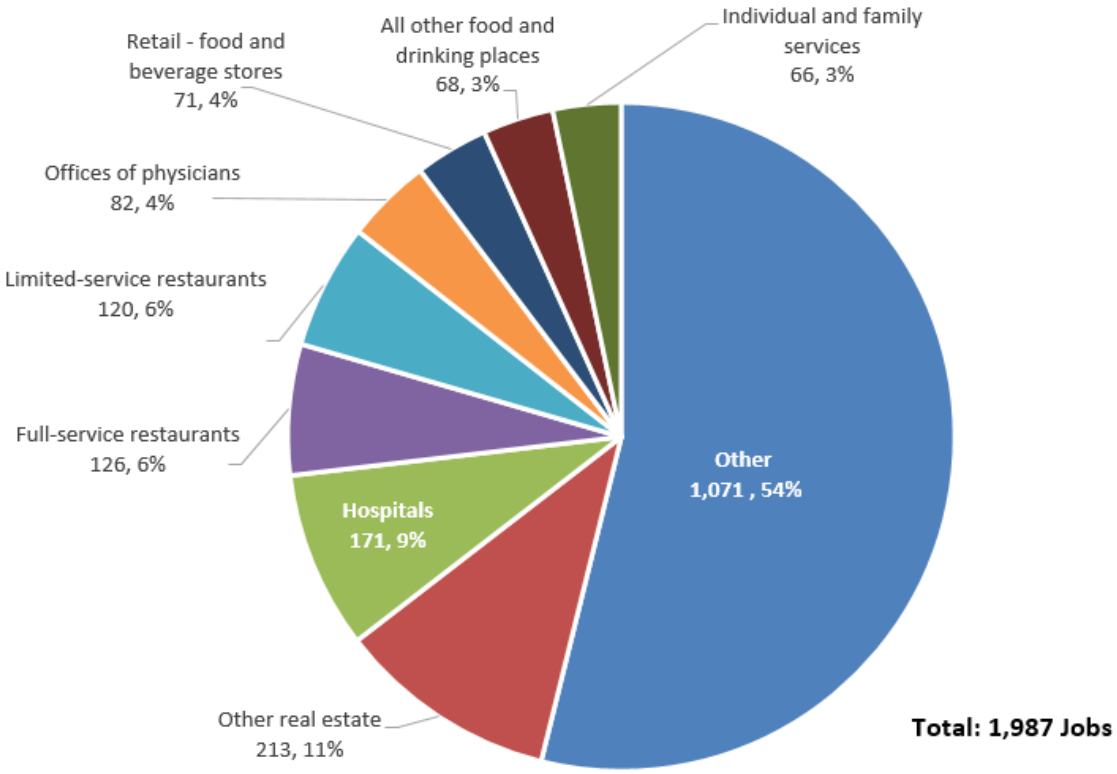


Figure 16. Increase in Jobs for Select Consumer-Driven Industries in Ohio, FY 2021



D.3.3. Labor Income Impact on the State of Ohio, FY 2021

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 created 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 supplier companies and the companies from which suppliers purchase their goods and services make up the indirect earnings impact. The induced impact was generated through the spending of NASA Glenn workers and 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 in 2022 dollars.

Table 13. Labor Income Impact in the State of Ohio, FY 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$117,926	$145,321	$263,248
Mining		$165,648	$19,598	$185,247
Utilities		$2,091,727	$1,060,642	$3,152,369
Construction		$12,788,790	$757,275	$13,546,065
Manufacturing		$3,458,845	$1,669,637	$5,128,482
Wholesale Trade		$3,398,004	$6,975,163	$10,373,166
Retail trade		$2,082,376	$12,423,140	$14,505,515
Transportation & Warehousing		$3,338,522	$4,583,230	$7,921,753
Information		$2,386,843	$4,755,953	$7,142,796
Finance & insurance		$4,432,248	$13,155,883	$17,588,131
Real estate & rental		$4,425,557	$3,504,938	$7,930,495
Professional- scientific & tech svcs		$118,662,446	$11,237,562	$129,900,008
Management of companies		$2,151,204	$1,059,263	$3,210,466
Administrative & waste services		$31,092,888	$6,779,285	$37,872,172
Educational services		$7,032,759	$9,919,678	$16,952,437
Health & social services		$678,544	$31,011,622	$31,690,166
Arts- entertainment & recreation		$250,854	$2,309,618	$2,560,472
Accommodation & food services		$1,974,279	$8,682,873	$10,657,151
Other services		$2,472,968	$9,641,127	$12,114,095
Government & non-NAICs	$262,807,573	$256,343,560	$1,506,434	$520,657,567
Total Output	**$262,807,573**	**$459,345,987**	**$131,198,241**	**$853,351,801**

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 2022 dollars.

In FY 2021, the total labor income increased by $853.4 million in the State of Ohio due to NASA Glenn's spending on goods and services. Of this amount, $262.8 million (30.8%) originated from wages and benefits paid directly to NASA Glenn employees (change in final demand, or direct effect measured in 2022 dollars). Of the $853.4 million in total labor income, $459.3 million (53.8%) 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 $131.2 million (15.4%), 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 $590.5 million increase in labor income generated across the State of Ohio due to indirect and induced impacts, $196.9 million (33.3%) was paid in Glenn-driven industries, $147.5 million (16.1%) was paid in consumer-driven industries, and $298.5 million (50.6%) occurred in other industries.[40]

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% ($8.6 million) and 3.0% ($3.2 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 2021 (Figure 17). Labor income in this sector increased by $64.4 million and accounted for 33% of the $196.9 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 2021 (Figure 18). Increasing by $15.3 million, labor income in the private hospitals' sector represented a 16% share of the $95.1 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.

[40] See section D.2.1. Output Impact on Northeast Ohio, FY 2021 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 2021

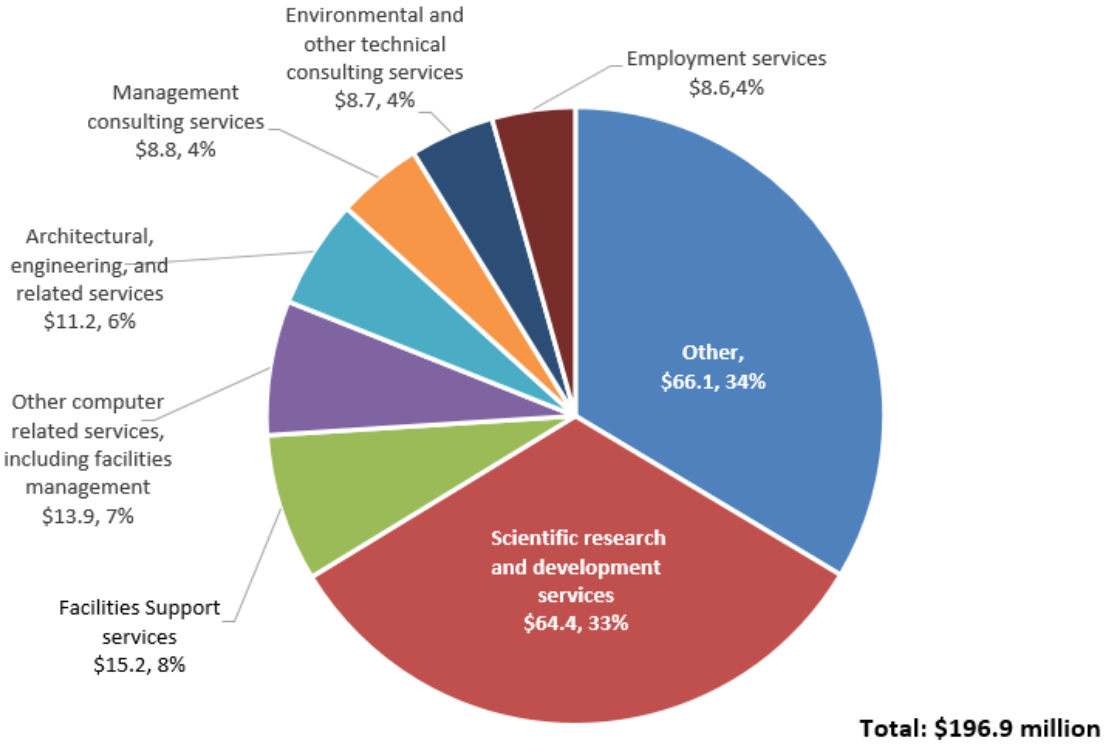
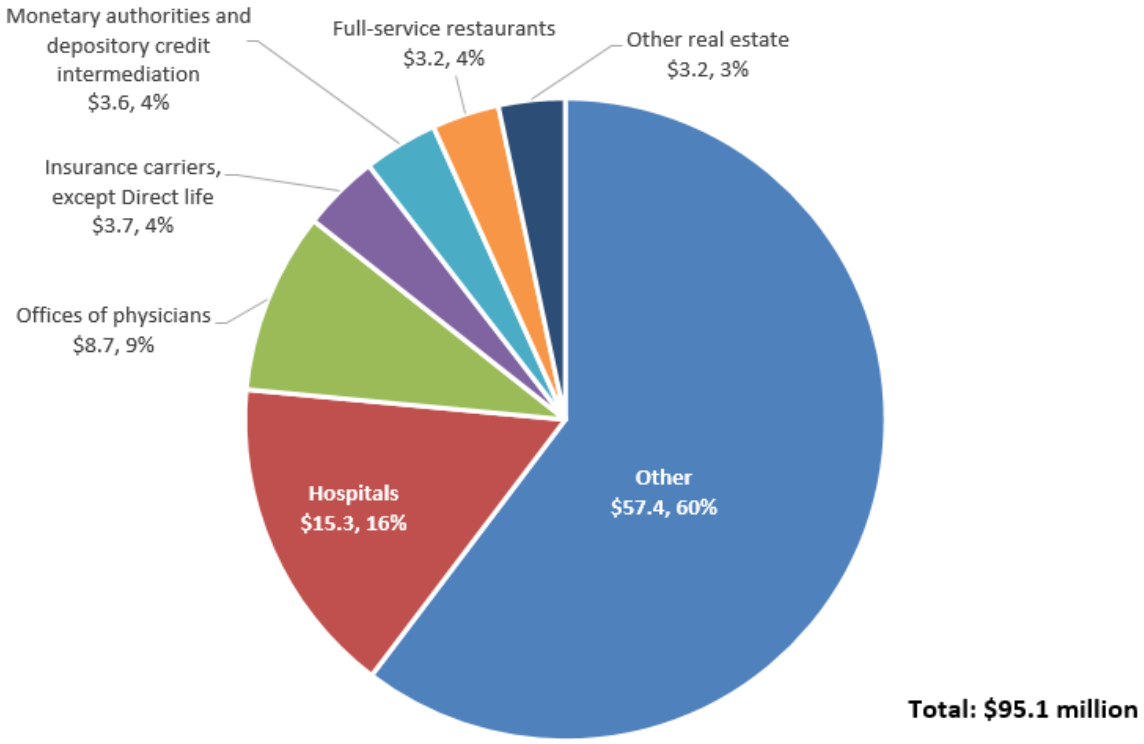


Figure 18. Increase in Labor Income for Select Consumer-Driven Industries in Ohio, FY 2021



D.3.4. Value Added Impact on the State of Ohio, FY 2021

NASA Glenn's spending in FY 2021 created an increase of $1.2 billion in value added for all industries.[41] Of this total, $305.8 million (25.9%) 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, which is typical for the research and development-intense companies and organizations. Another $641.7 million (54.3%) 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 $235.5 million (19.8%). It occurred as a result of NASA Glenn's spending rippling through the Ohio economy. The total value-added impact is a summation result of direct, indirect, and induced impacts (Table 14, in 2022 dollars).[42]

Table 14. Value Added Impact in the State of Ohio, FY 2021

Industry	Direct	Indirect	Induced	Total
Agriculture, Forestry, Fishing & Hunting		$263,282	$305,910	$569,192
Mining		$761,084	$158,133	$919,216
Utilities		$6,507,506	$3,716,761	$10,224,267
Construction		$21,373,207	$1,456,127	$22,829,334
Manufacturing		$6,452,960	$3,593,741	$10,046,701
Wholesale Trade		$6,504,608	$12,899,400	$19,404,007
Retail trade		$3,527,542	$20,066,594	$23,594,136
Transportation & Warehousing		$3,919,145	$5,312,294	$9,231,439
Information		$5,063,430	$10,358,711	$15,422,141
Finance & insurance		$17,964,228	$37,630,633	$55,594,861
Real estate & rental		$9,202,740	$45,216,917	$54,419,657
Professional- scientific & tech svcs		$139,666,814	$13,117,627	$152,784,442
Management of companies		$1,569,821	$814,964	$2,384,784
Administrative & waste services		$43,954,616	$8,018,208	$51,972,823
Educational services		$6,883,363	$9,554,622	$16,437,986
Health & social services		$829,593	$35,354,521	$36,184,114
Arts- entertainment & recreation		$325,939	$3,470,987	$3,796,927
Accommodation & food services		$2,512,554	$11,621,746	$14,134,300
Other services		$3,415,849	$11,334,190	$14,750,039
Government & non-NAICs	$305,755,380	$360,948,355	$1,502,548	$668,206,283
Total Output	**$305,755,380**	**$641,646,638**	**$235,504,633**	**$1,182,906,650**

[41] "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).

[42] 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. 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.
The value added impact is adjusted for inflation and shown in 2022 dollars.

Total value added in the State of Ohio increased by $1.2 billion as a result of NASA Glenn's spending for goods and services in FY 2021. Of this total amount, $305.8 million (29.7%) included the wages and benefits paid directly to NASA Glenn employees (change in final demand or direct impact). Another $641.6 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 $235.5 million (19.9%), occurred as the effects of NASA Glenn's spending rippled through the Ohio economy.

Of the $877.1 million increase in value added generated across Ohio due to indirect and induced impacts, $258.3 million (29.4%) was reported in NASA Glenn-driven industries, $162.4 million (18.5%) was generated in consumer-driven industries, and $420.7 million (47.9%) 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 $10 million (4%) and $8 million (5%), respectively.

The scientific research and development services industry saw the largest increase in value added of all NASA-Glenn driven industries, with its value-added totaling $81.1 million (Figure 19). This increase in value added is the result of totaling indirect and induced impacts that are generated primarily, though not exclusively, by NASA Glenn's spending on facilities support services. The $81.1 million accounted for 32% of the $258.3 million value added increase that was reported across all NASA Glenn-driven industries.

In the consumer-driven industries, employees working in monetary authorities and depository credit intermediation saw their value-added increase by $19.7 million in FY 2021 (Figure 20). This value-added increase is a result of totaling the indirect and induced impacts generated by consumer spending for banking. The increase of $19.7 million accounted for 12% of the $162.4 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 2021

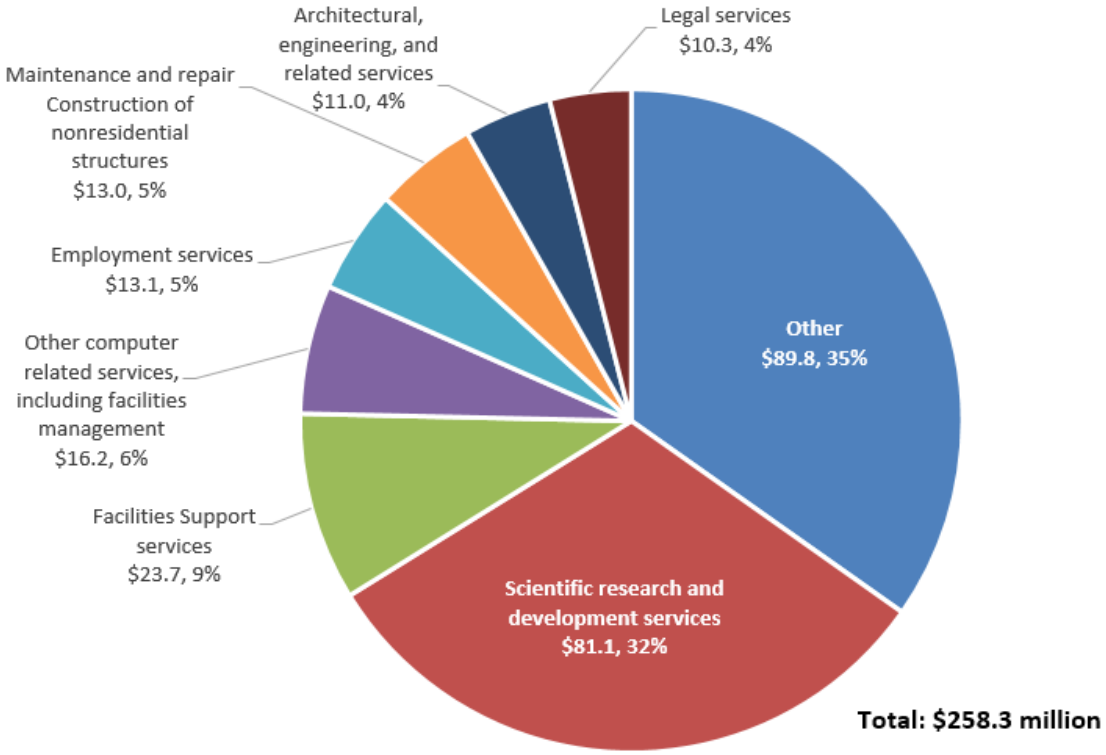
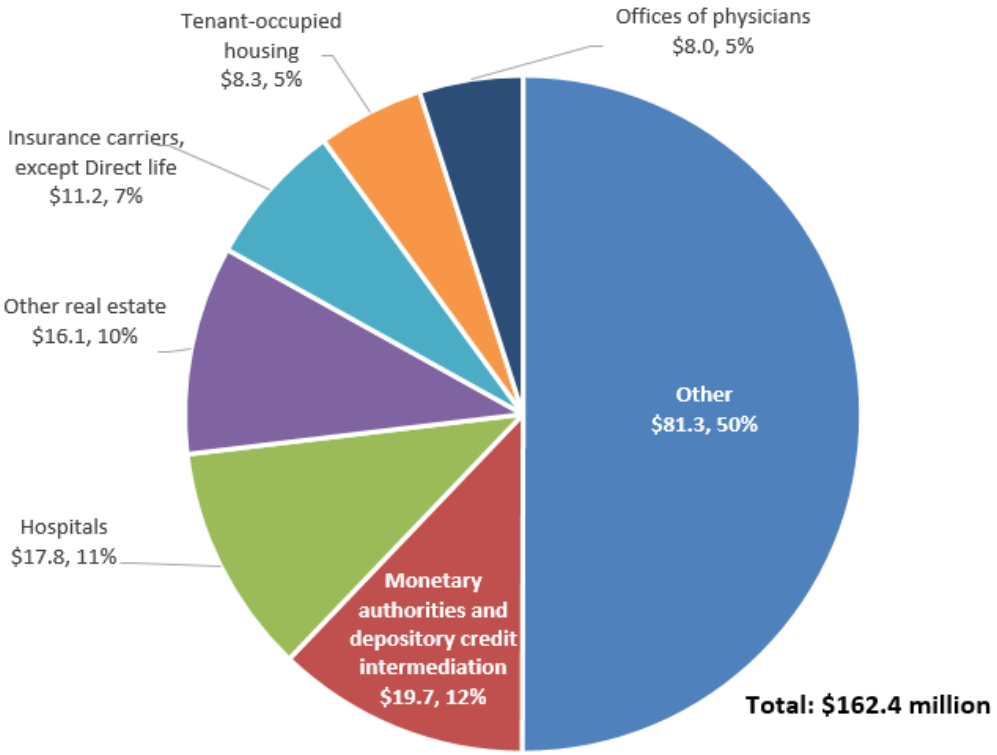


Figure 20. Increase in Value Added for Consumer-Driven Industries in Ohio, FY 2021



D.3.5. Tax Impact on the State of Ohio, FY 2021

NASA Glenn's operations and economic impact on the state of Ohio in FY 2021 increased tax revenues by a total of $210.7 million (in 2022 dollars). Of this total amount, direct tax impact to all levels of government was $34.7 million in Glenn's employee taxes on wages. $40.4 million were paid in taxes to the state and local governments in the state of Ohio, including $22.3 million in state tax.

D.3.6. FY 2021 Ohio Impact Summary

The economic activity in FY 2021 generated by NASA Glenn Research Center created the following economic impact on the State of Ohio:

- Total Output Impact: $1,937.1 M
- Total Employment Impact: 9,095 jobs
- Total Labor Income Impact: $853.4 M
- Total Value Added Impact: $1,182.9 M
- Total Tax Impact: $210.7 M

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

In FY 2021, NASA Glenn's expenditures in the State of Ohio totaled to $595.6 million, including $250.9 million (42.1%) in labor income. The total expenditures in all of Ohio were $38.3 million more than in the total expenditures in Northeast Ohio.

Similarly, to the expenditures made in Northeast Ohio in FY 2021, the largest share of the total payments, $203.4 million was spent on professional, scientific, and technical services. Excluding labor income, this constitutes 59% of all expenditures. In addition, $62.4 million was paid for administrative and support and waste management and remediation services (18.1%), $51.3 (14.9%) for construction, $13.6 million (3.9%) for educational services, and $6.7 million (1.9%) for utilities. These five largest areas of spending accounted for $337.5 million or 98% of all non-labor expenditures in FY 2021.[43]

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.

[43] Amounts in parentheses detailing percentage numbers are presented in 2021 dollars and correspond to Appendix table A.4.

APPENDIX A: DATA TABLES

Table A.1. NASA Glenn Spending by State, Excluding Payroll, FY 2021

Region	Total	Share
Ohio	$344,759,561	60.4%
California	$100,856,668	17.7%
Alabama	$39,584,068	6.9%
Washington	$27,293,186	4.8%
Maryland	$12,269,977	2.2%
Colorado	$4,066,732	0.7%
Texas	$3,898,457	0.7%
New York	$3,866,601	0.7%
Florida	$3,596,459	0.6%
Pennsylvania	$3,445,123	0.6%
Massachusetts	$3,219,886	0.6%
Connecticut	$3,088,156	0.5%
Virginia	$3,006,854	0.5%
Illinois	$1,994,161	0.3%
Indiana	$1,598,925	0.3%
New Jersey	$1,489,772	0.3%
Michigan	$1,368,418	0.2%
Missouri	$1,355,400	0.2%
Arizona	$1,313,381	0.2%
Georgia	$1,242,306	0.2%
New Mexico	$993,818	0.2%
New Hampshire	$957,130	0.2%
Wisconsin	$855,060	0.1%
Minnesota	$837,567	0.1%
Tennessee	$770,915	0.1%
South Dakota	$512,210	0.1%
North Carolina	$355,526	0.1%
Oregon	$353,887	0.1%
Delaware	$313,460	0.1%
South Carolina	$281,102	0.0%
Kansas	$201,102	0.0%
Nevada	$148,716	0.0%
Rhode Island	$78,915	0.0%

Region	Total	Share
Kentucky	$60,905	0.0%
Montana	$49,302	0.0%
District of Columbia	$41,433	0.0%
Iowa	$36,746	0.0%
Utah	$32,910	0.0%
Oklahoma	$27,924	0.0%
Vermont	$22,219	0.0%
Nebraska	$11,245	0.0%
North Dakota	$7,141	0.0%
Mississippi	$6,769	0.0%
Louisiana	$5,096	0.0%
Alaska	$1,590	0.0%
Puerto Rico	$225	0.0%
Arkansas	$68	0.0%
U.S. Total (47 states and the District of Columbia)	**$570,277,073**	**99.96%**
Great Britain	$50,190	0.0%
Canada	$48,338	0.0%
Denmark	$38,923	0.0%
France	$35,938	0.0%
Switzerland	$29,233	0.0%
Germany	$23,602	0.0%
Czech Republic	$17,555	0.0%
Japan	$1,600	0.0%
Australia	$1,138	0.0%
Norway	$797	0.0%
Foreign Total	**$247,313**	**0.04%**
Grand Total	**$570,524,386**	**100.0%**

Table A.2. NASA Glenn Grants Allocated to Academic Institutions by State, FY 2021

State	College / University	Share
California	$945,199	11.9%
Georgia	$747,965	9.4%
Maryland	$656,061	8.3%
Ohio	$630,113	8.0%
Illinois	$612,828	7.7%
Michigan	$503,968	6.4%
Pennsylvania	$458,500	5.8%
New York	$431,287	5.4%
New Jersey	$348,202	4.4%
Texas	$344,952	4.4%
Florida	$331,409	4.2%
Indiana	$269,962	3.4%
Tennessee	$206,740	2.6%
Colorado	$188,344	2.4%
Virginia	$154,983	2.0%
Oregon	$139,225	1.8%
Connecticut	$133,875	1.7%
Kansas	$132,717	1.7%
Arizona	$121,785	1.5%
New Mexico	$112,467	1.4%
North Carolina	$93,413	1.2%
Massachusetts	$71,242	0.9%
South Carolina	$59,878	0.8%
South Dakota	$50,178	0.6%
Missouri	$47,214	0.6%
Washington	$40,469	0.5%
Kentucky	$35,641	0.4%
New Hampshire	$35,473	0.4%
Iowa	$15,146	0.2%
Mississippi	$3,476	0.0%
Wisconsin	$1,458	0.0%
Total	**$7,924,172**	**100.0%**

Table A.3. NASA Glenn Detailed Expenditures in Northeast Ohio, FY 2021

	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			**$6,538,174**
	Electric power transmission and distribution	47	$3,169,718
	Natural gas distribution	48	$1,275,149
	Water, sewage and other systems	49	$2,093,307
Construction			**$49,432,465**
	Construction of other new nonresidential structures	56	$21,200,338
	Maintenance and repair construction of nonresidential structures	60	$28,232,127
Manufacturing			**$1,943,930**
	Industrial gas manufacturing	160	$15,600
	Nonferrous metal, except copper and aluminum, shaping	225	$36,703
	Sheet metal work manufacturing	239	$31,187
	Hardware manufacturing	245	-$15,538
	Spring and wire product manufacturing	246	$72,045
	Machine shops	247	$500,686
	Metal heat treating	249	$260
	Metal coating and nonprecious engraving	250	$19,076
	Valve and fittings, other than plumbing, manufacturing	252	$253,375
	Fabricated pipe and pipe fitting manufacturing	258	$70,513
	All other industrial machinery manufacturing	269	$12,900
	Photographic and photocopying equipment manufacturing	271	$63,130
	Pump and pumping equipment manufacturing	285	$39,440
	Air and gas compressor manufacturing	286	$40,580
	Industrial process furnace and oven manufacturing	294	$0
	Scales, balances, and miscellaneous general-purpose machinery manufacturing	297	$17,898
	Broadcast and wireless communications equipment manufacturing	302	$491,446
	Watch, clock, and other measuring and controlling device manufacturing	319	$8,000
	All other miscellaneous electrical equipment and component manufacturing	339	$48,479
	Automobile manufacturing	340	$238,151
Wholesale Trade & Retail Trade			**$909,834**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$284,300
	Wholesale - Machinery, equipment, and supplies	395	$57,313
	Retail - Miscellaneous store retailers	412	$568,221
Transportation and Warehousing			**$3,434**
	Truck transportation	417	$3,434
Information			**$4,308**
	News syndicates, libraries, archives and all other information services	437	$4,308

	Description	IMPLAN Sector (a)	Expenditure (b)
Real Estate and Rental and Leasing			**$22,523**
	Commercial and industrial machinery and equipment rental and leasing	453	$22,523
Professional, Scientific, and Technical Services			**$178,143,414**
	Legal services	455	$23,300
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,193,510
	Architectural, engineering, and related services	457	$11,893,841
	Other computer related services, including facilities management	461	$31,135,100
	Management consulting services	462	$3,090,097
	Environmental and other technical consulting services	463	$11,280,263
	Scientific research and development services	464	$116,388,344
	Marketing research and all other miscellaneous professional, scientific, and technical services	468	$138,960
Administrative and Support and Waste Management and Remediation Services			**$60,625,445**
	Facilities support services	471	$53,142,953
	Investigation and security services	475	$4,998,944
	Services to buildings	476	$2,298,838
	Other support services	478	$1,082
	Waste management and remediation services	479	$183,629
Educational Services			**$13,398,940**
	Junior colleges, colleges, universities, and professional schools	481	$452,467
	Other educational services	482	$12,946,473
Health Care and Social Assistance			**$1,294,282**
	Other ambulatory health care services	489	$1,294,282
Labor Income			**$244,985,914**
	Employee Compensation (c)		$244,985,914
TOTAL EXPENDITURES IN NEO			**$557,302,664**

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 2021. 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 2021

	Description	IMPLAN Sector (a)	Expenditure (b)
Utilities			**$6,707,717**
	Electric power transmission and distribution	47	$3,169,718
	Natural gas distribution	48	$1,311,894
	Water, sewage and other systems	49	$2,226,105
Construction			**$51,265,034**
	Construction of other new nonresidential structures	56	$21,200,338
	Maintenance and repair construction of nonresidential structures	60	$30,064,696
Manufacturing			**$3,309,126**
	Industrial gas manufacturing	160	$15,600
	Plastics material and resin manufacturing	164	$196,519
	Nonferrous metal (Excl aluminum) smelting and refining	223	$12,000
	Nonferrous metal, except copper and aluminum, shaping	225	$36,703
	Sheet metal work manufacturing	239	$31,187
	Hardware manufacturing	245	-$15,538
	Spring and wire product manufacturing	246	$72,045
	Machine shops	247	$565,992
	Metal heat treating	249	$14,317
	Metal coating and nonprecious engraving	250	$19,076
	Valve and fittings, other than plumbing, manufacturing	252	$529,548
	Fabricated pipe and pipe fitting manufacturing	258	$70,513
	All other industrial machinery manufacturing	269	$24,560
	Optical instrument and lens manufacturing	270	$2,517
	Photographic and photocopying equipment manufacturing	271	$63,130
	Heating equipment (except warm air furnaces) manufacturing	274	$30,826
	Pump and pumping equipment manufacturing	285	$39,440
	Air and gas compressor manufacturing	286	$40,580
	Industrial process furnace and oven manufacturing	294	$685,419
	Fluid power pump and motor manufacturing	296	$20,571
	Scales, balances, and miscellaneous general-purpose machinery	297	$17,898
	Broadcast and wireless communications equipment	302	$491,446
	Electricity and signal testing instruments manufacturing	316	$1,053
	Watch, clock, and other measuring and controlling device	319	$8,000
	All other miscellaneous electrical equipment and component	339	$48,479
	Automobile manufacturing	340	$238,151
	Aircraft engine and engine parts manufacturing	355	$37,846
	Gasket, packing, and sealing device manufacturing	386	$11,250
Wholesale Trade & Retail Trade			**$1,126,733**
	Wholesale - Motor vehicle and motor vehicle parts and supplies	392	$284,300
	Wholesale - Machinery, equipment, and supplies	395	$123,271
	Retail - Miscellaneous store retailers	412	$719,162

	Description	IMPLAN Sector (a)	Expenditure (b)
Transportation and Warehousing			**$4,175**
	Truck transportation	417	$4,175
Information			**$16,584**
	News syndicates, libraries, archives and all other information	437	$4,308
	Internet publishing and broadcasting and web search portals	438	$12,276
Real Estate and Rental and Leasing			**$22,523**
	Commercial and industrial machinery and equipment rental and	453	$22,523
Professional, Scientific, and Technical Services			**$203,429,308**
	Legal services	455	$23,300
	Accounting, tax preparation, bookkeeping, and payroll services	456	$4,193,510
	Architectural, engineering, and related services	457	$12,228,990
	Computer systems design services	460	$12,465
	Other computer related services, including facilities management	461	$31,141,634
	Management consulting services	462	$3,090,097
	Environmental and other technical consulting services	463	$11,285,966
	Scientific research and development services	464	$141,306,469
	Marketing research & all other miscellaneous professional,	468	$146,878
Administrative and Support and Waste Management and Remediation Services			**$62,460,996**
	Facilities support services	471	$53,164,196
	Investigation and security services	475	$6,813,252
	Services to buildings	476	$2,298,838
	Other support services	478	$1,082
	Waste management and remediation services	479	$183,629
Educational Services			**$13,587,089**
	Junior colleges, colleges, universities, and professional schools	481	$640,616
	Other educational services	482	$12,946,473
Health Care and Social Assistance			**$1,294,282**
	Other ambulatory health care services	489	$1,294,282
Other Services (except Public Administration)			**$1,535,995**
	Grantmaking, giving, and social advocacy organizations	522	$790,906
	Other federal government enterprises	528	$745,089
Labor Income			**$250,857,300**
	Employee Compensation (c)		$250,857,300
TOTAL EXPENDITURES IN OHIO			**$595,616,861**

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 2021. 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.