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The NASA Glenn Research Center: an Economic Impact Study

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THE NASA GLENN RESEARCH CENTER: AN ECONOMIC IMPACT STUDY

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EXECUTIVE SUMMARY

INTRODUCTION

The Glenn Research Center (GRC) is one of ten National Aeronautics and Space Administration (NASA) centers. GRC is situated on 350 acres and occupies over 150 buildings and over 500 specialized research and test facilities. The Center, formerly the Lewis Research Center, was officially renamed the NASA John H. Glenn Research Center at Lewis Field on March 1, 1999. GRC is NASA's lead center for aeropropulsion, aerospace power systems, spectrum management, small business technology transfer and research contracting, small business innovation research contracting, and environmental information systems. As the Center of Excellence for Turbomachinery, GRC has a critical role in advancing NASA's aeronautics and space goals. GRC has full responsibility for applications requiring turbomachinery, and for NASA's Propulsion Systems Research and Technology (R&T) program, one of six base R&T programs within the Aeronautics and Space Transportation Technology Enterprise. GRC has also become the preeminent research facility within the Agency's microgravity programs as program manager for fluid physics and combustion microgravity research.

This study describes the impact of GRC on the State of Ohio and on Northeast Ohio, where GRC is located. Northeast Ohio includes the eight counties in the Akron and Cleveland metropolitan areas.[1] This report is an expansion and update of an earlier study, published in February 1996.[2] As before, this study employs two methods to determine GRC's influence on the state and local economies. The first method uses quantitative models to estimate the effect of GRC on the studied economies. These models measure economic impact in terms of growth in total output, household earnings, and number of new jobs created. The second method uses GRC's internal documents and interviews with GRC's staff, as well as interviews with leaders in industry, academia, and the non-profit sector who are affiliated with GRC or are knowledgeable about its activities. This is the primary method in the analysis of GRC's technology transfer activities and its educational contributions.

PROGRAMMATIC CHANGES IN NASA AND THEIR IMPACT ON GRC

Since the mid-1990s, NASA has been experiencing budget cuts. Its FY1999 budget was $13,665 billion and its FY2000 budget is projected to decrease further to $13,578 billion. Following annual budget increases during FY1988-FY1992, NASA's administrator, Dan Goldin, presented his plan in May 1995 to trim the budget by $4.9 billion by the end of the decade. NASA has dealt with programmatic changes throughout the late 1990s.

NASA experienced a number of transformations in the past five years. One major change was the restructuring and consolidation of the Space Station program from four work packages and contracts to a single prime contractor. As a result, GRC, the lead for the

[1] These counties include Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit.

[2] See T*he NASA Lewis Research Center: An Economic Impact Study*, February 12, 1996.

Space Station power system, lost $300 million annually and a staff of about 200. GRC was also affected when the management for the expendable launch vehicle (ELV) program became the responsibility of the Kennedy Space Center, resulting in a loss of approximately $100 million annually for GRC. A major portion of GRC's microgravity science program is now focusing on the development of facilities for the Space Station, as well as planning for the experimental utilization of those facilities, due to a changed emphasis on Space Station utilization. In addition, two major aeronautics programs have been eliminated: the High Speed Research (HSR) and the Advanced Subsonic Technology (AST). However, these programs developed a technology foundation that led to a new initiative, and GRC was named lead Center for the initiation of the Ultra Efficient Engine Technology (UEET) program. This five-year program (FY2000 - FY2005) will enable the development of the next generation engines and has military and commercial applications. UEET's total funding is expected to be $250 million and will utilize approximately 200 employees, shifted from other programs. GRC also anticipates a significant increase in funding starting in FY2001 due to its expertise and capabilities supporting the Reusable Launch Vehicle (RLV) program, which is a major element of the NASA's Space Transportation activities.

DIRECT IMPACT: RECENT TRENDS AND PROJECTIONS

- Total employment at GRC in FY1998 was 3,355; 61 percent of which was civil service employment. The large declines in GRC's labor force of 544 civil service employees and 545 contractors during FY1994-FY1998 are primarily a result of the severe budget cuts at NASA and the buy-outs offered to civil service employees at GRC.

- Total GRC employment is projected to decline by another 301 jobs between FY1998 and FY2004. Almost all of the employment loss (97 percent) is projected to be among contractors' employees.

- Total compensation for GRC's civil service employees amounted to $131.6 million in FY1998, while benefits to current employees accounted for another $21.7 million.

- Total compensation declined by $12.9 million from FY1994, a decline of 8.9 percent. During this time period, total compensation per GRC civil-service employee increased from $55,800 in FY1994 to $64,350 in FY1998, an increase of 15.3 percent.

- Between FY1994 and FY1998, the severe job cuts affected all occupational categories.

- Scientists and engineers, with 1,148 jobs, remained the largest occupational category at GRC, accounting for 56 percent of GRC's labor force.

- The vast majority of GRC's civil-service employees (98 percent) live in Northeast Ohio. Two-thirds live in Cuyahoga County; Lorain and Medina counties account for another 14 and 12 percent respectively. Within Cuyahoga County, in order of number of employees, Strongsville, Cleveland, North Olmsted, Westlake, Parma, Fairview Park, and Berea have the most GRC employees.

- In FY1998, GRC spent a total of $514 million on contractors, a decline of $153 million, or 23 percent since FY1994. Forty seven percent of total spending on contractors was spent in Ohio and 33 percent was spent in Northeast Ohio.

- While spending on business and engineering services in Ohio declined only slightly, in Northeast Ohio, this spending fell significantly ($33.6 million, or close to 24 percent) during FY 1994-FY1998.

- Seven out of ten dollars spent on Ohio's contractors were spent on contractors located in Northeast Ohio. In engineering and business services and in manufacturing, Northeast Ohio accounted for 60 and 63 percent respectively of spending in Ohio while more than 93 percent of each of the other contractors' categories were spent in Northeast Ohio.

- In FY1998, GRC awarded $61.3 million in grants, significantly more than the $43.1 million awarded in FY1994.

- In FY1998, Ohio's educational institutions received only $15.1 million compared to $21 million in FY1994, awards in Northeast Ohio declined from $16.1 to $12.3 million.

- Of any state, Ohio received the largest share of educational grants awarded by GRC.

- CCC received larger grants to support its educational outreach program, especially those for the Science, Engineering, Mathematics, and Aerospace Academy.

- Located in Northeast Ohio, Case Western Reserve University ($2.8 million) and Cleveland State University ($1.8 million) received more grants from GRC than any other universities (18 percent and 12 percent respectively).

- Ohio Aerospace Institute (OAI) received the largest amount of funding, $4.9 million, almost one-third of total Ohio grants

- GRC's total revenues fell by one third over the past five years, from $1,039 million in FY1994 to $699 million in FY1998. GRC's revenues are projected to continue to decline until FY2000, falling to the low level of $582 million. After that, revenues are projected to increase to a level of $683 million by FY2004.

- During the five-year period, FY1994-FY1998, the City of Cleveland received $9.5 million from GRC's employees and the City of Fairview Park received $2.3 million. The State of Ohio collected almost $28 million from GRC's employees.

GRC TOTAL ECONOMIC IMPACT ON THE NORTHEAST OHIO ECONOMY

GRC economic activities in FY 1998 produced the following economic impacts in the northeast Ohio region:

- Total Output Impact: $879 million, a reduction of 24 percent from FY1994
- Total Employment Impact: 9,360 jobs, a reduction of 27 percent from FY1994
- Total Earnings Impact: $315 million, a reduction of 24 percent from FY1994

- Of the $879 million in spending generated by GRC in FY1998, $318 resulted from direct spending impacts and $561 million resulted from indirect and induced spending impacts.

- Of the 9,360 jobs generated by GRC in FY1998, 2,045 resulted from direct impact (civil service employees at the Center) and 7,315 resulting from indirect and induced impacts.

- The total earnings impact in FY1998 of $315 million was made up of $137 million in direct impacts and $178 in indirect and induced impacts.

GRC Total Economic Impact in the State of Ohio

GRC economic activities in FY1998 produced the following economic impacts in the State of Ohio:

- Total Output Impact: $1,155 million
- Total Employment Impact: 12,062 jobs
- Total Earnings Impact: $384 million

- Of GRC's spending of $1,155 million, $394 resulted from direct impact and $761 resulted from indirect and induced spending impact.

- In FY1998, 12,062 jobs were generated in Ohio through GRC's activities. Of these, 2,045 resulted from direct impact (civil service employees at the Center) and 10,017 resulting from indirect and induced impacts.

- From a FY 1998 total earnings impact in Ohio of $384 million, $137 resulted from direct impact and $247 resulted from indirect and induced impact.

GRC Technology Transfer and Related Activities

Interviews with organizations that interact with GRC have indicated that GRC has greatly improved its technology transfer procedures and efforts in the past five years. However, the Center still must struggle to overcome barriers that include public perceptions about the difficulties of working with a federal lab and internal processes that hinder researchers ability to participate.

COMMERCIAL TECHNOLOGY OFFICE (CTO)

The mission of the CTO is to increase the competitiveness of U.S. industry through the commercial application of GRC's technologies, expertise, and facilities. The CTO's responsibilities include managing intellectual property, promoting opportunities for partnership with industry and applying NASA capabilities to improve a company's competitive advantage and ultimately promote economic growth. The CTO utilizes a number of tools including:

- Space Act Agreements- formalize commitments between NASA and an industry partner to accomplish a joint endeavor. Between 1997 and 1999, 193 Space Act Agreements have occurred between firms and GRC.

- Patents and licensing- GRC manages much of its intellectual property through the use of patents and licensing. This not only protects the public investment but also provides a more valuable product to private industry.

- Software Use Agreements- much of the intellectual property developed at GRC is in the form of software. This software is transferable to interested parties by Software Use Agreements.

- Summits- the GRC's Commercial Technology Office regularly hosts or supports conferences and summits with industry. In November 1999, it hosted the IDEAS (Innovations, Demonstrations, Exhibits, Applications, Spinoffs) Microsystems Forum.

- Consortia- NASA also uses consortia for transferring specific technologies and capabilities to entire industries.

- Alignment with regional industry clusters- in 1998 and 1999, a number of Ohio and Northeast Ohio government and nonprofit organizations announced initiatives to help foster the establishment of industry clusters in specific technology areas. Some of the industry areas promoted by the initiatives include biomedical, information, instruments and controls, motor vehicles and equipment, and advanced materials. GRC constitutes a significant source of cutting-edge technology in a number of the cluster areas identified as critical to long-term economic development in Ohio.

- Commercial Technology Fund- GRC's Commercial Technology Office has recently initiated this program to facilitate more efficient technology transfer. The funding is being used to bridge the gap between the genesis of an interesting idea and the demonstration of its feasibility in the commercial marketplace. It is hoped that this approach will help NASA better identify industrial partners and "push" their technology out into the market place.

- Small Business Innovation Research (SBIR) and Technology Transfer Programs- NASA's SBIR was established to promote innovative research by small businesses in order to increase private-sector commercialization and innovation. Since the inception of the program in 1983, GRC has awarded 66 SBIR contracts to 34 Ohio companies totaling more than $15M. Of the total Ohio awards, GRC has given 15 Northeast Ohio companies 35 awards totaling $8M. The Small Business Technology Transfer (STTR)

program is an additional program that awards contracts to small business concerns for cooperative research and development, with a research institution (RI) through a uniform, three-phase process.

GRC DIRECTORATES

In addition to the activities of the CTO, an important mission of GRC's technical Directorates is to research, develop, verify, and transfer advanced aeronautics, space, and related technologies to the private sector.

Space

Space Communication- Two examples of GRC's impact on the local economy can be drawn from the Space Communication Program. First, GRC has a partnership with Ohio University investigating communications protocols over a satellite link. Second, a partnership between GRC, the Cleveland Clinic Foundation and the Ashtabula County Medical Center. Together, they have developed an experiment to investigate transporting mammography imagery over satellites.

Microgravity Research- GRC is the center of excellence for fluids and combustion research within the Microgravity Research Program. The Program also supports undergraduate and graduate students and has a number of educational outreach activities. In addition, Cleveland is home to the National Center for Microgravity Research on Fluid and Combustion (NCMR), an innovative partnership between GRC, Case Western Reserve University (CWRU) and the Universities Space Research Association (USRA). NCMR gives Northeast Ohio the greatest concentration of microgravity fluids and combustion talent in the world. Created in 1997, the Center's tasks include performing cutting edge research, providing expertise to assist experimenters across the nation, engaging and sharing knowledge with industry and academia, and providing outreach to students in K-12 and assisting teachers in engaging students in the areas of mathematics and science. GRC 's Imaging Technology Center has developed a strong capability in video image enhancement to support the work in microgravity and other disciplines. One example of GRC's impact on Northeast Ohio is through this center. As a community service, GRC has been providing local law enforcement with image enhancement of surveillance tapes. Since January 1999, GRC assisted 27 Ohio organizations in a wide variety of crimes.

Aeronautics

This directorate has significant partnerships with Universities in Ohio, including Cleveland State University, the University of Toledo, Case Western Reserve University (CWRU), the University of Akron, Ohio State University and Wright State University. Aeronautics also has a number of grants, cooperative agreements, and support service contracts with the Ohio Aerospace Institute to support experimental tests and modeling at GRC. The directorate is also involved in extensive joint projects with prime contractors in Ohio.

Research and Technology
One example is its relationship with a large company based in Northeast Ohio, TRW, where a GRC researcher served as a technical consultant and lecturer on the subject of structural durability of automotive components. Another example is a joint shuttle flight experiment with Hathaway Brown School for Girls. The flight experiment, designed to promote science and technology education among young women in grades nine through twelve, relates to spacecraft durability in the low Earth orbit space environment.

GRC'S PARTNERS

The Ohio Aerospace Institute (OAI)
The Ohio Aerospace Institute is a private, nonprofit, university, industry and government consortium that includes GRC, Wright Patterson Air Force Base, nine Ohio Universities, and technology driven corporations. OAI specializes in bringing together teams from different sectors. In order to assist technology transfer, OAI facilitates and manages collaborative research groups composed of industry, academia, and government engineers. These groups are established to deliver solutions for industry's needs. In most activities sponsored by OAI, both government and industry provide funding to develop technologies for industry's commercial needs. NASA is a major funder of OAI, second to the Department of Defense.

GLITeC
The Great Lakes Industrial Technology Center (GLITeC) is one of six NASA Regional Technology Transfer Centers (RTTC's) established to turn mission technology developed by NASA into additional valuable products, processes, and solutions. GLITeC manages a highly integrated technology commercialization network of affiliate organizations within its six-state Midwest region, each of which is uniquely positioned to commercialize NASA technology and to benefit NASA, particularly the GRC. The Commercial Technology Office and GLITeC provide technical assistance to companies in Northeast Ohio, Ohio and the Midwest region, drawing on the technology resources and facilities of GRC, other NASA Field Centers, GLITeC affiliates, and other organizations. GLITeC fielded 903 inquiries in 1998, that resulted in 18 licenses, 82 Space Act Agreements, 86 endorsements/commendations. In addition, 174 significant single projects were assessed in depth to determine the full value of technology assistance services to companies, with 98 percent of the companies surveyed reporting that GLITeC's assistance was helpful and that they would use GLITeC again.

GLENNAN Initiative
The GLENNAN Initiative was created to advance the development and use of microsystems by industry and NASA. A five-year program that partners GRC, the State of Ohio, Case Western Reserve University, and industry, GLENNAN's purpose is to expand the application of microelectromechanical systems (MEMS). MEMS are integrated systems of miniaturized devices such as sensors, actuators, motors, valves and microprocessors manufactured together on a single semiconductor chip. The main goal of the initiative is to identify and manufacture prototype devices for industry with a diverse range of applications.

Garrett Morgan Initiative
The GRC Garrett Morgan Commercialization Initiative (GMCI) is a program for small, minority-owned, and woman-owned businesses that can benefit from NASA resources. The Initiative provides services that enable companies to grow or strengthen their business by leveraging NASA technology, expertise, and programs. In 1998, GMCI successfully increased the competitiveness of 17 small, minority- and women-owned businesses in the Great Lakes Region by providing enhanced access to NASA technology, programs and expertise as well as other tailored services.

Lewis Incubator for Technology (LIFT)
LIFT is a business incubator program designed to nurture new and emerging technology-based businesses with the potential to incorporate NASA technology or develop linkages with NASA. LIFT is a partnership formed by GRC, Enterprise Development Inc. (EDI), a not for profit subsidiary of Case Western Reserve University, the State of Ohio's Department of Development, and GLITeC. Managed by EDI, LIFT is jointly funded by GRC and the State of Ohio. Its purpose is the identification of viable technology on which fledgling businesses can base their business. Primary objectives of the incubator are to create jobs and businesses in Ohio and to increase the commercial value of NASA knowledge, technology and expertise.

The BP site currently houses 9 tenant companies and the newer GRC site has two tenants and a number of higher priority companies currently evaluating an application to the program. Currently employing close to 40 highly-educated individuals, they have a strong potential for rapid growth in employment and ultimately in sales revenue.

Ohio Aerospace Council
The Ohio Aerospace Council (OAC) is an independent organization that is run by Battelle and allied with the Greater Cleveland Growth Association. OAC seeks to increase GRC's impact in the state of Ohio through education and advocacy and by providing the business community input to GRC decision makers. The OAC is attempting to maintain and increase the visibility of GRC, develop a coordinated statewide aerospace agenda, increase the community's understanding of the value of GRC, and establish a congressional budget request that has a positive impact on GRC. Members include the Greater Cleveland Growth Association, BF Goodrich, Parker, GE Aircraft Engines and Battelle. In terms of technology related activities, OAC helps to facilitate connections between GRC leadership and local industry and makes suggestions to GRC for research areas that are of interest to industry.

The Ohio Department of Development (ODOD)
GRC works in partnership with the ODOD Edison Program to provide an extensive network information, referral, and technology assistance services designed to strengthen the competitiveness of Ohio companies. One example of this partnership is ODOD and GRC's shared funding of the Lewis Incubator for Technology (LIFT). ODOD also funds both GLITeC and the GLENNAN initiative. In addition, GRC's Director, Donald Campbell, has been appointed to the Ohio Technology Action Board by Governor Taft.

Wright Patterson Air Force Base
GRC has a long relationship with the Air Force Research Laboratory (AFRL), which is located at Wright Patterson Air Force Base near Dayton, Ohio. Both GRC and AFRL are

involved in research on propulsion and power, high speed propulsion, space launch propulsion, and aircraft power. AFRL and GRC have a number of joint partnerships and work synergistically. One example is with the lithium polymer Ohio initiative and the lithium ion battery consortium, which will eventually involve several Ohio colleges and universities.

GRC CONTRIBUTIONS TO THE QUALITY OF EDUCATION IN OHIO

GRC contributes to the education system in Ohio at both the K-12 and the higher education levels and it supports programs that are intended to enhance and improve the level of education in Ohio, especially in the fields of math, science, and engineering.

HIGHER EDUCATION

The benefits realized by universities through their relationship with GRC include:

- Research funding: direct grants awarded by GRC to fund faculty, research associates, and graduate and undergraduate students.
- Access to GRC's highly specialized high-tech facilities and equipment for conducting experiments that cannot be done on campus.
- Access to GRC's scientists and engineers and their expertise.
- Exchange of ideas and knowledge among faculty, students, and GRC staff.
- GRC's senior management sits on boards of trustees of research centers or labs affiliated with Ohio universities.
- Using GRC's technology to develop a virtual classroom.
- Improved and enriched curricula resulting from research conducted by faculty at GRC facilities. New and advanced techniques learned at GRC are incorporated into the classroom.
- Some placement of graduating students at GRC, although this has become a very small benefit due to the hiring freeze at GRC over the past several years.

The Summer Faculty Fellowship Program

The Program provides science and engineering faculty the opportunity to participate in research at a NASA facility during a 10-week session in the summer. Each participant works closely with an assigned GRC researcher. In 1999, there were 46 participants, 26 of which were from Ohio.

The Graduate Student Researchers Program

This program provides up to three-year support to full-time students working towards advanced degrees in aerospace-related science and engineering areas. The annual award to each student is $22,000. Each student works closely with a GRC advisor and spends some part of his or her time at GRC. Typically, about a quarter of the students come from Ohio institutions.

On-Site Graduate Engineering Program
This program, administered by OAI under a contract with GRC, provides opportunities for GRC's working engineers to pursue master and doctorate degrees at the Center. The students must register in a graduate program with one of OAI's member universities and classes are either on-site or through interactive television and distance learning.

Summer Internship Program for Undergraduate Students
This is an educational program that provides internships for students in science, engineering, professional administrative, and technical areas. In FY 1998, 105 undergraduate students spend their summer as interns at GRC; of these, 63 students were from Ohio. In FY 1999, 127 students participated with 79 from Ohio.

GRC Relationship with Wilberforce University
Over the past three years, the University received three major grants that contributed to the enhancement of undergraduate education and to the increase in the number of minority students going into the fields of science and technology. Under the CARET (Consortium for Advancing Renewable Energy Technology) grant, several Wilberforce students work with renewable energy projects, especially with wind turbine and solar energy. The WUPTEP (Wilberforce University Power Technology and Education Program) grant funds a summer bridge program for incoming freshmen that provides accelerated courses in math and science to prepare them for college. The newest grant, SORET (Student Outreach using Renewable Energy Technology) will improve the distance learning facility and support a solar lighting project to be implemented in a high school or community building.

GRC CONTRIBUTIONS TO THE QUALITY OF K-12 EDUCATION

NASA contributes to educational excellence by involving the education community in NASA's endeavors to inspire America's students and create learning opportunities. At GRC, the Office of Educational Programs (OEP) is responsible for NASA's commitment to enhancing education at the regional level. OEP's mission is to utilize NASA's inspiring mission, the unique GRC laboratories, and its diverse and specialized workforce in participating in appropriate educational programs and activities for enhancing the teaching and student learning of science, mathematics, and technology education.

GRC's Educational Programs cover a six-state region. The programs are directed toward teacher/faculty preparation and enhancement, student support, systemic improvement, curriculum support, and educational technology. 78,211 people participated in the GRC's educational programs during FY 1999. Benefits provided by the education programs include:

- Access to GRC scientists and engineers and their expertise
- Opportunities to see real-world applications of science, mathematics, and technology
- Introduction of career choices to students
- Improved and enriched curricula resulting from research done at GRC facilities

- Incorporation of new and advanced knowledge and techniques learned at GRC into the classroom

- Opportunities for students and teachers to work at GRC for a summer

NASA's Aerospace Education Services Program
Three Aerospace Education Specialists, who are assigned to GRC as part of the national Aerospace Education Services program, travel GRC's six-state region to conduct teacher workshops, student programs, and to give presentations at education and technology conferences. In Ohio, these specialists conducted on- and off-site programs for 1,108 teachers during FY 1999 and for 5,423 Ohio students. In addition, the specialists reached about 250,000 educators and students through conferences, TV, radio, and videoconferences for distance learning.

NASA Educational Workshops
NASA's educational workshops, conducted every summer, support 50 competitively selected teachers from across the country who spend two weeks at GRC. About ten percent are from Ohio. During the workshops, teachers are exposed to GRC's research and development activities, observe specialists at work, learn about the latest technology, and develop new interdisciplinary and team-teaching strategies for the classroom.

SEMAA: the Science, Engineering, Mathematics, and Aerospace Academy
SEMAA was established in 1993 as a partnership between NASA's GRC and Cuyahoga Community College (CCC). Its primary goal is to provide K-12 students with a better understanding of and a greater appreciation for science and mathematics. SEMAA provides academic enrichment and career awareness programs to encourage K-12 students to acquire a strong academic background in science and math and to prepare them to pursue undergraduate programs in science, mathematics, engineering, and technology. Each year, GRC provides CCC with about $550,000 to operate SEMAA.

The SEMAA program has been so successful that since 1998 it has been replicated at nine other sites in the U.S. SEMAA's national office is located at CCC. During FY 1999, over 3,700 students were enrolled in SEMAA's programs in six sites. Of the participants, 45 percent were female, and 75 percent were African American.

School Partnerships
For ten years, GRC has had a partnership with East Technical High School in the City of Cleveland. The partnership includes GRC's staff assistance in one-to-one tutoring of students during the year and for science fairs, as well as student participation in on-site GRC programs. In FY 1999, 120 students participated in the East Tech Technical Acedemy, which aims to improve academic achievement and attendance. Although this program targets entering 9th graders, it plans to track those cohorts throughout their tenure at East Tech. GRC also donates many computers and helps sponsor the year-end awards ceremony at the school. GRC has also provided financial and technical support of the school's robotic team for the past six years. The East Tech High-School robotic team participated in FIRST (For Inspiration and Recognition of Science and Technology), a national engineering contest that immerses high school students in the world of engineering. Approximately 25-30 students from Cleveland's East Technical High School

are involved each year and have won regional and national awards. In FY 2000, GRC will fund FIRST teams from two Cleveland high schools, East Tech and James Rhodes, as well as a team from a consortium of urban schools in Columbus.

CONCLUSIONS

Declining GRC budgets, triggered by external forces, resulted in a smaller labor force and a reduction in GRC spending on contractors. Not surprisingly, GRC's impact on NEO declined somewhat over the past five years, although it remained significant. The total economic impact of GRC in Ohio shows that in FY 1998 the Center generated $1,155 million in spending (output produced), created 12,062 jobs, and household earnings increased by $384 million. Moreover, GRC continues to significantly contribute to the quality of education locally and in the state and has increased its ties with companies located in northeast Ohio and the rest of the State through technology transfer activities. The Urban Center offers the following recommendations based on these trends:

- GRC should continue to build on its relationships and partnerships with industry and educational institutions located in Ohio.
- The Center should continue to seek more matches between GRC's needs and Ohio talent.
- GRC should continue to improve its working relations with Ohio companies through more transfer of its research and technology.
- GRC use of intermediaries has grown over the past several years to benefit both industry and academia; we recommend that the Center continue to work with intermediary organizations and leverage its revenues with other partners and stakeholders.
- Given the fact that revenues and workforce have been reduced, we believe that GRC should continue to build on its relationships with the Center's partners and stakeholders, to increase its impact on Ohio's economy and quality of life.
- GRC's projections of increased revenues suggest opportunity for the Center to strategically increase its economic impact on the region and the state of Ohio.

STATEMENT OF PURPOSE

This report describes the impact of the National Aeronautics and Space Administration's (NASA) Glenn Research Center (GRC) on the State of Ohio and on Northeast Ohio, where GRC is located. Northeast Ohio includes the eight counties in the Akron and Cleveland metropolitan areas.[3] The study was conducted by the Urban Center at Cleveland State University's Levin College of Urban Affairs.

This report is an expansion and update of an earlier study, published in February 1996.[4] It updates GRC's economic impact on Northeast Ohio for 1998 and also expands the study to estimate impact on the State of Ohio as a whole. As before, this study employs two methods to determine GRC's influence on the state and local economies. The first method uses quantitative models to estimate the effect of GRC on the studied economies. These models measure economic impact in terms of growth in total output, household earnings, and number of new jobs created.

The second method uses GRC's internal documents and interviews with GRC's staff, as well as interviews with leaders in industry, academia, and the non profit sector who are affiliated with GRC or are knowledgeable about its activities. This is the primary method used in the qualitative analysis of GRC's educational contributions and its technology transfer activities in the areas of aeronautics, space, and aerospace technology.

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NASA GLENN RESEARCH CENTER: BACKGROUND

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PROGRAMMATIC CHANGES IN NASA AND THEIR IMPACT ON GRC

NASA experienced a number of transformations in the past five years. Much of these changes were based on the results of the "Zero Base Review" (ZBR), which was completed by the Agency in 1995. The major changes can be grouped into four categories: defining roles and responsibilities, consolidations, contracting for operations, and the establishment of Agency level priorities.

Defining roles and responsibilities refers to NASA's attempts to eliminate duplication, assign work based on expertise and capabilities, and move program responsibilities to the field centers. As a result, "Centers of Excellence" were named, lead Centers were identified for each program, and work assignments were shifted. GRC was initially named the center of excellence for Turbomachinery and lead center for Aeropropulsion. Other lead center designations have since been added.

The second major change, consolidations, resulted in the loss of both staff and funding for GRC. The Space Station program was restructured and consolidated from four work packages and contracts to a single prime contractor. As a result, GRC, the lead for the Space Station power system, lost $300 million annually and a staff of about 200, which was accomplished through a buy-out. Another consolidation occurred in the management for the Agency's expendable launch vehicle (ELV) program. Prior to these changes, GRC had been responsible for the acquisition and integration of medium and large class ELVs. However, that activity became the responsibility of the Kennedy Space Center, resulting in a loss of approximately $100 million annually for GRC.

During the assessment of roles and responsibilities, the Agency decided not to perform operations activities with civil servants. The most significant changes that resulted from this decision were the consolidation of both Space Shuttle operations as well as all Space Operations each into a single prime contract. In addition, NASA decided to move towards more "performance-based contracts," which require less NASA oversight, holding the contractors more accountable for their performance.

In addition to ZBR's changes in roles, budget, and workforce, there have also been more recent programmatic changes driven by Agency priorities. NASA has identified safety as its number one priority and Space Station and Space Transportation as its highest priority programs. As the result of this emphasis on Space Station utilization, a major portion of GRC's microgravity science program is now focusing on the development of facilities for the Space Station, as well as planning for the experimental utilization of those facilities. This new focus has a positive impact on GRC, resulting in a significant increase in funding and responsibility for GRC in this area.

Other programmatic changes at GRC include the elimination of two major aeronautics programs: the High Speed Research (HSR) and the Advanced Subsonic Technology (AST). GRC received the majority of NASA's funds for these recently eliminated programs. However, these programs developed a technology foundation that led to a new initiative, the Ultra Efficient Engine Technology (UEET) program, of which GRC was named the lead center. This five-year program (FY 2000 - FY 2005) will enable the development of next-

generation engines and has military and commercial applications. UEET's total funding is expected to be $250 million and will utilize approximately 200 employees, shifted from other programs.

GRC also anticipates a significant increase in funding starting in FY 2001 due to its expertise and capabilities supporting the Reusable Launch Vehicle (RLV) program, which is a major element of the NASA's Space Transportation activities. The RLV program, which will become a major component within the Aero-Space Technology Enterprise, will develop the technologies for the next generation RLV to replace the Space Shuttle.

GRC'S ROLE IN NASA'S STRATEGIC ENTERPRISES

NASA has developed four strategic enterprises to focus agency resources:[5]

- The Aero-Space Technology Strategic Enterprise (ASTT): to pioneer the identification, development, verification, transfer, application, and commercialization of high-payoff aero-space technologies.
- The Human Exploration and Development of Space Strategic Enterprise (HEDS): to open the space frontier by exploring, using, and enabling the development of space and to expand human experience into the far reaches of space.
- The Space Science Strategic Enterprise: to solve the mysteries of the universe, explore the solar system, discover planets around other stars, and search for life beyond Earth.
- The Earth Science Strategic Enterprise: to understand the total Earth system and the effects of natural and human-induced changes on the global environment.

GRC has an integral role in supporting each of NASA's four enterprises. GRC contributes to the ASTT through a number of activities, such as high-speed research, propulsion systems research and technology, advanced subsonic technology, aviation safety, rotorcraft research and technology, and information systems research and technology.

[5] Source: NASA 1998 Accountability Report

For HEDS, GRC provides expertise in research, development, and planning for the International Space Station; technology development for human missions of exploration; and research in microgravity science, space power, onboard propulsion, space communications, and space transportation. The Center also sponsors, with Case Western Reserve University and the Universities Space Research Association, the National Center for Microgravity Research on Fluids and Combustion.

For the Space Science Strategic Enterprise, GRC contributions include advanced power, onboard propulsion technologies, and communications technology. The ion engine that is being used to propel the Deep Space 1 spacecraft is an example of a contribution to this enterprise.

For the final enterprise, Earth Science, GRC support includes advanced power, onboard propulsion, and space communications technology.

GRC Roles as Lead Center and Center of Excellence[6]

GRC is NASA's lead center for Aeropropulsion. Each of NASA's centers has a specific mission and area of excellence. GRC's agency-specific mission is to develop, verify, and transfer air breathing propulsion technology for subsonic, supersonic, hypersonic, general aviation, and high performance aircraft and rotorcraft. GRC also conducts fundamental research in propulsion-related materials, structures, internal fluid mechanics, instrumentation, controls, and systems.

GRC is also the lead center for aerospace power systems technology development, spectrum management, Small Business Innovation Research contracting, and environmental information systems.

As the Center of Excellence for Turbomachinery, GRC has a critical role in advancing NASA's aeronautics and space goals. GRC has full responsibility for applications requiring turbomachinery, which include air breathing propulsion and space power systems,

[6] Sources: GRC Annual Report 1998 and GRC Strategic Implementation Plan Fiscal Year 1999.

primary and auxiliary propulsion and power systems, onboard systems, and rotating machinery for pumping fuels. The Center is committed to developing new and innovative technology and leveraging its computational, analytical, and experimental expertise in turbomachinery to future aerospace programs. The results will be improvements in reliability, performance, and efficiency; increases in affordability, capacity, safety, and environmental capability; and reductions in design cycle time and development costs.

GRC also has full responsibility for NASA's Propulsion Systems Research and Technology (R&T) program, one of six base R&T programs within the Aeronautics and Space Transportation Technology Enterprise. This program focuses on maintaining U.S. superiority in engine development and ensuring the long-term environmental compatibility of engine systems.

GRC has also become the preeminent research facility within the Agency's microgravity programs as program manager for fluid physics and combustion microgravity research. GRC leads NASA's research in the microgravity science disciplines of fluid physics, combustion science, and some materials science. The Center also designs power and propulsion systems for space flight systems in support of such NASA programs as the International Space Station, Mars Pathfinder, and Deep Space 1. Glenn also leads NASA's Commercial Space Communications Program including the operation of the ACTS satellite.

GRC has a number of recent accomplishments that demonstrate its key role as a NASA center. For example, GRC conceived and constructed a microphone tracking system predicted to cut in half the time required to gather data from the Nozzle Acoustic Test Rig, which is used to test jet engine exhaust nozzles in its Aero-Acoustic Propulsion laboratory. The development of an ion engine is another recent accomplishment for GRC. The engine reduces travel time and offers a propellant efficiency ten times that of current chemical systems for deep space missions. It was used as the primary propulsion source for Deep Space 1, a mission designed to validate technologies for future spacecraft.

GRC'S TEST FACILITIES AT PLUM BROOK

GRC also operates four large, unique aerospace test facilities at Plum Brook, its 6,400 acre field station, located about 50 miles west of Cleveland in Sandusky, Ohio. The test facilities are available on a full cost reimbursable basis (where users pay all costs) to support major national and international aerospace test programs. One facility, the Space Power Facility, is the world's largest space environment simulation chamber. In this chamber, large space-bound hardware can be ground-tested in a severe space environment similar to that encountered in space including the simulation of vacuum conditions of space up to an altitude of about 145 statute miles, very cold and very hot temperatures, and the actual sunlight experienced in space. The Spacecraft Propulsion Research Facility is the world's only facility for full-scale engine and launch vehicle system level tests in a thermal vacuum environment up to 400,000 pound thrust. In this facility, upper stage rocket vehicles can undergo complete integrated system testing, including engine firings, in a simulated space environment. These test firings of fueled vehicles are conducted by remote control from a blockhouse one-half mile away. The facility was designed and built to safely handle the large quantities of liquid hydrogen and oxygen carried on a fully-fueled Centaur Rocket vehicle. The third test facility, the Cryogenic Tank Facility, is used to develop technology for storing and transferring liquid hydrogen in space. It includes the world's largest Slush Hydrogen (800 gallon) generator and associated support systems. Finally, the Hypersonic Tunnel Facility is the United States' only large non-vitiated (clean air) wind tunnel. It is capable of simulating Mach 5, Mach 6, and Mach 7 true enthalpy flight conditions.

In summary, GRC has significant expertise in a number of specialized areas. GRC's continued growth in these areas depends on continued support from NASA and an end to the recent trends of budget reductions.

DIRECT IMPACT: RECENT TRENDS AND PROJECTIONS

This section describes Glenn Research Center's (GRC) labor force, payroll, spending on grants and contracts, taxes, and revenues. Where available, this section presents trends since 1990 as well as projections.

LABOR FORCE

The GRC labor force is composed of two components: civil service employees and on-site or near-site contractors. This dual approach is common to federal labs, because contract employees provide federal labs the desired flexibility regarding the size of their labor force. The number of contract employees can easily be adjusted according to the needs of the research lab, while hiring of civil service employees is more complex and permanent.

EMPLOYMENT

Total employment at GRC in FY 1998 was 3,355 (Table 1). Of these, 2,045 (61 percent) were civil service employees and 1,310 (39 percent) were contractors' employees who worked for 19 on-site/near-site contractors. Since FY 1990, GRC has lost 28.3 percent of total employees, or 1,322 jobs. However, most of the decline occurred between FY 1994 and FY 1998. Between FY 1990 and FY 1994, GRC's employment declines were achieved by a loss of civil service jobs that were somewhat offset by gains in contractors' employment. In comparison, both groups lost about the same number of jobs in the latter period, FY 1994-98.[7] Overall, during the employment loss of the 1990s, the share of civil service employment remained constant; in 1990, civil service employees accounted for 62

[7] The reduction in contractors' employment could partially be attributed to a change in the reporting system. Previously, contractors were hired on the basis of "support-service contracting," which paid for contractors' employees. Under the new system, contractors are hired under "performance-based contracting," where contractors are paid for completed tasks and not people. Contractors do not have to report the number of employees that work on these tasks.

percent of GRC's labor force, dropped to 58 percent in 1994, and increased back to 61 percent of all workers in 1998.

Table 1: GRC's Employment, FY 1990 - 2004

Year	Total Employment	Civil Service Employment	On-site/Near-site Contractors
1990	4,677	2,894	1,783
1991	4,853	3,021	1,832
1992	4,859	2,947	1,912
1993	4,602	2,851	1,751
1994	4,444	2,589	1,855
1995	4,089	2,365	1,724
1996	3,881	2,294	1,587
1997	3,652	2,172	1,480
1998	3,355	2,045	1,310
Projections			
1999	3,383	2,050	1,333
2000	3,048	2,030	1,018
2001	3,037	2,018	1,019
2002	3,023	2,035	988
2003	3,054	2,036	1,018
2004	3,054	2,036	1,018

The large declines in GRC's labor force are primarily a result of the severe budget cuts at NASA and the buy-outs offered to civil service employees at GRC. GRC's labor force reached a level that was very close to its own projections, as required by NASA headquarters, by 1998, when it had about 50 jobs fewer than what was projected. GRC, due to pressures on NASA and other federal agencies, became a smaller organization with a significantly lower budget and fewer employees.

In order to facilitate the necessary reduction in the number and occupations of its employees, GRC has undertaken the following actions:[8]

- Used four targeted buy-outs.
- Reorganized to improve the supervisory ratio from 1:5.8 to 1:11.
- Reassessed skill mix requirements to maintain core competencies consistent with GRC's mission and Center of Excellence requirements.
- Expanded the use of term appointments to fill critical needs.

[8] More information can be found on the web at <http://www.hq.nasa.gov/office.HR-Education/workforce.>

Employment is projected to continue to fall, as is shown in Table 1. However, the severe declines of the mid-1990s are not projected to continue. Total GRC employment is projected to decline by another 301 jobs between 1998 and 2004, a loss of another nine percent. Almost all of the employment loss (97 percent) is projected to be among contractors' employees.[9] GRC believes that employment targets for FY 2000 and beyond will be easily achievable through normal attrition, and that the Center will be able to concentrate on revitalizing its workforce to meet programmatic requirements. GRC is currently engaged in an inventory and assessment of its workforce skill mix. The Center will plan how to reconcile the current and future program skill needs with those available in its workforce.

GRC's labor force is highly skilled and highly educated. Thirteen percent of GRC's civil servants have a doctoral degree; 23 percent have a master's degree; and an additional 31 percent have a bachelor's degree. Consequently, declines in employment at GRC could cause a "brain drain" from Northeast Ohio.

PAYROLL

Total compensation for GRC's civil service employees amounted to $131.6 million in FY 1998, while benefits to current employees accounted for another $21.7 million.[10] Total compensation declined by $12.9 million from FY 1994, a decline of 8.9 percent. These changes are a direct result of the smaller number of civil service employees working at the Center.

The rate of decline in employment was larger than the rate of decrease in total payroll between FY 1994 and FY 1998. As a result, during this time period, total compensation per GRC civil service employee increased from $55,800 in FY 1994 to $64,350 in FY 1998, an increase of 15.3 percent. Accounting for the rate of inflation, in real dollars, total compensation per employee rose by 4.2 percent.

[9] In the earlier study, projections for 1995 through 1998 also predicted an employment loss, with 62 percent of it coming from contractors' jobs. However, historical data for 1994-98 provided for this study reveals that an equal number of jobs were lost by contractors and civil service employees.

[10] Regular benefits for current employees include retirement, thrift plan, FICA, Medicare, health insurance, life insurance, and worker's compensation.

OCCUPATIONS

Civil service employees at GRC are categorized into five occupational groups: administrative professionals, clerical, scientists and engineers, technicians, and trades. Table 2 presents the changing occupational mix at GRC during the 1990s. Between 1990 and 1994, employment declines occurred in the clerical, scientists and engineers, and trade occupations. Between 1994 and 1998, the severe job cuts affected all occupational categories. Scientists and engineers, accounting for more than half of the losses, lost 20 percent, or 289 jobs. However, scientists and engineers, with 1,148 jobs, remained by far the largest occupational category at GRC, accounting for 56 percent of GRC's labor force.

Table 2: GRC Civil-Service Employment by Major Occupational Categories FY 1990 to 1998

Year	Administrative Professional	Clerical	Scientists & Engineers	Technician	Trades	Total
1990	296	287	1,525	339	447	2,894
1991	321	282	1,642	373	403	3,021
1992	325	263	1,623	373	363	2,947
1993	334	243	1,586	374	314	2,851
1994	309	216	1,437	339	288	2,589
1995	278	186	1,340	306	255	2,365
1996	306	162	1,292	305	229	2,294
1997	315	135	1,218	288	216	2,172
1998	297	126	1,148	263	211	2,045

In relative terms, the clerical and trades occupations lost the highest shares of their jobs, 42 and 27 percent respectively, becoming the smallest occupational categories in the second half of the 1990s. In the mid-1980s, administrative professionals and trade occupations were the smallest categories. However, administrative professional lost the smallest number of jobs and had the smallest rate of decline between FY 1994 and 1998, becoming the largest occupational category among the four smaller categories.

Table 3 presents the share of each occupational category among GRC's civil service employees. The share of scientists and engineers has increased from 53 percent of all employees in FY 1990 to 56 percent in FY 1998. The only other occupational category that increased over the years in relative terms is administrative professional.

Administrative professionals accounted for 10 percent of all GRC's employees in 1990, growing to 14.5 percent by 1998.

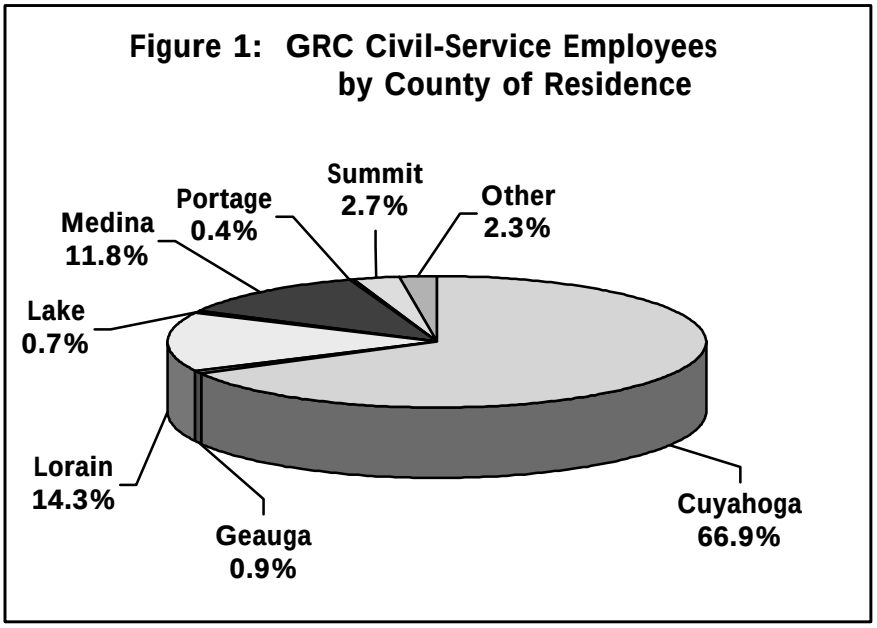
Table 3: GRC Civil-Service Employment Distribution by Major Occupational Categories FY 1990 to 1998 (percent)

Year	Total	Administrative Professional	Clerical	Scientists & Engineers	Technician	Trades
1990	2,894	10.2	9.9	52.7	11.7	15.5
1991	3,021	10.6	9.3	54.4	12.4	13.3
1992	2,947	11.0	8.9	55.1	12.7	12.3
1993	2,851	11.7	8.5	55.7	13.1	11.0
1994	2,589	11.9	8.3	55.6	13.1	11.1
1995	2,365	11.8	7.9	56.7	12.8	10.8
1996	2,294	13.3	7.1	56.3	13.3	10.0
1997	2,172	14.5	6.2	56.1	13.3	9.9
1998	2,045	14.5	6.2	56.1	12.9	10.3

PLACE OF RESIDENCE FOR GRC'S EMPLOYEES

The vast majority of GRC's civil service employees (98 percent) live in Northeast Ohio. Figure 1 illustrates that two-thirds of GRC employees live in Cuyahoga County; Lorain and Medina counties account for another 14 and 12 percent respectively. Another three percent come from the Akron counties of Summit and Portage.

Figure 1: GRC Civil-Service Employees by County of Residence



GRC's employees are more concentrated in Cuyahoga County than the general population of Northeast Ohio; 49 percent of Northeast Ohio residents live in Cuyahoga County, while 67 percent of GRC's employees reside in the central county. However, this share declined since 1994, when 72 percent of GRC's employees lived in Cuyahoga County. Within the county, the cities with the most GRC employees, in order of number of employees, include Strongsville, Cleveland, North Olmsted, Westlake, Parma, Fairview Park, and Berea. Among the top ten cities in terms of GRC employees are also Brunswick and Medina in Medina County and North Ridgeville in Lorain County.

Table 4 reports on county of residence by occupational category. As expected, the majority of employees in all occupations live in Cuyahoga County. As indicated in Table 4 and in Figure 1, Lorain is the second county in terms of place of residence for GRC's employees: almost a quarter of the technicians, 17 percent of administrative professionals, 16 percent of trade personnel, and 13 percent of clerical live in Lorain County. Medina County is the second-largest county of residence for scientists and engineers.

Table 4: GRC's Civil-Service Employees by Occupation and Place of Residence (percent)

County	Administrative Professional	Clerical	Scientists & Engineers	Technician	Trade	Total
Ohio	100.0	100.0	100.0	100.0	100.0	100.0
Northeast Ohio	97.4	98.0	97.6	97.6	98.5	97.7
Cuyahoga	64.4	76.0	69.3	55.8	67.2	66.9
Geauga	0.0	0.7	1.4	0.0	1.5	0.9
Lorain	17.3	12.7	10.8	23.8	15.9	14.3
Lake	1.0	0.0	0.7	0.7	1.0	0.7
Medina	11.1	7.3	12.2	14.3	10.0	11.8
Portage	0.0	0.0	0.4	0.0	2.0	0.4
Summit	3.6	1.3	2.8	3.1	1.0	2.7
Other Ohio	2.6	2.0	2.4	2.4	1.5	2.3

Among scientists and engineers, the largest occupational category, almost 70 percent live in Cuyahoga County. North Olmsted and Strongsville are each home to one-tenth of all scientists and engineers working in GRC. Other cities with concentrations of GRC's scientists and engineers are Westlake, Cleveland, Medina, and Brunswick. The first four cities are located in Cuyahoga County, while the latter two are in Medina County.

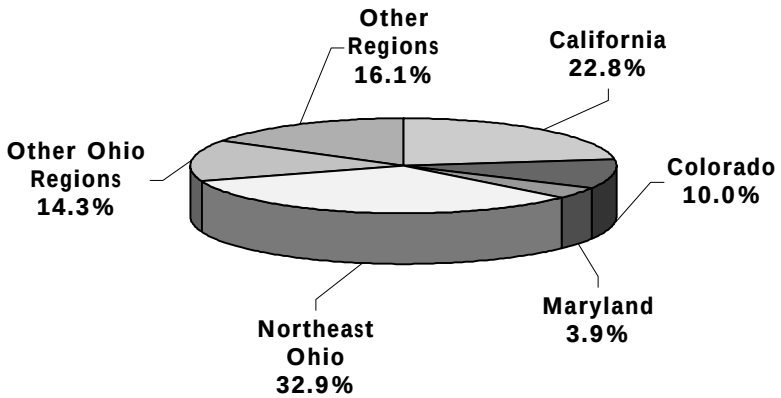
GRC Spending on Contractors and Suppliers

In FY 1998, GRC spent a total of $514 million on contractors, a decline of $153 million, or 23 percent since FY 1994. Figure 2 illustrates that, of total GRC spending on contractors in FY 1998, $243 million, or 47 percent, was spent in Ohio. In Northeast Ohio, GRC spent $169 million, or 33 percent of all its contract spending.

The overall picture of declining spending negatively affects businesses in Ohio, especially Northeast Ohio. GRC spending on contractors in Ohio increased between FY 1994 and FY 1995 and then declined gradually, resulting in a decline of $13 million, or five percent over the FY 1994-98 period. However, Northeast Ohio fared much worse. Over the same period, GRC spending on contractors located in Northeast Ohio fell by close to one-fifth (19 percent), declining from $208 to $169 million. Some of the decline in spending in Northeast Ohio is being captured by contractors located in other regions of Ohio. Ohio contractors who are located outside Northeast Ohio experienced increased sales to GRC by 55 percent, growing from $47 million in FY 1994 to $73 million in FY 1998.

Figure 2 presents the states where contractors received at least $20 million from GRC during FY 1998. California, the second-ranked state after Ohio, received $117 million in contracts from GRC, accounting for 23 percent of GRC spending on contracts. Colorado ranked third with $51 million in GRC contracts. The next three states are Maryland, with

Figure 2: GRC Spending on Contractors, FY 1998



$20 million in contracts, and Michigan and Connecticut with $18 million each. Table A-1 in Appendix 1 provides information on GRC spending on contractors in each state during FY 1998.

Table 5 breaks down spending on contractors in Ohio by major industries. The economic sector that benefited most from GRC's spending is engineering and business services, for which GRC spent $173.5 million during FY 1998, accounting for 72 percent of GRC's contract spending in Ohio. During all the years presented in the table, spending on business and engineering services surpasses all other industries by a wide margin. These contractors provide engineering services, scientific services, environmental services, logistics and administrative support, systems support, computational services, and computer network support. As with most other spending categories, GRC spent less on engineering and business services in FY 1998 than earlier. GRC's spending on engineering and business services increased in FY 1995, remained stable for the next two years, and then declined some. Over the FY 1994-98 period, spending on business and engineering services declined by only one million dollars. Table 4 also illustrates that the only spending category that increased over the past five years is miscellaneous services. The dominant contractors in miscellaneous services supply services in janitorial, security, support, and visitor center services. Spending in this category increased from one million dollars in FY 1994 to almost $11 million in FY 1998. However, much of this increase is due to a change in how these services were coded in FY 1994 compared to FY 1998.

Table 5: GRC Spending in Ohio by Supplier Industry, FY 1994 - 1998

Industry	FY1998	FY1997	FY1996	FY1995	FY1994
Total	$242,705,920	$268,105,620	$263,531,538	$272,826,301	$255,778,347
Construction: new and repair	34,390,876	49,596,974	46,166,523	45,391,910	47,714,573
Manufacturing	6,135,659	8,005,578	8,982,253	14,181,734	10,943,582
Transportation & Communication	693,779	1,037,034	1,083,077	3,560,530	3,793,388
Utilities	16,050,339	18,480,813	16,294,246	18,307,162	16,521,273
Real estate	0	76,357	0	1,017,014	1,174,410
Engineering & Business services	173,513,083	188,037,351	188,462,617	189,193,616	174,456,215
Health services	965,437	1,021,029	1,017,726	1,045,873	1,173,914
Other services	10,956,747	1,850,484	1,525,096	128,462	992

Table 6 compares the changes in contract spending between Ohio and Northeast Ohio. The major difference in these trends is that while spending on business and engineering

services in Ohio declined only slightly, this spending fell significantly in Northeast Ohio. Between FY 1994 and FY 1998, GRC's spending on engineering and business services in Northeast Ohio declined by $33.6 million, or close to 24 percent. This decrease is primarily attributed to the decline in spending on the near-site or on-site contractors who provide these services. Table 6 also illustrates that in both regions spending on utilities declined very slightly and that the only spending category that increased over the past five years is miscellaneous services.

Table 6: GRC Spending in Northeast Ohio and Ohio by Supplier Industry, FY 1994 & 1998

	Ohio			Northeast Ohio		
Industry	**FY1998**	**FY1994**	**FY1994-98**	**FY1998**	**FY1994**	**FY1994-98**
Total	$242,705,920	$255,778,347	-$13,072,427	$169,343,276	$208,446,529	-$39,103,253
Construction: new and repair	34,390,876	47,714,573	-13,323,697	32,162,099	39,441,685	-7,279,586
Manufacturing	6,135,659	10,943,582	-4,807,923	3,890,194	9,380,902	-5,490,708
Transportation & Comm.	693,779	3,793,388	-3,099,609	667,701	3,060,592	-2,392,979
Utilities	16,050,339	16,521,273	-470,934	15,925,059	16,042,332	-117,273
Real estate	0	1,174,410	-1,174,410	0	1,174,410	-1,174,410
Engineering & Business services	173,513,083	174,456,215	-943,132	104,820,352	138,171,702	-33,351,350
Health services	965,437	1,173,914	-208,477	965,437	1,173,914	-208,477
Other Services	10,956,747	992	10,955,755	10,912,522	992	10,911,530

Figure 3 (the donut) shows the relative shares of GRC spending on contractors by major industry. The outside circle describes Ohio, while the inside circle describes Northeast Ohio. Regarding the largest industrial category, the figure illustrates that 72 percent of GRC spending in Ohio went to business and engineering services, while only 62 percent of spending in Northeast Ohio went to that industry. The shares in Northeast Ohio are larger than in Ohio in construction, utilities, health, and other services because these types of services are usually supplied by local suppliers. Figure 3 also shows that the second largest industry in terms of GRC spending is construction, accounting for almost one-fifth (19 percent) of all contractors' spending in Northeast Ohio ($32 million) and 14 percent ($34 million) in Ohio.

Figure 3: GRC Spending in Northeast Ohio (NEO) and Ohio by Supplier Industry, FY 1998

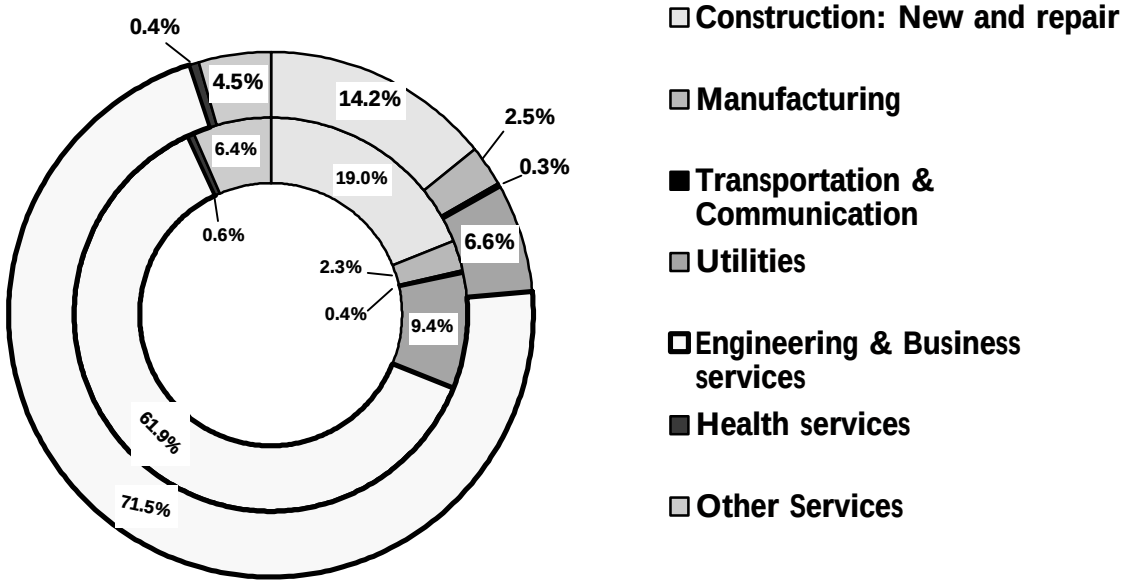
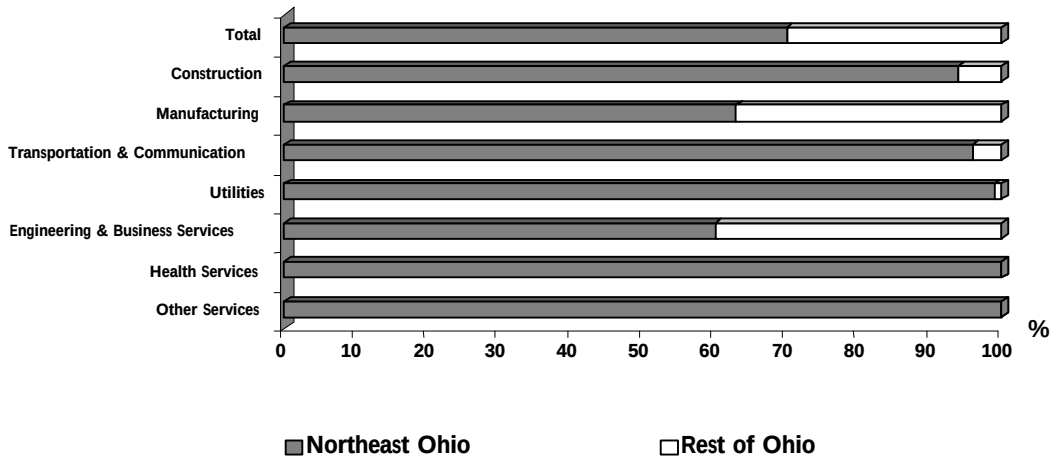


Figure 4 describes the spending on contractors located in Northeast Ohio as a share of spending in Ohio. For total contracts, seven out of ten dollars spent by GRC on Ohio's contractors were spent on contractors located in Northeast Ohio. In engineering and business services and in manufacturing, Northeast Ohio accounted for 60 and 63 percent respectively of spending in Ohio. As shown in the figure, more than 93 percent of each of the other contractors' categories were spent in Northeast Ohio. As mentioned earlier, these are logical because of the local nature of these contractors, who are in the areas of construction, transportation, utilities, and health.

Figure 4: GRC Spending in Northeast Ohio as a Share of Ohio, FY 1998



GRC's purchasing from Ohio's businesses is important to both Ohio's small and disadvantaged businesses. In Ohio, more than one-half (54 percent) of GRC's purchases were from small and/or disadvantaged contractors, amounting to $131 million in FY1998.[11] Purchases from disadvantaged businesses accounted for 32 percent of GRC contract spending in Ohio. With the declining spending on Ohio's contracts over the FY1994-1998 period, purchases from contractors receiving 8a loans from the U.S. Small Business Administration (those that are small and disadvantaged) declined as well. However, purchases from contractors defined as disadvantaged increased between FY1994 and FY1998, while purchases from small businesses declined only slightly. Most of Ohio's small and disadvantaged businesses that benefited from contracts with GRC were located in Northeast Ohio.

[11] These categories of contractors include businesses that are defined as disadvantaged, small, or those that are designated by the U.S. Small Business Administration as eligible to receive 8a loans.

GRC GRANTS AWARDED

GRC supports research and other educational activities in schools, colleges, and universities around the country. In FY1998, GRC awarded $61.3 million in grants, significantly more than the $43.1 million awarded in FY1994. Although GRC awarded substantially more grants, Ohio did not benefit from the additional spending on grants; in fact, Ohio's institutions received far less money in FY 1998 than four years earlier. In FY1998, Ohio's institutions received only $15.1 million, compared to $21 million in FY1994 and awards to Northeast Ohio institutions declined from $16.1 to $12.3 million. As can be seen, the decline to Northeast Ohio institutions was less severe, thus the grants awarded to Northeast Ohio educational institutions increased as a share of grants awarded to all of Ohio's institutions from 76.6 percent in 1994 to 81.5 percent in 1998.

Of all the states, Ohio received the largest share of educational grants awarded by GRC. Figure 5 shows that Ohio's institutions received a quarter of all grants awarded by GRC in FY1998; Northeast Ohio's institutions received 20 percent of the total and the rest of Ohio another five percent. It should be noted that the share of educational grants awarded to Ohio's institutions fell dramatically, from one-half of all awards in 1994 to only one-quarter in 1998. The other states that received more than three million dollars in grants are California ($5.1 million), accounting for eight percent of GRC grants; Alabama ($4.7 million), accounting for close to eight percent; and Texas and Virginia, which received around six percent each. A list of grants awarded by GRC by state is included in Table A-1 in Appendix A.

Figure 5: GRC's Educational Grants by Region, FY 1998

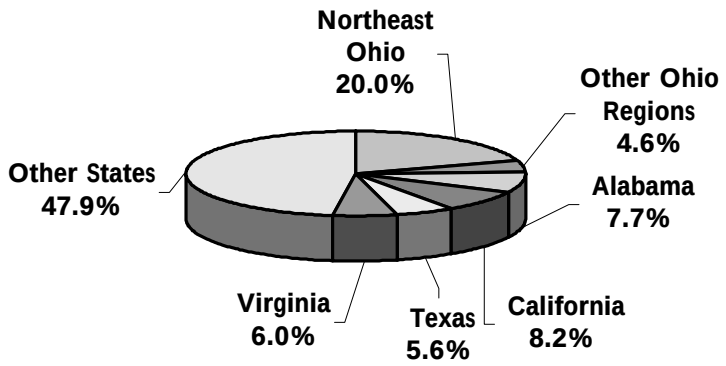


Table 7 presents grants awarded to Ohio's educational institutions over the past five years. All of the institutions, except for Cuyahoga Community College (CCC), experienced declining grants during the past five years. CCC received larger grants to support its educational outreach program, especially that for grades K-12, known as the Science, Engineering, Mathematics, and Aerospace Academy (SEMMA). SEEMA will be described in more details in the section on GRC's contribution to education.

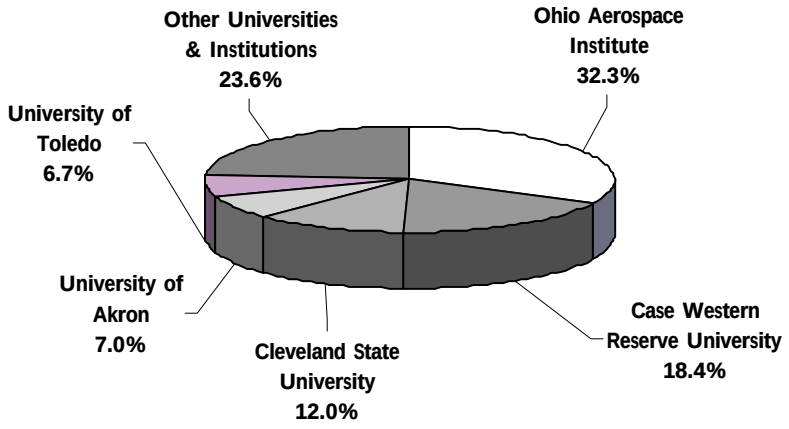
Table 7: GRC's Educational Grants in Ohio by Institution, FY 1994 -1998

Universities & Institutions	FY1994	FY1995	FY1996	FY1997	FY1998
Total Ohio Universities & Institutions	20,945,473	18,829,503	18,700,081	21,068,146	15,052,125
Northeast Ohio Universities & Institutions	16,053,316	13,847,969	15,149,785	18,029,448	12,260,341
Case Western Reserve University	4,425,806	3,944,063	3,164,607	3,163,396	2,770,964
Central State University	927,830	1,013,419	807,767	61,876	128,089
Cleveland State University	3,117,886	2,358,555	1,691,398	1,865,165	1,803,251
Cuyahoga Community College	178,186	307,745	668,949	717,676	660,359
Kent University	343,960	309,773	204,177	236,913	171,105
Ohio Aerospace Institute	5,864,293	5,743,414	8,060,380	10,361,718	4,856,665
Ohio State University	877,427	1,412,078	963,853	949,065	792,273
University of Cincinnati	640,315	481,822	457,872	442,679	173,459
University of Akron	1,236,136	845,949	913,453	880,101	1,059,133
University of Toledo	2,133,399	1,664,796	969,654	1,052,937	1,005,593
Other Universities & Institutions	1,200,235	747,889	797,971	1,336,620	1,631,234

Note: The table presents universities or educational institutions that received at least $100,000 in one of the years.

The two universities that received the most grants from GRC in FY 1998, Case Western Reserve University (CWRU- $2.8 million) and Cleveland State University (CSU-$1.8 million), are both located in Northeast Ohio. Figure 6 shows that CWRU received 18 percent of all grants awarded in Ohio and CSU received 12 percent of all Ohio's grants. The Ohio Aerospace Institute (OAI) received the largest amount of funding, $4.9 million, almost one-third of total Ohio grants. OAI was established under GRC leadership in 1990 as a private, nonprofit corporation dedicated to research, education, and the application of high technology. OAI is a consortium of nine Ohio universities, GRC, Wright-Patterson Air Force Base, and technology-driven companies. It is dedicated to facilitating collaboration on research between Ohio's federal labs, universities, and industry. OAI channels some of its funding back to Ohio's universities for research and student training. The individual grants reported in Figure 6 and Table 7 include only direct grants awarded by GRC to the respective universities.

Figure 6: GRC's Educational Grants in Ohio by Major Institution, FY 1998



Note: Major institutions include university or educational institutions that received more than one million dollars in FY 1998.

GRC REVENUES

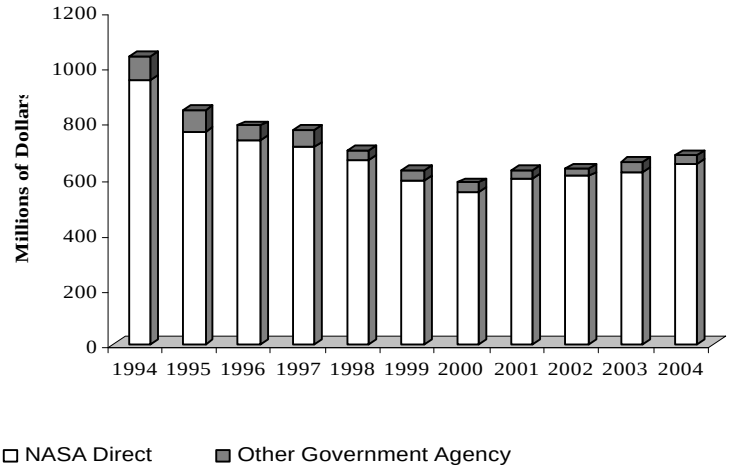
GRC's total revenues fell by one-third over the past five years, from $1,039 million in FY 1994 to $699 million in FY 1998 (Table 8). In contrast, over the period FY 1990 - FY 1994, GRC's total budget grew by $166 million, or 19 percent. As can be seen in Figure 7, the entire decline is mostly attributed to declining revenues from NASA, which remains the almost sole provider of revenues to GRC. During the years 1994-1998, NASA accounted for 91 to 95 percent of GRC's revenues. The second-largest revenue source is The National Oceanic and Atmospheric Administration (NOAA), contributing anywhere from two to five percent of GRC's revenues. The other federal revenue sources that account for more than one percent of GRC's revenues in some years are the Department of Defense and Department of Energy. Virtually all of GRC's revenues are derived from federal sources.

Table 8: GRC's Historical and Projected Revenues
FY 1994-2004
(millions of dollars)

Year	Total Revenues	Percent of Revenues from NASA
1994	1,039.1	91.5%
1995	842.3	91.2%
1996	786.5	93.3%
1997	774.2	91.7%
1998	699.0	94.7%
Projections		
1999	627.5	94.2%
2000	581.8	94.7%
2001	627.0	95.6%
2002	634.3	95.6%
2003	654.6	95.3%
2004	683.3	95.6%

Table 8 shows that GRC's revenues are projected to continue to decline, falling to the low level of $582 million in the year 2000. After that, revenues are projected to increase slightly to a level of $683 million by the year 2004. NASA's share in GRC's revenues is projected to fluctuate slightly between 94 and 96 percent.

Figure 7: GRC's Revenue Sources
FY 1994 to 2004



TAXES PAID BY GRC'S EMPLOYEES

The taxes GRC's employees pay to the State of Ohio, the City of Cleveland, and the City of Fairview Park are important to Ohio's economy. These taxes are determined based on the number of civil service employees, their location within the Center, and their wages and salaries. Most of GRC's employees work on sites that are part of the City of Cleveland; other GRC facilities fall within the boundaries of the cities of Fairview Park and Brook Park. Data on Brook Park could not be quantified because taxes collected by Brook Park are paid through the Regional Income Tax Agency (RITA).

Table 9 shows that during the five-year period FY 1994-1998, the City of Cleveland received $9.5 million from GRC's employees, for an annual average of $1.9 million. The City of Fairview Park received $2.3 million over these years. These taxes are one part of GRC's direct impact on Northeast Ohio. While the number of civil service employees declined significantly during these years, the taxes levied by the cities and the State of Ohio declined only slightly, suggesting that the salaries and wages of the remaining employees increased over these years to partially offset the decline in the number of employees. The State of Ohio collected almost $28 million from GRC's employees over the five years, or an annual average of $5.6 million.

Table 9. Taxes Paid by GRC Employees, FY 1994 - 1998 (in dollars)

	City of Cleveland	CITY OF FAIRVIEW PARK	State of Ohio
1994	1,950, 519	465,630	5,945,929
1995	1,885,492	461,788	5,630,567
1996	1,900,723	471,585	5,217,210
1997	1,870,655	449,255	5,467,572
1998	1,868,324	430,697	5,657,176
Five-Year Total	9,475,713	2,278,955	27,918,454

GRC TOTAL ECONOMIC IMPACT ON THE NORTHEAST OHIO ECONOMY

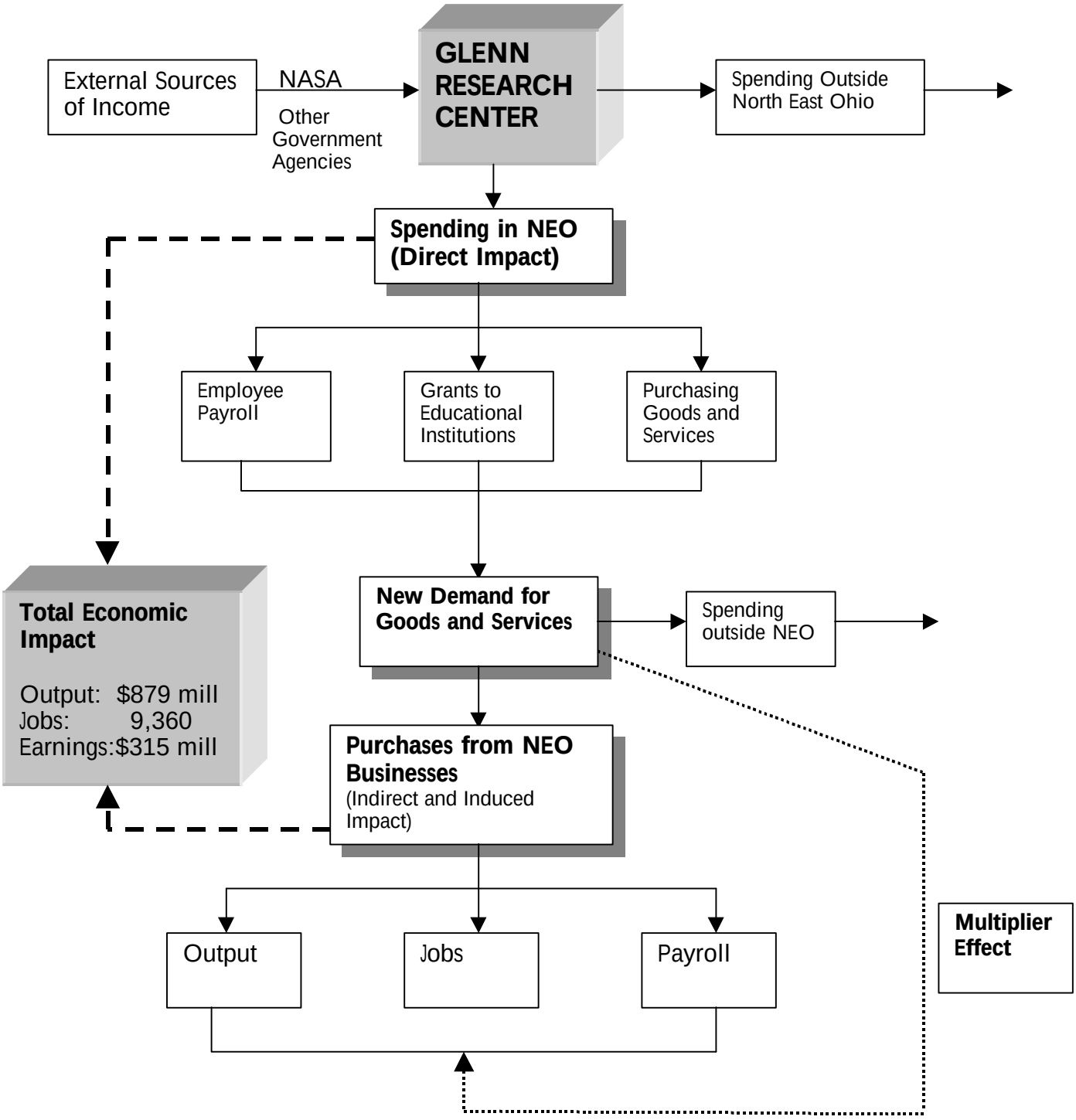
This section measures the direct and indirect effects of the Glenn Research Center during FY1998 on the economy of Northeast Ohio. It will also compare these impacts to GRC's impacts in FY1994. The direct impact refers to an institution's spending on goods and services, its sources of income, employment, and taxes. The indirect impact measures the effect of the institution's spending and employment on other sectors of the economy. The total economic impact presents quantitative estimated impacts on the region's total output, total earnings by regional households, and total employment in the area. Qualitative descriptions of impact in the areas of technology transfer and education will be presented in other sections of the report.

METHODOLOGY

Economic impact analysis takes into account inter-industry relationships within a region, or in other words, the buy-sell relationships among companies located in the same region. These relationships largely determine how a regional economy responds to changes in economic activity. Input-Output (I-O) models estimate inter-industry relationships in a region, state, or country by measuring the industrial distribution of inputs purchased and output sold by each industry. Thus, using I-O models, it is possible to calculate how the impact of one dollar or one job "ripples" through the local economy, creating additional expenditures and jobs.[12] The economic multiplier measures the ripple effect that an initial expenditure has on the local economy. Figure 8 describes the process by which GRC affects the regional economy through its spending in Northeast Ohio; the figure also summarizes the total impact.

[12] For example, suppose that company XYZ sells $1million of goods. From the receipts of $1 million, the company takes a profit, pays its suppliers and workers, and covers other production costs. Once the suppliers and employees receive their payments, they will spend a portion of their money in the local economy purchasing some goods and services, while another portion of funds will be spent outside the local economy. 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.

Figure 8. GRC Economic Impact in Northeast Ohio



This study, like the one conducted earlier, utilizes regional I-O multipliers from the Regional Industrial Multiplier System (RIMS II) model developed by the U.S. Department of Commerce, Bureau of Economic Analysis. RIMS II provides regional industry multipliers for output, employment, and earnings, which are used to estimate economic impact. This report uses RIMS II final demand multipliers to estimate GRC's impact on Northeast Ohio and on the State of Ohio as a whole based on GRC spending patterns.[13] RIMS II is widely used in both the public and private sectors.

ECONOMIC IMPACT ON OUTPUT (SPENDING)

To estimate economic impact on regional output, final demand multipliers for output are utilized. These multipliers measure the effect of GRC spending on gross receipts or sales in the region. First, GRC spending is divided into spending on goods and services purchased from companies located in Northeast Ohio and spending for goods and services from businesses located elsewhere. Second, local spending is categorized into industries. The RIMS II I-O model is used to calculate final demand multipliers for output for each of these industries.

The total impact on Northeast Ohio output is estimated by summing up individual industries' output impacts, which are calculated by multiplying GRC local spending in each industry (the direct impact) by its corresponding multiplier. For example, as indicated in Table 10, the indirect and induced output impact of GRC engineering and business services in FY 1998 is $217.3 million ($104.8 million x 2.073). The total output impact for each industry is composed of direct impact (GRC spending on this industry), indirect impact, and induced impact. Figure 9 shows the breakdown by direct and

[13] Final demand multipliers reflect three types of impact: direct impact, which represents the initial value of goods and services purchased by GRC; indirect impact, which represents the value of goods and services purchased by local companies to provide goods and services demanded by GRC; and induced impact, which measures the change in local household spending patterns resulting from increased earnings by employees in local industries producing goods and services for GRC.

indirect impacts for each major industrial sector.[14] Figure 10 shows the relative size of total direct versus indirect and induced impacts.

Table 10: NEO Output Impact of GRC Spending, FY 1998

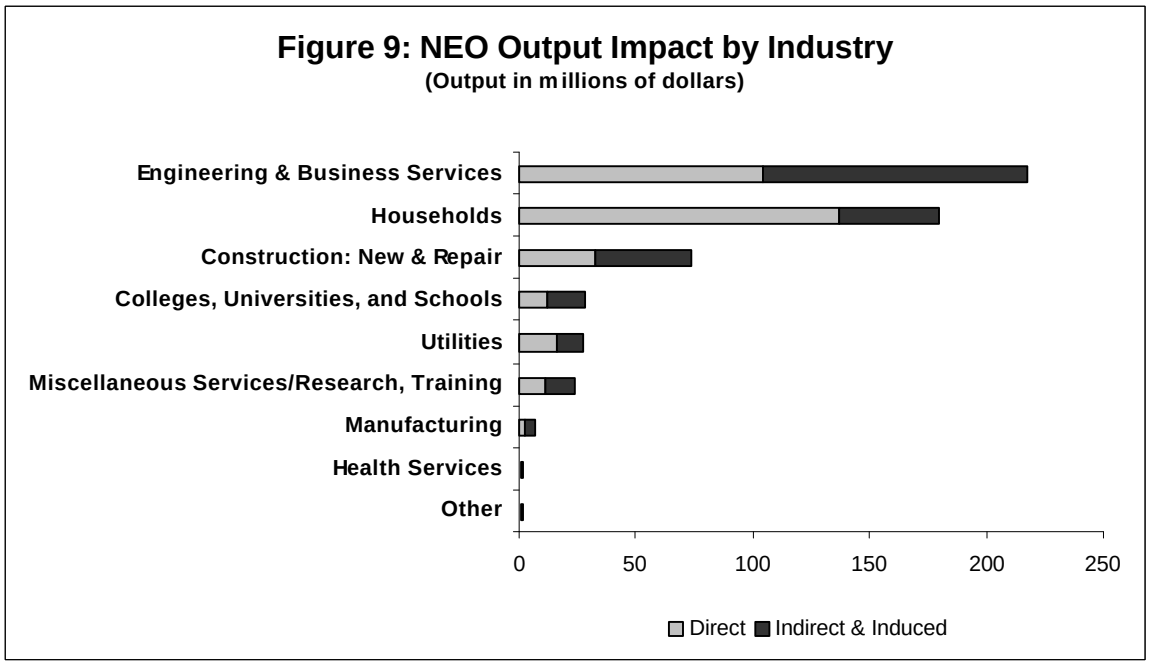
Industry	Spending	Multiplier	Impact
Total	317,988,481		
Households	137,212,000	1.3121	180,035,865
Engineering & business services	104,820,352	2.0730	217,292,590
Construction: new & repair	32,162,099	2.2891	73,622,261
Electric, gas, water, and sanitary services	15,925,059	1.7055	27,160,188
Colleges, universities, and schools	12,260,341	2.2970	28,162,003
Miscellaneous services / research, training	10,912,522	2.2117	24,135,225
Fabricated metal products	1,619,796	2.3558	3,815,915
Health services	965,437	2.1592	2,084,572
Transportation	667,701	2.1671	1,446,975
Electric and electronic equipment	515,169	2.0558	1,059,084
Industrial machinery and equipment	215,486	2.2681	488,744
Lumber and wood products and furniture	207,916	2.0257	421,175
Wholesale trade	172,732	1.8927	326,929
Instruments and related products	159,925	1.9621	313,789
Chemicals and petroleum refining	142,046	2.0244	287,558
Printing and publishing	29,900	1.9006	56,828
Subtotal (Indirect and Induced Impact)			560,709,701
Plus Direct Impact			317,988,481
Total Impact			878,698,182

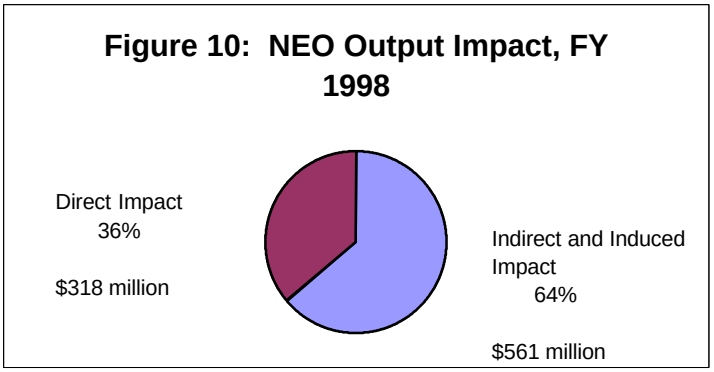
Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 6 includes all spending on manufacturing in Northeast Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Northeast Ohio by wholesale margins.

[14]The following industries (see Table 10) are classified as manufacturing: fabricated metal products; electric and electronic equipment; industrial machinery and equipment; lumber and wood products and furniture; instruments and related products; chemicals and petroleum refining; and printing and publishing.





Thus, in FY 1998, GRC generated almost $879 million in spending throughout Northeast Ohio. Of these, $318 million resulted from direct spending impacts and $561 million resulted from indirect and induced spending impacts throughout the regional economy. This represents a 16 percent decline over the output impact in FY 1994 in nominal dollars and 24 percent decline after adjusting for inflation.

ECONOMIC IMPACT ON EMPLOYMENT

GRC's activities in the regional economy affect jobs beyond the 2,045 civil servants the Center employs. The total job impact by industry is detailed in Table 11, where the RIMS II multipliers are multiplied by spending in 1997 dollars.[15] For example, for each one million dollar spent by GRC on engineering and business services, 31 jobs were created in the regional economy. Thus, GRC's spending of $102 million (in 1997 dollars) on engineering and business services has created 3,173 indirect and induced jobs throughout the region. Summing up the indirect and induced impact created by each spending category provides the total indirect and induced impacts on jobs in Northeast Ohio (7,315 jobs). Direct employment impact includes the number of civil service employees at GRC; it does not include the on-site/near-site contractors. Expenditures on these contractors are captured in GRC's spending on the different sectors, mainly in the engineering services. Figure 11 shows the relative size of direct employment impact versus indirect and induced impact, illustrating that the direct impact of jobs accounts for only one-fifth of the total job impact (22 percent).

In FY 1998, 9,360 jobs were generated through GRC's activities. Of these, 2,045 resulted from direct impact (civil service employees at the Center) and 7,315 resulting from indirect and induced impacts. This represents a 27 percent decline over the number of jobs generated by GRC in FY 1994.

[15] To calculate GRC's employment impact, GRC's spending is deflated to 1997 dollars because the employment multipliers are calculated based on spending in 1997 dollars. Also, the employment multipliers are calculated based on number of jobs created per one million dollars in spending.

Table 11: NEO Employment Impact of GRC Spending, FY 1998

Industry	Spending (In 1997 dollars)	Multiplier	Impact
Total	310,546,843		
Households	134,013,535	16.5862	2,223
Engineering & business Services	102,376,949	30.9890	3,173
Construction: new & repair	31,412,388	26.8903	845
Electric, gas, water, and sanitary services	15,553,840	9.8988	154
Colleges, universities, and schools	11,974,548	39.7816	476
Miscellaneous services / research, training	10,658,147	32.3697	345
Fabricated metal products	1,582,038	19.9176	32
Health services	942,932	29.3529	28
Transportation	652,137	23.5787	15
Electric and electronic equipment	503,160	16.6169	8
Industrial machinery and equipment	210,463	20.5335	4
Lumber and wood products and furniture	203,069	19.6353	4
Wholesale trade	168,705	19.0985	3
Instruments and related products	156,197	16.9053	3
Chemicals and petroleum refining	138,735	11.7670	2
Printing and publishing	29,203	17.9383	1
Subtotal (Indirect and Induced Impact)			7,315
Plus Direct Impact			2,045
Total Impact			9,360

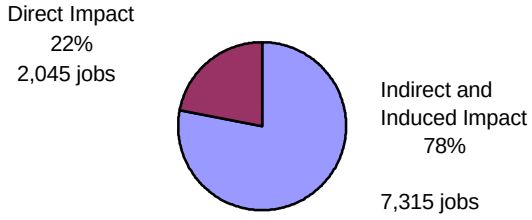
Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 6 includes all spending on manufacturing in Northeast Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Northeast Ohio by wholesale margins.

Job impact is calculated based on multiplying the spending in millions by the number of jobs created per million dollars of spending (the multiplier). Spending is measured in 1997 dollars.

Figure 11: NEO Employment Impact, FY 1998



ECONOMIC IMPACT ON EARNING

Every new job created by GRC's purchasing of goods and services from Northeast Ohio industries generated new earnings for local households. The earning multipliers for each industry, shown in Table 12, estimate the total change in earnings that occur to locally-employed households for each additional dollar for goods and services delivered to GRC. For example, the $105 million spent by GRC to purchase engineering and business services in the region created an additional $80 million in indirect and induced earnings by households employed by Northeast Ohio businesses in a variety of industries. Adding the indirect and induced impacts created by the different spending categories to the payroll received by GRC civil service employees results in the total earnings impact. Figure 12 shows that direct-earning impact accounts for 44 percent of total earning impact.

In FY 1998, GRC spending on grants and contracts generated $315 million of earnings for Northeast Ohio households. Of these, $137 million were direct impact (those earnings that were earned as payroll and benefits by GRC's civil service employees). The other $178 million were indirect and induced earnings impact, or those earnings that were earned by local households in other industries in Northeast Ohio. The total earnings impact in FY 1998, $315 million, was 16 percent lower than the FY 1994 earnings impact. Measured in real dollars, the decline was more severe: earnings impact declined by 24 percent over the FY 1994 - 1998 period.

Table 12: NEO Earnings Impact of GRC Spending, FY 1998

Industry	Spending	Multiplier	Impact
Total	317,988,481		
Households	137,212,000	0.3705	50,837,046
Engineering & business services	104,820,352	0.7662	80,313,354
Construction: new & repair	32,162,099	0.6952	22,359,091
Electric, gas, water, and sanitary services	15,925,059	0.3126	4,978,173
Colleges, universities, and schools	12,260,341	0.7804	9,567,970
Miscellaneous services / research, training	10,912,522	0.6534	7,130,242
Fabricated metal products	1,619,796	0.6239	1,010,591
Health services	965,437	0.8034	775,632
Transportation	667,701	0.6422	428,798
Electric and electronic equipment	515,169	0.5219	268,867
Industrial machinery and equipment	215,486	0.6670	143,729
Lumber and wood products and furniture	207,916	0.5247	109,094
Wholesale trade	172,732	0.5772	99,701
Instruments and related products	159,925	0.5324	85,144
Chemicals and petroleum refining	142,046	0.4115	58,452
Printing and publishing	29,900	0.5063	15,138
Subtotal (Indirect and Induced Impact)			178,181,021
Plus Direct Impact			137,212,000
Total Impact			$315,393,021

Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 6 includes all spending on manufacturing in Northeast Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Northeast Ohio by wholesale margins.

Figure 12: NEO Earnings Impact, FY 1998

GRC Impact on Northeast Ohio: Summary

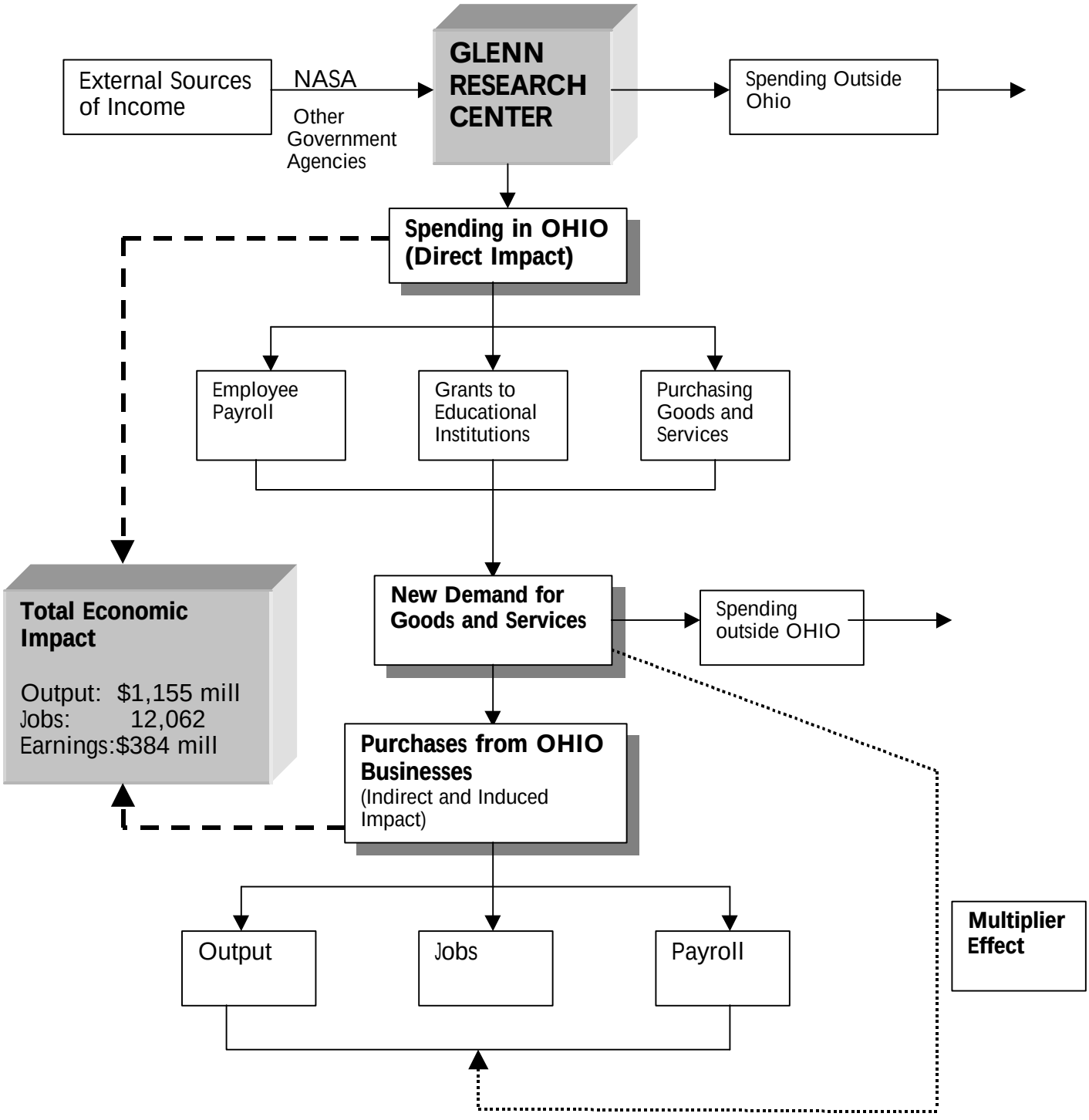
GRC economic activities in FY 1998 produced the following economic impacts in the northeast Ohio region:

- Total Output Impact: $879 million, a reduction of 24 percent from FY 1994
- Total Employment Impact: 9,360 jobs, a reduction of 27 percent from FY 1994
- Total Earnings Impact: $315 million, a reduction of 24 percent from FY 1994

GRC TOTAL ECONOMIC IMPACT ON THE STATE OF OHIO

This section measures the direct and indirect effects of the Glenn Research Center during FY 1998 on the economy of the State of Ohio as a whole. The same methodology is utilized as that used for calculating impact on Northeast Ohio. RIMS II final demand multipliers for output, employment, and earnings are used. However, the multipliers that are applied to spending in Ohio are generally higher than the multipliers applied for Northeast Ohio. This is because a larger geographic area assures less leakage in economic activity, meaning that the larger the area being analyzed, the less goods and services are purchased from outside the region, and the larger the multiplier is. In addition, GRC's spending in Ohio is higher or the same as GRC spending in Northeast Ohio. As before, the total economic impact presents quantitative estimated impacts on the region's total output, total earnings by regional households, and on total employment in the area. Figure 15 presents the process of economic impact of GRC activities on the Ohio economy.

Figure 13. GRC Economic Impact in Ohio



ECONOMIC IMPACT ON OUTPUT (SPENDING)

Final demand output multipliers measure the effect of GRC spending on gross receipts or sales in the state. To calculate the industry output impact, GRC's purchases from each industrial sector in Ohio are multiplied by the industry's output multiplier (see Table 13). For example, the indirect and induced output impact of GRC engineering and business services in Ohio in FY 1998 is $368.9 million ($173.5 million x 2.1261). The sum of these industries' output impact adds up to the indirect and induced output impact ($761 million). The total output impact for each industry is composed of direct impact (GRC spending on this industry), indirect impact, and induced impact. Figure 13 shows the breakdown by direct and indirect for each major industrial sector. Figure 14 shows the relative size of total direct versus indirect and induced impacts.

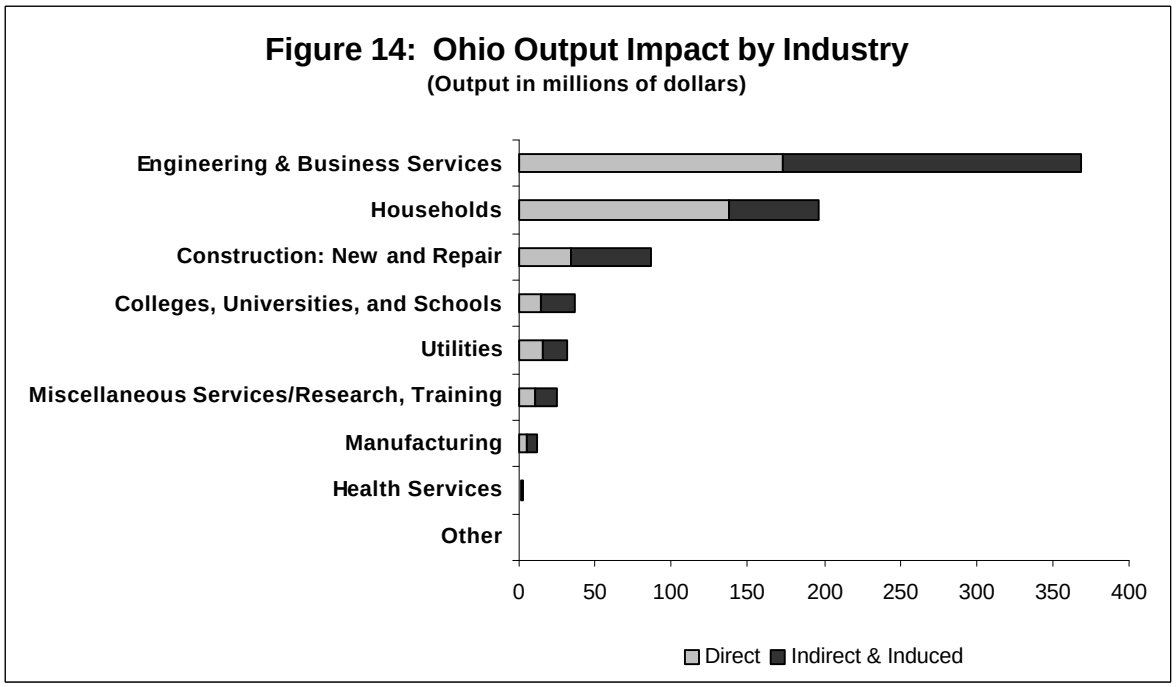
Table 13: Ohio Output Impact of GRC Spending, FY 1998

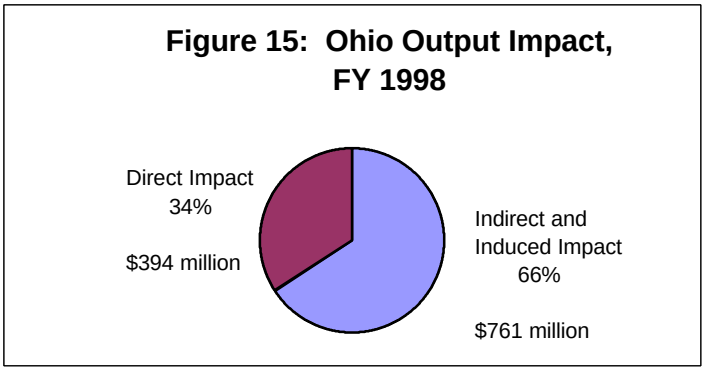
Industry	Spending	Multiplier	Impact
Total	394,121,109		
Engineering & business services	173,513,083	2.1261	368,906,166
Households	137,212,000	1.4368	197,146,202
Construction: new and repair	34,390,876	2.5104	86,334,855
Electric, gas, and sanitary services	16,050,339	1.9317	31,004,440
Colleges, universities, and schools	15,052,125	2.3977	36,090,480
Miscellaneous services	10,956,747	2.3220	25,441,567
Industrial machinery and equipment	2,014,164	2.4195	4,873,270
Fabricated metal products	1,840,086	2.5408	4,675,291
Health services	965,437	2.2495	2,171,751
Transportation	667,701	2.2510	1,502,995
Electronic and other electric equipment	515,169	2.2461	1,157,121
Instruments and related products	325,271	2.0673	672,433
Lumber & wood products & furniture	207,916	2.1358	444,067
Wholesale trade	177,004	1.9706	348,805
Chemicals and petroleum refining	142,046	2.1704	308,297
Miscellaneous manufacturing industries	35,167	2.3733	83,462
Printing and publishing	29,900	2.2628	67,658
Communications	26,078	1.8975	49,483
Subtotal (Indirect and Induced Impact)			761,278,340
Plus Direct Impact			394,121,109
Total Impact			1,155,399,449

Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries (see footnote 12 on page 29 for a list of specific manufacturing industries) includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 5 includes all spending on manufacturing in Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Ohio by wholesale margins.





In FY 1998, GRC generated $1,155 million in spending throughout Ohio. Of this, $394 million resulted from direct spending impacts and $761 million resulted from indirect and induced spending impacts throughout the regional economy.

ECONOMIC IMPACT ON EMPLOYMENT

GRC's activities in the regional economy affect jobs beyond those that are employed at the Center. The total job impact by industry is detailed in Table 14, where the RIMS II multipliers are multiplied by GRC spending in Ohio in 1997 dollars.[16] For example, each one million dollars spent by GRC on purchasing engineering and business services from companies located in Ohio created 31 jobs in the state economy. Thus, GRC's spending of $169 million (in 1997 dollars) on engineering and business services in Ohio has created an indirect and induced employment impact of 5,294 jobs in the State. Adding the indirect and induced impacts on jobs from the different spending categories results in a indirect and induced employment impact in Ohio of 10,017 jobs. Direct employment impact includes the number of civil service employees at GRC; it does not include the on-site/near-site contractors. Expenditures on these contractors are captured in GRC's spending on the different sectors, mainly in engineering services. Figure 15 presents the proportion of total impact; direct jobs account for only 17 percent of total job impact while the majority of the total job impact is due to the indirect and induced employment impacts.

In FY 1998, 12,062 jobs were generated in Ohio through GRC's activities. Of these, 2,045 resulted from direct impact (civil service employees at the Center) and 10,017 resulting from indirect and induced impacts.

[16] To calculate GRC's employment impact, GRC's spending is deflated to 1997 dollars because the employment multipliers are calculated based on spending in 1997 dollars. Also, the employment multipliers are calculated based on number of jobs created per one million dollars in spending.

Table 14: Ohio Employment Impact of GRC Spending, FY 1998

Industry	Spending (In 1997 dollars)	Multiplier	Impact
Total	384,933,993		
Engineering & business services	169,468,426	31.2360	5,294
Households	134,013,535	18.0533	2,419
Construction: new and repair	33,589,211	29.6084	995
Electric, gas, and sanitary services	15,676,199	11.7827	185
Colleges, universities, and schools	14,701,254	41.0630	604
Miscellaneous services	10,701,341	34.6050	370
Industrial machinery and equipment	1,967,213	21.2393	42
Fabricated metal products	1,797,193	21.4026	38
Health services	942,932	30.8848	29
Transportation	652,137	24.9922	16
Electronic and other electric equipment	503,160	18.0078	9
Instruments and related products	317,689	18.1419	6
Lumber & wood products & furniture	203,069	21.5025	4
Wholesale trade	172,878.37	20.0731	3
Chemicals and petroleum refining	138,735	12.9148	2
Miscellaneous manufacturing industries	34,347	24.0208	1
Printing and publishing	29,203	21.5366	1
Communications	25,470	14.6952	0
Subtotal (Indirect and Induced Impact)			10,017
Plus Direct Impact			2,045
Total Impact			12,062

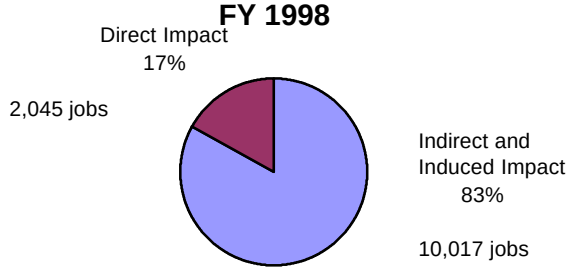
Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 5 includes all spending on manufacturing in Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Ohio by wholesale margins.

Job impact is calculated based on multiplying the spending in millions by the number of jobs created per million dollars of spending (the multiplier). Spending is measured in 1997 dollars.

Figure 16: Ohio Employment Impact, FY 1998



ECONOMIC IMPACT ON EARNING

Every new job created by GRC's purchasing of goods and services from companies located throughout Ohio generated new earnings for local households. The earning multipliers for each industry, shown in Table 15, estimate the total change in earnings that occur to households employed in Ohio for each additional dollar of goods and services delivered to GRC. For example, the $174 million spent by GRC to purchase engineering and business services from Ohio's companies created an additional $134 million in indirect and induced earnings by households employed by Ohio businesses in a variety of industries. Figure 16 illustrates the relationship between the direct earnings impact and the indirect and induced impact.

In FY 1998, GRC spending on grants and contracts generated almost $384 million of earnings for Ohio households. Of these, $137 million were direct impact (those earnings that were earned as payroll and benefits by GRC's civil service employees). The other $247 million were indirect and induced earnings impact, or those earnings that were earned by households employed by other industries in the state.

Table 15: Ohio Earnings Impact of GRC Spending, FY 1998

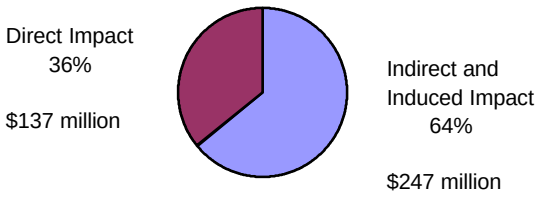
Industry	Spending	Multiplier	Impact
Total	394,121,109		
Engineering & business services	173,513,083	0.7727	134,073,559
Households	137,212,000	0.4047	55,529,696
Construction: new and repair	34,390,876	0.7673	26,388,119
Electric, gas, and sanitary services	16,050,339	0.3696	5,932,205
Colleges, universities, and schools	15,052,125	0.8131	12,238,883
Miscellaneous services	10,956,747	0.7014	7,685,062
Industrial machinery and equipment	2,014,164	0.6816	1,372,854
Fabricated metal products	1,840,086	0.6665	1,226,417
Health services	965,437	0.8444	815,215
Transportation	667,701	0.6778	452,568
Electronic and other electric equipment	515,169	0.5612	289,113
Instruments and related products	325,271	0.5666	184,299
Lumber & wood products & furniture	207,916	0.5691	118,325
Wholesale trade	177,004	0.6029	106,716
Chemicals and petroleum refining	142,046	0.4399	62,486
Miscellaneous manufacturing industries	35,167	0.6233	21,920
Printing and publishing	29,900	0.6134	18,341
Communications	26,078	0.4585	11,957
Subtotal (Indirect and Induced Impact)			246,527,735
Plus Direct Impact			137,212,000
Total Impact			383,739,735

Notes: The industry categories in this table are more detailed that those in Tables 5 and 6.

Spending on manufacturing industries includes only purchases of goods produced locally; spending on goods purchased locally but produced elsewhere are excluded. Spending on manufacturing presented in Table 5 includes all spending on manufacturing in Ohio without regard to production location.

Wholesale trade is calculated by multiplying spending on goods produced locally and produced outside of Ohio by wholesale margins.

Figure 17: Ohio Earnings Impact, FY 1998



GRC Impact on Ohio: Summary

GRC economic activities in FY 1998 produced the following economic impacts on the State of Ohio:

- Total Output Impact: $1,155 million
- Total Employment Impact: 12,062 jobs
- Total Earnings Impact: $384 million

GRC TECHNOLOGY TRANSFER AND RELATED ACTIVITIES

One important aspect of GRC's impact on the regional economy is its technology transfer activities and its extensive partnerships. This section will take a qualitative look at GRC's efforts as well as the coordinated efforts of its partners in both technology transfer and business assistance programs and will describe some of the impacts that these programs have had on individual firms in the region. This section discusses the work of GRC's Commercial Technology Office, which is the Center's primary agent for fostering technology transfer. It also discusses the technology transfer derived from the primary mission of GRC's Technology Directorates.

TECHNOLOGY TRANSFER

Technology transfer has undergone a dramatic evolution in the past decade. Northeast Ohio companies, reflecting a national trend, are demonstrating an increased appetite and sophistication about acquiring external technology. New technology and evolving regulations for the transfer of federally developed technology have greatly enhanced and facilitated technology transfer from GRC to industry, including small entrepreneurial companies.

Technology transfer is broadly defined as "the transition of scientific or engineering knowledge from one entity to another for a potentially useful purpose".[17] Technology transfer between a federal lab and a private firm can be used to advance or create products, processes, and services. Technology transfer can occur in two ways: "technology push" strategies, where technologies are developed before commercial applications are sought for them, and "technology pull" strategies, where a technology-oriented problem or a new market opportunity leads a private company or industry to seek a solution.

[17] J. Creddon, K. Abbott, L. Ault, C. Ginty, G. Masakowski, S. Sheriq, W. Spack. *NASA Technology Transfer: Report of the NASA Technology Transfer Team. December 21, 1992.*

Interviews with organizations that interact with GRC have indicated that GRC has greatly improved its technology transfer procedures and efforts in the past five years. Interviewees commented that GRC seems more open to outside companies and is clearly committed to facilitating the commercialization of its technology. However, the Center still must struggle to overcome barriers including public perceptions about the difficulties of working with a federal lab and internal processes that hinder researchers' ability to participate.

COMMERCIAL TECHNOLOGY OFFICE

A good starting point for describing GRC's interactions with local industry is its Commercial Technology Office (CTO). Congress has mandated that NASA maximize the value of its research and development activities for the benefit of the public. The CTO at Glenn is one of ten offices Agency-wide that were established and funded by NASA in response to this congressional mandate. The mission of the CTO is to increase the competitiveness of U.S. industry through the commercial application of GRC's technologies, expertise, and facilities.

The Commercial Technology program mission includes:

- Managing intellectual property (technologies, expertise, and facilities).
- Promoting opportunities for partnership with industry to further develop or use NASA technologies, expertise and facilities.
- Applying NASA capabilities to improve a company's competitive advantage and ultimately promote economic growth.

GRC has approached technology transfer and commercialization by providing a variety of avenues for partnering. These partnerships have varying levels of formality and resource commitment by each partner. The major mechanisms and strategies for partnership, which are described below, include Space Act Agreements, Patent Licensing, Software Use Agreements, Industry Summits, Consortia, Alignment with Regional Industry Clusters, Commercial Technology Fund, and Small Business Innovation Research Programs and Technology Transfer Programs.

SPACE ACT AGREEMENTS

Many of the technology transfers and commercial products that were supported by NASA have their origins in Space Act Agreements. These agreements formalize commitments between NASA and an industry partner to accomplish a joint endeavor. Between 1997 and 1999, 193 Space Act Agreements have occurred between firms and GRC. GRC has recently updated and standardized its process for entering into Space Act Agreements. This revised process includes using risk analysis and cost-benefit analyses in the decision-making process, the development of a simple, straightforward method of cost estimating, and the implementation of a short approval cycle. As a result, the average time span for entering into an agreement was reduced from nine weeks in 1998 to 4.8 weeks in 1999. These changes have made it easier for industry to enter into Space Act Agreements with GRC.

One example of a small company in Cleveland who has utilized a Space Act Agreement is Micro Medical Devices, Inc. (MMD). MMD teamed with GRC to develop a micro arthroscopy system. This system involves an endoscope the size of a needle, and is aimed at expanding the use of minimally invasive surgery on the knee, ankle, and other small joints. MMD used software developed by NASA to clarify the focus on images from the Hubbell telescope to enlarge the images taken from the tiny cameras at the end of the endoscope. The enlarged images are transmitted to a monitor watched by the surgeon in the operating room.

PATENT LICENSING

GRC manages much of its intellectual property through the use of patents and licensing. This not only protects the public investment but also provides a more valuable product to private industry. GRC licenses to both large and small businesses.

Both Solar Universal and Howard Industries are examples of companies that have licensed a GRC patent. In this case, the patent was for a technology called an Ion Exchange Material that was developed from research on space battery separators. The material can remove hazardous metals such as lead, cadmium, silver, copper, zinc, and mercury ions

from liquids. Applications are being explored in removing lead from drinking water and in environmental cleanups and radioactive metal recovery in wastewater.

SOFTWARE USE AGREEMENTS

Much of the intellectual property developed at GRC is in the form of software. This software is transferable to interested parties by Software Use Agreements.

For example, NASA developed "Ceramic Analysis and Reliability Evaluation of Structures" (CARES) software to establish the reliability and life of brittle material components in aircraft engines. The software incorporates extensive computational capabilities into one comprehensive package. This software has been shared with a number of partners for use in aerospace, automotive, bioengineering, and glass manufacturing applications.

INDUSTRY SUMMITS

The GRC's Commercial Technology Office regularly hosts or supports conferences and summits with industry. In November 1999, it hosted the IDEAS (Innovations, Demonstrations, Exhibits, Applications, Spinoffs) Microsystems Forum. The purpose of this forum was to bring researchers and industry representatives together to stimulate partnering in this rapidly evolving arena. Technologies showcased focused on health monitoring in harsh environments including sensors, actuators, microelectronics, packaging, micromachining, and other supporting topical areas. Technology transfer and partnering with industry was facilitated through detailed technical presentations, industry requirement panel discussions, and one-on-one discussion sessions. The conference also included tours of key NASA aerospace research and testing sites. The IDEAS forum had approximately 160 participants from a variety of organizations, among them universities, the Cleveland Clinic, Cleveland Tomorrow, Daimler Chrysler, Proctor and Gamble, and Dow Chemical.

CONSORTIA

NASA has also used consortia for transferring specific technologies and capabilities to entire industries. In 1997, GRC and Battelle's Great Lakes Industrial Technology Center

(GLITeC) launched the Consortium for the Design and Analysis of Composite Materials. The consortium enables members to tap into the design and analysis expertise of GRC researchers in the areas of polymer, ceramic, and metal matrix composites, and monolithic ceramics. The consortium takes advantage of NASA's leadership in developing math models and associated software for analyzing the deformation and failure of composite materials. It also leverages Battelle's expertise in modifying government codes for industrial use.

One participant, Goodyear, estimates that benefits from one year's membership in the consortium have resulted in a $5,000-25,000 production or operation cost savings. The company has continuously renewed membership in the consortium since 1997 to investigate other NASA software and to further understand and apply NASA's micromechanics analysis code.

ALIGNMENT WITH REGIONAL INDUSTRY CLUSTERS

In 1998 and 1999, a number of Ohio and Northeast Ohio government and nonprofit organizations announced initiatives to enhance regional economic development and industrial competitiveness by fostering the establishment of industry clusters in specific technology areas. Some of the industry areas promoted by the initiatives include biomedical, information, instruments and controls, motor vehicles and equipment, and advanced materials. The premise of the industry cluster approach is that a region's economic performance, in terms of quality of jobs, quantity of out-of-region exports, and generation of wealth and income, is based on a geographic concentration of industries. These industries have close customer-supplier relationships, utilize common technologies, and share a labor pool that provides them with a competitive advantage.

One major requirement for the economic success of industry clusters is the existence of organizations in the region that are the sources of the cutting-edge technologies upon which the clusters are based. GRC constitutes a significant source of cutting-edge technology in a number of the cluster areas identified as critical to long-term economic development in Ohio. GRC's resources include specialized research and test facilities, the development and transfer of aeronautical propulsion technology, and fundamental

research on propulsion-related materials, structures and acoustics, instrumentation and controls, and internal fluid mechanics. GRC also conducts high-risk-high-payoff R&D on communication technologies ranging from microwaves to antennas and digital applications and on power technologies for aerospace systems.

Numerous projects have been implemented by GRC that strengthen its alignment with industry cluster areas. For example, in the biomedical area, a fiber optic probe initially developed for conducting fluid physics space experiments has been adapted for early detection of eye diseases. In the information technology area, GRC established in May 1999 the Lewis Incubator for Technology (LIFT), a business incubator to nurture the creation of new and early stage businesses based on NASA-developed software, electronics, and communications technologies. In the motor vehicle area, GRC is a member of a consortium consisting of the Ohio Department of Development, the Greater Cleveland Regional Transit Authority, and Ohio businesses and academia that is developing a ultra-efficient, environmentally friendly transit bus. This bus uses a natural gas engine to produce electricity that powers a variable speed powertrain. In the instruments and controls area, GRC is a key partner in the Glennan Microsystems Initiative, a five-year program that couples the resources and expertise of the Center, Case Western Reserve University, the State of Ohio, and industry to expand the application of micro-electromechanical systems, or MEMS. MEMS include integrated systems of miniaturized devices such as sensors, actuators, motors, valves, and micro-sensors manufactured together on a single semiconductor chip. GRC is investing a total of $20 million in the five-year program. In the materials area, an affordable process was invented for fabricating silicon-based ceramics and fiber-reinforced composites. The process was selected by *R&D Magazine* and a panel of distinguished scientists and engineers as one of the 100 most technologically significant new products of 1999. The inventor of the process was granted the prestigious R&D100 award.

COMMERCIAL TECHNOLOGY FUND

GRC's Commercial Technology Office has recently initiated this program to facilitate more efficient technology transfer. The funding is being used to bridge the gap between the genesis of an interesting idea and the demonstration of its feasibility in the commercial

marketplace. It is hoped that this approach will help NASA better identify industrial partners and "push" their technology out into the market place.

One of the recent proposals funded under this program is for further development of a room temperature, wet chemical growth method of silicon oxide dielectrics on silicon and other semiconductor substrates. This partnership is between a researcher in the Photovoltaic and Space Environments Branch at GRC and SPECMAT, Inc. of North Olmsted, Ohio. A patent is pending on this process that involves soaking the substrates in a growth solution using inexpensive liquid precursors, along with homogenous catalysts that increase growth rates. Originally developed to serve as a method of applying protective coatings to solar cells, the applications of this technology are mainly based on its speed over conventional methods and the reduced equipment costs required due to the reduced number of steps in this process over conventional methods. Integrated optics, electo-optic devices, acoustic devices, photonics, and high-temperature and corrosion-resistant metal coating are some of the potential applications.

SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND TECHNOLOGY TRANSFER PROGRAMS

NASA's Small Business Innovation Research Program (SBIR) was established to promote innovative research by small businesses in order to increase private sector commercialization and innovation. Whenever possible, the program aids and encourages minority and disadvantaged businesses. Since the inception of the program in 1983, GRC has awarded 66 SBIR contracts to 34 Ohio companies totaling more than $15 million. Of the total Ohio awards, GRC has given 15 Northeast Ohio companies 35 awards totaling $8million. Forty percent of the Ohio awards went to small disadvantaged or women-owned companies.

The Small Business Technology Transfer (STTR) program is an additional program that awards contracts to small business concerns for cooperative research and development with a research institution (RI) through a uniform, three-phase process. STTR, though modeled after the SBIR Program, is a separate activity and is separately funded. The NASA STTR Program is designed as a vehicle for converting the nation's investment in research carried out by research institutions into new commercial technologies for advancing U.S.

economic competitiveness and high-tech development, thus contributing to technology transfer.

GRC encourages SBIR and STTR awardees to commercialize their projects. After the company has achieved a success, GRC works with them on promoting their success. One company, AI Ware, Inc., was selected by *R&D magazine* for the R&D ELITE Awards Program. Subsequently, the company was acquired by Computer Associates International, Inc. Participating companies, such as AI Ware, have a diverse customer base that includes the Eli Lilly and Company, B. F. Goodrich, Dow Chemical, Glidden Paint Company, Wright Patterson Air Force Base, Defense Advanced Research Projects Agency (DARPA), the U.S. Navy, the U. S. Department of Agriculture (USDA), the U.S. Department of Energy (DOE), and NASA Kennedy Space Center.

GRC DIRECTORATES

In addition to the activities of the CTO, an important mission of GRC's technical directorates is to research, develop, verify, and transfer advanced aeronautics, space, and related technologies to the private sector. The Directorates' activities to accomplish their mission contributed to the local and state economies through technology transfer. Here are few examples:

SPACE

Within the Space Directorate, examples can be drawn from the Space Communications and Microgravity Research Programs.

Space Communication

Two examples of GRC's impact on the local economy can be drawn from the Space Communication Program. First, GRC has a partnership with Ohio University that investigates communications protocols over a satellite link. The results of this experiment have been incorporated into requests for change with the Internet Engineering Task Force, the governing body that determines the technical operation of the Internet. In summary,

the results of this joint experiment are helping to ensure that satellite communications will be an integral part of future communications networks.

Another local partnership within Space Communications includes the Cleveland Clinic Foundation and the Ashtabula County Medical Center. Together, these organizations have developed an experiment to investigate transporting mammography imagery over satellites. This experiment has shown that satellites can provide a viable medium for transporting mammography imagery. Moreover, this project has shown that advanced satellite communications can improve health care in rural communities by providing the ability to link to urban medical facilities for consultation with experts in near real time.

Microgravity Research

GRC is the Center of Excellence for fluids and combustion research within the Microgravity Research Program. The emphasis of the program is on peer-reviewed, world class science, with scientists across the nation in universities and other organizations receiving funding for cutting-edge fluids and combustion research.

Since 1996, Ohio-based principal investigators have received over six million dollars in funding from GRC's Microgravity Research Program. Research institutions receiving the funds include Case Western Reserve University, Cleveland State University, Ohio State University, and the University of Dayton. The program also supports undergraduate and graduate students and has a number of educational outreach activities.

In addition, Cleveland is home to the National Center for Microgravity Research on Fluid and Combustion (NCMR), an innovative partnership between GRC, Case Western Reserve University (CWRU), and the Universities Space Research Association (USRA). USRA is a national research consortium dedicated to assisting universities, other research institutions, and the government in the development of knowledge associated with space science and technology. The Center has offices both on the campus of CWRU and at GRC. NCMR is national in scope and mission, and is overseen by USRA. NCMR gives Northeast Ohio the greatest concentration of microgravity fluids and combustion talent in the world. Created in 1997, the Center's tasks include performing cutting-edge research, providing expertise

to assist experimenters across the nation, engaging and sharing knowledge with industry and academia, and providing outreach to students in K-12 and assisting teachers in engaging students in the areas of mathematics and science. NCMR is funded by NASA through a cooperative agreement, with total funding of $19.7 million spread over five years. The Center has 37 full time equivalent staff, with almost 40 percent employed by CWRU and over 60 percent employed by USRA. Almost 90 percent of the staff is located at GRC.

Within the program a new emphasis is being placed on broadening the benefit from scientific research to industry. This research has applications for such industries as biomedical engineering, automotive and aircraft engine combustion, paints, films, coating and lubricants, industrial and appliance burners and furnaces, utilities, pollution/emissions detection and control and food and consumer products and processing. In 1998 and 1999, the program began an initiative to engage industry and formed an Industry Liaison Board, comprised of Vice Presidents of Research and Technology or equivalent. This board has strong representation from local and Ohio industry. Its purpose is to allow NCMR to build awareness of GRC's capability in fluids and combustion research and seek guidance about which aspects have the highest commercial potential. Local Board members include TRW, Eaton Corporation, The Cleveland Clinic, Sherwin Williams, Teledyne Continental Motors, Nordson Corporation, and ICI Paints. As a result of this activity, Teledyne, located in Toledo, is currently considering utilizing GRC expertise in lean combustion to assist in new product development.

To broaden its interactions beyond the board members, NCMR has also begun to convene industry workshops and focus groups for industry. One result of the first workshop is a relationship between ICI Paints, in Cleveland, and NCMR on diagnostic technologies. NCMR will be convening more focused workshops, including one on biomedical engineering on non-invasive diagnostics.

NCMR has had a specific impact on a number of local companies. For example, NCMR has been working with Ford Motor Casting in Cleveland to improve engine core manufacturing.

Another significant activity of GRC's Microgravity Research Program is its responsibility for the fluids and combustion facility that will fly on the International Space Station. In order to allow investigators across the nation to manage experiments on the Space Station remotely, GRC developed Tempest, a software package that uses embedded web technology to allow users to monitor and control a remote device using the Internet. Tempest was an R&D 100 award winner in 1999. Tempest has many applications for the private sector and training in the use of the software has been given to several local companies such as Allen-Bradley, Reliance Electric, General Electric, National School of Sleep Medicine (Akron), Diebold, and Keithley Instruments.

Microgravity research usually requires capturing images of experiments in progress under difficult conditions. As a result, GRC's Imaging Technology Center has developed a strong capability in video image enhancement to support the work in microgravity and other disciplines. As a community service, GRC has been providing local law enforcement with image enhancement of surveillance tapes. Since January 1999, GRC has assisted 27 different Ohio organizations in a wide variety of crimes. The most recent example being assistance in the solution of the Bond Court office building murder in downtown Cleveland. The Imaging Technology Center has also developed an educational tool, LEADS, which utilizes a video and guide to teach law enforcement and businesses the optimal use and handling of evidence tapes and security cameras.

Finally, GRC's Microgravity program has an impact on local tourism through its scientific conference. This conference annually brings 250-350 attendees to downtown Cleveland for three days.

AERONAUTICS

The Aeronautics Directorate has broad ties to Ohio's industry and education institutions. It has significant partnerships with universities in Ohio, including Cleveland State University, the University of Toledo, Case Western Reserve University (CWRU), the University of Akron, the Ohio State University, and Wright State University. Some examples of joint projects with these partners include the modeling of flutter in aircraft compressors with the University of Toledo and the evaluation of advanced fire detection sensors with CWRU. In

addition, Aeronautics has a consortia agreement with Ohio State University, Westinghouse Electric, and four out-of-state universities to develop an aeroelasticity code to model flutter and forced responses in aircraft turbines. This Directorate also has a number of grants, cooperative agreements, and support service contracts with the Ohio Aerospace Institute to support experimental tests and modeling at GRC. The Directorate is also involved in extensive joint projects with prime contractors in Ohio including BF Goodrich and General Electric Aircraft Engines, such as for the development of improved engines, and a number of smaller engineering firms. Finally, the Aeronautics Directorate is involved in a number of collaborative activities with the Wright Patterson Air Force Base.

RESEARCH AND TECHNOLOGY

The Research and Technology Directorate also has broad ties with Ohio's industry and educational institutions. One example is its relationship with a large company based in Northeast Ohio, TRW, where a researcher from GRC served as a technical consultant and lecturer on the subject of structural durability of automotive components. TRW's current fatigue testing and life prediction modeling capabilities were critiqued and recommendations were made. As a result of this relationship, TRW is better able to perform more accurate and pertinent fatigue analysis, which in turn permits the design of safer, more reliable, and more durable components.

Another example from Research and Technology is a joint shuttle flight experiment with Hathaway Brown School for Girls. The flight experiment, which is designed to promote science and technology education among young women in grades nine through 12, relates to spacecraft durability in the low earth orbit space environment. Students come to GRC full-time over the summer and typically once a week during the school year to conduct pre-flight and post-flight analyses.

GRC AWARDS

The NASA Glenn Research Center has distinguished itself from other federal laboratories by winning a number of prestigious awards in the last few years. These awards demonstrate GRC's significance as a leader in cutting-edge technologies and in technology transfer activities.

NASA Government Invention of the Year

In 1996, the High Temperature, Flexible Fiber Preform Seal won the NASA Government Invention of the Year Award. The seal was patented in 1992 and has been demonstrated as an enabling technology in several key applications.

NASA Software of the Year

In 1998 the GRC project Tempest was named NASA Software of the Year. The software was originally developed to support the science experiments on the International Space Station. Its embedded web remote control mechanisms are likely to be developed for the automotive, consumer electronics, office products, and medical industries.

In 1999, NASA GRC was again awarded Software of the Year, this time for Genoa, a progressive failure-analysis software with unique prediction capabilities. Genoa is the first and only software that can predict progressive aging and failure of materials as diverse as metals, ceramics, concrete, and all types of composites.

Federal Laboratory Consortium (FLC) Director of the Year

NASA Glenn's Center Director was named as the 1998 FLC Director of the Year for Technology Transfer. The annual award honors laboratory directors who have made exemplary contributions to the overall enhancements of technology transfer for economic development. More than 600 federal research labs are members of the FLC.

THE R & D 100 AWARD

The R&D 100 Award was presented in 1999 to four GRC projects. This prestigious award is presented annually to innovators of the most technologically significant new products. The winners were:

- Robust Ceramics Joining Technology, a process for manufacturing ceramics and ceramic matrix composites
- Large Area 3-D Surface Profiling Using Only Focused Air Pulses, a scan system that can profile over larger areas and larger depth depressions at higher speeds
- Tracker, a software program that automates the image analysis process
- Tempest, a server that allows real-time applications to be controlled over the Internet with a standard web browser

GRC has won 74 out of NASA's 105 R & D 100 Awards. Previous GRC winners include the Advanced Communication Technology Satellite, High-Temp Flexible Ceramic Wafer Seal, CARES software, and the PdCR Strain Gauge.

GRC'S PARTNERS

A description of GRC's impact on the local economy would not be complete without describing the technology transfer and business assistance activities of its local partners. In fact, much of GRC's interactions with local industry are facilitated through these partnerships with local organizations. This section highlights the major partner organizations of GRC and describes some of their joint contributions to the local economy.

THE OHIO AEROSPACE INSTITUTE (OAI)

The Ohio Aerospace Institute is a private, nonprofit university, industry, and government consortium that includes GRC, Wright Patterson Air Force Base, nine Ohio universities, and technology driven corporations.[18] OAI specializes in bringing together teams from

[18] The nine Ohio universities that are part of the OAI consortium include: Case Western Reserve University, Cleveland State University, Ohio University, The Ohio State University, The University of Akron, The University of Akron, The University of Cincinnati, The University of Dayton, The University of Toledo, and Wright State University.

different sectors. In order to assist technology transfer, OAI facilitates and manages collaborative research groups composed of industry, academia, and government engineers. These groups are established to deliver solutions for industry's needs. In most activities sponsored by OAI, both government and industry provide funding to develop technologies for industry's commercial needs. NASA is a major funder of this organization, second to the Department of Defense.

OAI also offers extensive educational programming, which is discussed in the Education Section of this report.

OAI's Collaborative Core Research Program provides funding opportunities for OAI member university faculty in response to research topics that are specified by sponsor industries. This program pools industry sponsorship fees along with state and federal funding to competitively award funding for university projects. Projects must include an industry partner and must address a demonstrated industry need. The results of the projects often become the basis for broader-based research initiatives.

OAI's technology teaming program allows for industry, university, and federal government researchers to jointly pursue pre-competitive high-risk technologies. OAI's role in this program includes targeting market-driven high-risk industry and government needs, building teams of experts, facilitating proposals to obtain funding, providing contract management and administration, and protecting proprietary information. GRC is involved in many of these projects. One example of a recent team project involving GRC is computer-assisted minimally invasive surgery (CAMIS), which has received $10 million in funding to attempt to improve surgical precision and patient outcomes by enabling surgeons to obtain accurate 3-D images of internal surgical fields before and during surgery. The first phase has been so successful that the prototype CAMIS has already been commercialized and is undergoing FDA Beta testing. Another example of a technology teaming program that included GRC as a partner is the propulsion instrumentation working group, the first collaborative effort in the area for the major domestic aircraft gas turbine engine manufacturers. This 36-month effort was formed to collaboratively address critical propulsion engine development test instrumentation and sensor issues.

GLITEC

The Great Lakes Industrial Technology Center (GLITeC) is one of six NASA Regional Technology Transfer Centers (RTTCs) established to turn NASA developed mission technology into additional valuable products, processes, and solutions. GLITeC manages a highly integrated technology commercialization network of affiliate organizations within its six-state Midwest region, each of which is uniquely positioned to commercialize NASA technology and to benefit NASA, particularly the GRC. GLITeC is a technology assistance and technology commercialization resource for Northeast Ohio companies. The unique relationship between GLITeC and the GRC Commercial Technology Office staff has enabled GLITeC to meet a full range of company technology requirements and to provide a comprehensive array of commercialization assistance services to these client companies.

As NASA Glenn's RTTC and partner to the GRC Commercial Technology Office, GLITeC facilitates access to NASA technology via traditional licensing and technology assistance and also through innovative methods such as a unique reimbursable umbrella Space Act Agreement established by GRC and GLITeC. This umbrella Space Act Agreement provides immediate, barrier-free access for Northeast Ohio industry to GRC facilities and personnel. This agreement, unique to Northeast Ohio and the Great Lakes region, has been recognized throughout NASA and elsewhere in the federal system as the state-of-the-art in industry-government linkages. The umbrella Space Act Agreement allows NASA work to start immediately after the receipt of payment from the firm. No additional negotiations are required.

The commercialization of GRC Tempest technology illustrates another innovative technology commercialization mechanism devised by the GRC Commercial Technology Office and GLITeC -- software licensing through workshops. Three Northeast companies are now incorporating GRC Tempest technology into their products or shop floors and the technology has been praised by many key organizations, including the National School of Sleep Medicine, Keithley Instruments, and General Motors. Tempest, the 1998 NASA software of the year, was developed at GRC to resolve the problem of controlling remote systems such as experiments on the shuttle and space station in real time. This revolutionary embedded web technology lets the user link embedded devices together, connect them to higher order, multi-purpose processors, and plug them into the Internet.

Commercial product opportunities are unlimited, from home appliances to automobiles and medical diagnostic equipment. Tempest has been commercialized with the assistance of GRC Commercial Technology Office and GLITeC through three Embedded Web Training Workshops. Workshop participants acquire the source code for Tempest, NASA's web server for real-time operating systems. They also received step-by-step instructions for integrating their applications with Tempest and other commercially available web software.

The Commercial Technology Office and GLITeC provide technical assistance to companies in Northeast Ohio, Ohio and the Midwest region, drawing on the technology resources and facilities of GRC , other NASA Field Centers, GLITeC affiliates, and other organizations (including Manufacturing Extension Partnerships centers and other federal labs). This customized assistance draws on Battelle Memorial Institute's experience in finding technology solutions, and on Battelle's unique network of client companies, agencies, and universities. Often off-the-shelf technologies are appropriate, and the Commercial Technology Office and GLITeC staff members refer clients to the appropriate partners. If analysis reveals that the customer has thoroughly investigated the problem and not found a solution, a NASA-based solution can be developed. The fact that GRC has selected a technology assistance partner, GLITeC, with no vested interest in a particular solution, gives clients confidence, and helps build enduring relationships with clients.

GLITeC fielded 903 inquiries in 1998, which resulted in 18 licenses, 82 Space Act Agreements, and 86 endorsements/commendations. In addition, 174 significant single projects were assessed in depth to determine the full value of technology assistance services to companies, with 98 percent of the companies surveyed reporting that GLITeC's assistance was helpful and that they would use GLITeC again.

GSYS, Incorporated, a Northeast Ohio entrepreneurial company, is one example. Through GLITeC's experience and business connections, GSYS, Incorporated, a minority-owned research and development firm with an innovative retrofitable collision avoidance systems concept-patent for the trucking industry found a partner with IST (Imaging Systems Technology), another minority-owned firm with expertise in electronic and software development for the automotive market. Together, they are in the process of finalizing an

agreement to license their product with a large automotive supplier. GLITeC facilitated the meetings with both IST and the large corporation, ultimately providing GSYS. with crucial development support that brought development costs down to zero from initial estimates of one million dollars. Once the partnership is finalized between GSYS. and the automotive supplier, projected revenues will generate close to one billion dollars. In summary, GLITeC assessed the technical needs of GSYS. and introduced GSYS to the Lewis Incubator for Technology, in the process helping fill sensor system design gaps with GRC technology and expertise. GLITeC also helped GSYS to mature its business plan to cover commercialization strategies, management issues, market assessment, and business partners.

GLENNAN INITIATIVE

The GLENNAN Initiative was created to advance the development and use of microsystems by industry and NASA. A five-year program that partners GRC, the State of Ohio, and Case Western Reserve University (CWRU) with industry, GLENNAN's purpose is to expand the application of microelectromechanical systems (MEMS). MEMS are integrated systems of miniaturized devices such as sensors, actuators, motors, valves, and microprocessors manufactured together on a single semiconductor chip. The main goal of the initiative is to identify and manufacture prototype devices for industry with a diverse range of applications. Benefits to industry members of GLENNAN include access to multidisciplinary microsystems expertise, access to new innovations and developments, rapid prototyping and testing, reduced research to market cycle, and required economies of scale. The initiative has the potential to have a significant impact on Ohio's economy and leverages the research capabilities of CWRU and GRC.

GARRETT MORGAN INITIATIVE

The GRC Garrett Morgan Commercialization Initiative (GMCI) is a program for small minority-owned, and woman-owned businesses that can benefit from NASA resources. The Initiative provides services that enable companies to grow or strengthen their business by leveraging NASA technology, expertise, and programs.

The Initiative is designed to meet needs that are unique to small minority owned, and woman-owned businesses. Through the GMCI, companies can quickly identify opportunities and obtain the support they need to take advantage of them. The GMCI provides qualified companies with comprehensive business assessments, identification of promising NASA opportunities, strategic planning, linkage to resources, partnership and project facilitation, and market development assistance.

Consultation and basic services are free of charge. Participating companies are obligated to periodically complete service and progress assessment surveys, participate in mutually beneficial promotional activities, and provide written feedback on the Initiative's impact and value.

In 1998 the NASA Glenn Garrett Morgan Commercialization Initiative successfully increased the competitiveness of 17 small minority- and women-owned businesses in the Great Lakes region by providing enhanced access to NASA technology, programs, and expertise as well as other tailored services. Included in the benefits provided to these companies was a 10-week program to support companies in the development of a technology commercialization plan or components of a business plan to present to potential investors or strategic partners.

The Initiative also established a unique funding program to provide competitive technology commercialization awards totaling $200,000 to companies with promising SBIR-developed or other technologies.

LEWIS INCUBATOR FOR TECHNOLOGY (LIFT)

The Lewis Incubator for Technology (LIFT) is a business incubator program designed to nurture new and emerging technology-based businesses with the potential to incorporate NASA technology or develop linkages with NASA. LIFT is a partnership formed by GRC, Enterprise Development Incorporated (EDI) (a not for profit subsidiary of Case Western Reserve University), the State of Ohio's Department of Development, and the Great Lakes Industrial Technology Center (GIITeC). Managed by EDI, LIFT is jointly funded by GRC and the State of Ohio. One purpose of the program is the identification of viable

technology on which fledgling businesses can base their business. Primary objectives of the incubator are to create jobs and businesses in Ohio and to increase the commercial value of NASA knowledge, technology, and expertise.

LIFT operates two sites: the first opened in March 1997 and is located in a BP America research facility focusing on businesses needing wet-lab space. The second site, which opened in May 1999, is located on the GRC campus, focusing on software, electronics, and communications companies. Tenants have access to fully equipped wet laboratory and office space, machine and graphics shops, and conference and library facilities at BP America's Cleveland research and development site. The GRC site offers office and light lab space, high speed Internet access, and use of the NASA technical library.

The LIFT program has generally been successful so far. The BP site currently houses 9 tenant companies and has all available space either occupied or committed. The newer GRC site has two tenants and a number of higher priority companies currently evaluating an application to the program. The LIFT tenant companies now employ close to 40 highly-educated individuals and all tenant companies have a strong potential for rapid growth in employment and ultimately in sales revenue.

Services for LIFT tenants include managerial assistance, marketing, planning and business development, office services, assistance in locating financing sources, and public relations. Other services include assistance in building relationships with GRC and with locating NASA technologies, as well as the benefits of an informal association with other tenants. To be considered for the program, firms must have a sound business concept with commercially focused technology as its foundation. LIFT provides business plan development assistance in a pre-incubator portion of the program if the firm requires such assistance.

Essentially, all LIFT tenants have existing or potential linkages with GRC. One example is The Edgington Company. The company joined the LIFT program in 1997 and has developed revolutionary, environmentally friendly, high-performance coatings and polymers with reduced or eliminated volatile organic compounds for industrial and automotive markets. The Edgington Company recently executed a non-reimbursable Space

Act Agreement with GRC for Edgington to research and develop conversion coatings for metal substrates that would be highly beneficial to NASA and other users. In its short two-year history, the company has also developed relationships with several other major coatings and specialty chemical companies that will enhance the opportunities for commercialization of the Edgington's technologies.

Another LIFT project has been a student effort involving both business and engineering students. Three graduate students- two in business and one in engineering- have been involved. The first objective of this project was to evaluate technologies developed at GRC and select one that had a strong potential to be a new business. The next objective was to develop tools for future teams to do the same. Third, the students put together a detailed business plan for commercializing the technology. Finally, the students were directed to find an entrepreneur who would start a business using the technology and the plan they had developed. This project appears to have been highly successful. The students are tentatively planning to start a business themselves with their selected technology. Their evaluation tools are useful for future teams and are also being adopted by the Commercial Technology Office. In summary, the students have gained a project with real world possibilities and have received a practical education, while LIFT and GRC have received assistance in evaluating and assessing technologies for commercial potential and LIFT even has a potential tenant.

OHIO AEROSPACE COUNCIL

The Ohio Aerospace Council (OAC) is an independent organization run by Battelle and allied with the Greater Cleveland Growth Association. OAC seeks to increase the impact of GRC in the State of Ohio through education and advocacy and by providing business community input to GRC decision makers. The OAC is attempting to maintain and increase the visibility of GRC, develop a coordinated statewide aerospace agenda, increase the community's understanding and awareness of the value of GRC, and establish a congressional budget request that has a positive impact on GRC. Members include the Greater Cleveland Growth Association, BF Goodrich, Parker, GE Aircraft Engines, and Battelle. In terms of technology-related activities, OAC helps to facilitate connections

between GRC leadership and local industry and makes suggestions to GRC for research areas that are of interest to industry.

THE OHIO DEPARTMENT OF DEVELOPMENT (ODOD)

ODOD is involved with GRC in a number of ways. First, GRC works in partnership with the ODOD Edison Program to provide an extensive network of information, referral, and technology assistance services designed to strengthen the competitiveness of Ohio companies. One example of this partnership is ODOD and GRC's shared funding of the Lewis Incubator for Technology (LIFT). ODOD also funds both GLITeC and the GLENNAN initiative.

In addition, GRC's Director, Donald Campbell, has been appointed to the Ohio Technology Action Board by Governor Taft. The Board was created in order to oversee the annual distribution of $15 million in funds that are designed to stimulate Ohio's high-technology industries. The investments will be used to expand the research base, facilitate technology transfer out of universities and federal labs, and to build technology clusters.

WRIGHT PATTERSON AIR FORCE BASE

GRC has a long relationship with the Air Force Research Laboratory (AFRL), which is located at Wright Patterson Air Force Base near Dayton, Ohio. Both organizations have similar types of charters and have common research interests. Both GRC and AFRL are involved in research focused on propulsion and power, high speed propulsion, space launch propulsion, and aircraft power. AFRL and GRC have a number of joint partnerships and work synergistically. One example of cooperation between the two labs is with the lithium polymer Ohio initiative and the lithium ion battery consortium, which will eventually involve several Ohio colleges and universities. Another example is IHPTET (integrated high-performance turbine engine technology). IHPTET is an ongoing national program that is doubling the US military's 1988 propulsion capability. Through coordinated government and industry efforts, this program validates technology that has both military and commercial applications. IHPTET is considered to be a model program that addresses critical defense technology objectives, develops dual use technologies, has well defined goals with milestones, and provides continuous technology transition

opportunities. Partners include NASA, DOD, the Air Force, the Army, General Electric, the Navy, Pratt Whitney, Allied Signal, and other industry partners.

Another example of collaboration between GRC and AFRL is the Wright Technology Network. This organization, which is similar to GLITeC, has agreed to work with GLITeC to assist AFRL and GRC in efforts to find synergy in their work and to attempt to leverage off of each other.

GRC CONTRIBUTIONS TO THE QUALITY OF EDUCATION IN OHIO

This section describes GRC's contribution to the education system in Ohio at both the K-12 and the higher education levels. As described in the earlier section, GRC awarded $15.1 million in grants to Ohio's educational institutions during FY 1998. This section goes beyond the dollar amounts given to individual institutions and describes some of the programs supported by GRC that are intended to enhance and improve the level of education in Ohio, especially in the fields of math, science, and engineering.

HIGHER EDUCATION

This section is based on discussions with deans of engineering, faculty members, university presidents, Ohio Aerospace Institute leadership, and others at universities across the state as well as with the GRC Office of University Programs. The benefits realized by universities through their relationship with GRC include:

- Research funding: direct grants awarded by GRC to fund faculty, research associates, and graduate and undergraduate students. In some universities, GRC funding was instrumental in building a stronger department by attracting high-quality faculty.
- Providing major funding to research centers and new initiatives, such as the Micro-Gravity Center and the GLENNAN Microsystems Initiative at Case Western Reserve University.
- Access to GRC's highly specialized high-tech facilities and equipment for conducting experiments that cannot be done on campus.
- Access to GRC's scientists and engineers and their expertise.
- Exchange of ideas and knowledge among faculty, students, and GRC staff.
- GRC's senior management sits on boards of trustees of research centers or labs affiliated with Ohio universities.
- Using GRC's technology to develop a virtual classroom.

- Improved and enriched curricula resulting from research conducted by faculty at GRC facilities. New and advanced techniques learned at GRC are incorporated into the classroom.

- Some placement of graduating students at GRC, although this has become a very small benefit due to the hiring freeze at GRC over the past several years. Only recently (summer 1999) has GRC resumed its hiring of new research staff.

THE SUMMER FACULTY FELLOWSHIP PROGRAM

NASA Headquarters coordinates the Summer Faculty Fellowship Program, which is implemented by each of the field centers. At GRC, the implementation is conducted by the Office of University Programs, which provides a grant to the Ohio Aerospace Institute (OAI) to assist with the implementation of the program.

The Program provides science and engineering faculty the opportunity to participate in research at a NASA facility during a 10-week session in the summer. Faculty is chosen based on the match between their expertise and GRC's needs. Each participant works closely with an assigned GRC researcher. NASA views this program as a vehicle to introduce new faculty into the NASA system. Faculty members have the opportunity to develop a professional relationship with NASA's researchers, making the program mutually beneficial. The Program's objectives are to further the professional knowledge of science and engineering faculty members, to stimulate an exchange of ideas between faculty and NASA researchers, to enrich and refresh faculty's research and teaching activities, and to contribute to the research objectives of the NASA centers.

Short-term benefits to faculty include summer funding. Stipends are $1,000 per week plus a travel allowance; a relocation allowance is given to fellows who must relocate their residence. Long-term benefits are more comprehensive and include enhanced research skills, improved prospects for future research grants, and better classroom curricula. Although the program is advertised nationally and applicants are drawn from all states, the geographic proximity to a NASA center is evident at GRC as well as at other NASA Centers. In recent years, the percentage of faculty participants from Ohio has steadily increased at GRC to well over 60 percent of the total for 1999 (Table 16).

Table 16. Summer Faculty Fellowship Program Participation at GRC

Year	Number of Participants		Ohio as percentage of Total
	Ohio	Total	
1995	20	49	40.8
1996	26	55	47.3
1997	30	56	53.6
1998	25	45	55.6
1999	26	42	61.9

However, the table also shows that the total number of faculty members participating in the program at GRC has fluctuated from 49 in the summer of 1994 to 56 in 1997 to 42 in 1999.

THE GRADUATE STUDENT RESEARCHERS PROGRAM

Another program, centrally coordinated by NASA Headquarters and implemented locally by the GRC's Office of University Programs is the Graduate Student Researchers Program. This program provides up to three-year support to full-time students working towards advanced degrees in aerospace-related science and engineering areas. The annual award to each student is $22,000, providing for a $16,000 student stipend, plus a $3,000 student allowance, and a $3,000 university allowance. Each student works closely with a GRC advisor and spends some part of his or her time at GRC. One direct benefit is to provide financial support for graduate students. Other benefits include the creation of new opportunities for students as well as the development of a professional relationship between the student's academic advisor and the GRC advisor. Typically, about a quarter of the students come from Ohio institutions. During the 1999-2000 academic year there were nine students from Ohio universities.

ON-SITE GRADUATE ENGINEERING PROGRAM

Another relationship between GRC and some of Ohio's universities is through the collaborative on-site graduate engineering program at GRC. This program, administered by OAI under a contract with GRC, provides opportunities for working engineers to pursue master's and doctorate degrees at the Center. The students have to register in a graduate program with one of OAI's member universities. Several local universities participate by sending faculty to teach on-site while other Ohio universities participate by teaching through interactive television and distance learning.

SUMMER INTERNSHIP PROGRAM FOR UNDERGRADUATE STUDENTS

This is an educational program that provides internships for students in science, engineering, professional administrative, and technical areas. The internships are offered under the auspices of GRC's Educational and Research Collaborative Internship Program, and the program is conducted collaboratively by GRC's Office of Educational Programs and OAI's Programs Department.

The Program's objective is to provide students with introductory professional experiences to complement their academic programs. The interns work under the personal guidance of GRC's professional staff members and are given assignments that are commensurate with their academic level and field of study. In FY 1998, 105 undergraduate students spent their summer as interns at GRC; of these, 63 were from Ohio. In FY 1999, 127 undergraduate students participated in the program with 79 of them from Ohio. The application process is competitive and participants are selected by GRC's researchers. The students attend universities around the country, but the majority of them are from Ohio.

GRC RELATIONSHIP WITH WILBERFORCE UNIVERSITY

GRC has a unique relationship with Wilberforce University, a historically black college in Ohio. In 1992, the University received its first grant to upgrade its engineering and chemistry labs. Over the past three years, the University has received three major grants that contributed to the enhancement of undergraduate education and to the increase in the number of minority students going into the fields of science and technology.

Under the CARET (Consortium for Advancing Renewable Energy Technology) grant, several Wilberforce students work with renewable energy projects, especially with wind turbines and solar energy. They work on the set-up and implementation phases and make presentations to high-school students about their work. The grant was also used to pay for a distance learning classroom.

The WUPTEP (Wilberforce University Power Technology and Education Program) grant funds a summer bridge program for incoming freshmen that provides accelerated courses in math and science to prepare them for college. The newest grant, SORET (Student Outreach using Renewable Energy Technology) will improve the distance learning facility and support a solar lighting project to be implemented in a high school or community building.

GRC CONTRIBUTIONS TO THE QUALITY OF K-12 EDUCATION

NASA contributes to educational excellence by involving the education community in NASA's endeavors to inspire America's students and create learning opportunities. At GRC, the Office of Educational Programs (OEP) is responsible for NASA's commitment to enhancing education at the regional level. OEP's mission is to utilize NASA's inspiring mission, the unique GRC laboratories, and its diverse and specialized workforce in participating in appropriate educational programs and activities for enhancing the teaching and student learning of science, mathematics, and technology education.

GRC's Educational Programs cover a six-state region that includes Ohio, Illinois, Indiana, Michigan, Minnesota, and Wisconsin. The programs are directed toward teacher/faculty preparation and enhancement, student support, systemic improvement, curriculum support, and educational technology. GRC's education outreach programs involve average and high-achieving students in summer and academic year activities and increasing participation in these science and engineering programs of female and minority students as well as students with disabilities. The programs build a student "pipeline" to

science and engineering professions and provide teachers with real-world experiences to take back to their classrooms.

Benefits provided by the education programs include:

- Access to GRC scientists and engineers and their expertise
- Opportunities to see real-world applications of science, mathematics, and technology
- Introduction of career choices to students
- Improved and enriched curricula resulting from research done at GRC facilities
- Incorporation of new and advanced knowledge and techniques learned at GRC into the classroom
- Opportunities for students and teachers to work at GRC for a summer

According to the OEP, 78,211 people participated in the GRC's educational programs during FY 1999. Of that number, 891 Ohio teachers and student participants provided direct feedback.[19] In addition, nearly 250,000 educators and students were reached at conferences or through electronic means.

NASA'S AEROSPACE EDUCATION SERVICES PROGRAM

Three Aerospace Education Specialists are assigned to GRC as part of the national Aerospace Education Services program. These specialists travel GRC's six-state region to conduct teacher workshops, student programs, and to give presentations at education and technology conferences.

In Ohio, these specialists conducted on- and off-site programs for 1,108 teachers during FY 1999. Considering an average class size of 22 students per teacher, they indirectly affected 24,376 students. Programs conducted directly for students, on- and off-site, reached 5,423 Ohio students. In addition, the specialists reached about 250,000

[19] Participant data are collected through an agency-wide on-line tracking and evaluation program. Program managers report the numbers and categories of participants. For longer-term programs, participants complete on-line feedback forms.

educators and students through conferences, TV, radio, and videoconferences for distance learning.[20]

Comments from teachers include:

> "This workshop was very helpful in presenting a more personal side to what happens in science…the tours of the facilities were very cool…the interaction with other teachers was helpful in the sharing of ideas and ways of integrating what was presented today into the classroom and other presentations… tremendous opportunity to learn about space in this very professional and comfortable setting…you've given us a day to remember and use with our students…the program was quite effective…the resources that are available for teachers are phenomenal"

NASA EDUCATIONAL WORKSHOPS

NASA's educational workshops, conducted every summer, support 50 competitively selected teachers from across the country who spend two weeks at GRC. Generally, about ten percent are from Ohio. During these workshops, the teachers are exposed to GRC's research and development activities, observe specialists at work, learn about the latest technology, and develop new interdisciplinary and team-teaching strategies for the classroom.

Within this program, GRC has designed a new program for educators from Ohio's urban school districts. In FY 1999, 22 educators from five school districts (East Cleveland, Youngstown, Lorain, Columbus, and Cincinnati) spent two weeks at GRC as participants in the NASA Educational Workshop Systemic Urban Initiative. The educators worked with GRC's aerospace education specialists, scientists, and engineers to develop action plans to enhance systemic reform of mathematics and science education. The educators returned to their districts to revise their curricula to include NASA educational material at all grade levels. In addition, GRC's OEP suggests that the 22 participants will assist with the training of 10,000 teachers and will enhance the learning of 159,000 students in their districts. OEP offers follow-up assistance to the school districts.

[20] For FY 1998, individual state data are not available. However, based on the number of programs conducted in that year, OEP assumes that the number of participants is similar to the number for FY 1999.

SEMAA: The Science, Engineering, Mathematics, and Aerospace Academy

SEMAA was established in 1993 as a partnership between NASA's GRC and Cuyahoga Community College (CCC). Its primary goal is to provide K-12 students with a better understanding of and a greater appreciation for science and mathematics. SEMAA provides academic enrichment and career awareness programs to encourage K-12 students to acquire a strong academic background in science and math and to prepare them to pursue undergraduate programs in science, mathematics, engineering, and technology. Each year, GRC provides CCC with about $550,000 to operate SEMAA. CCC provides subcontracts to Cleveland State University and Case Western Reserve University to conduct some programs for SEMAA's students.

SEMAA students meet on Saturday mornings during the academic year and are actively involved in a hands-on, inquiry-based cooperative learning environment that allows students to learn by doing. Summer programs are also offered. Unique to the SEMAA program is a strong parent component, called the Parents' Cafe. Parents are taught how to enhance their children's knowledge of math and science through activities at home. In addition, parents receive information on college selection and admission as well as how to apply for financial assistance.

The SEMAA program has been so successful that it has been replicated at other sites in the U.S. Since 1998, the SEMAA program has been replicated at nine other sites around the country, in addition to the original site in Cleveland, Ohio. In 1998, two sites were added, one in Dayton, Ohio and one in Detroit, Michigan. The Dayton program is housed at Sinclair Community College and is utilizing the expertise at Wright Patterson Air Force Base. In 1999, seven more sites were added, including Atlanta, Georgia; Baltimore, Maryland; Chicago, Illinois; Jamaica, New York; St. Louis, Missouri; Warren County, North Carolina; and Washington, D.C.

During FY 1999, over 3,700 students were enrolled in SEMAA's programs in six sites (all sites except for Warren County, Baltimore, Chicago, and Atlanta, which started to serve

students only in fall 1999 or January 2000). Of the participants, 45 percent were female and 75 percent were African American.[21]

Most of the SEMAA sites are equipped with an Aeronautics Education Laboratory (AEL).[22] The AEL is a computerized classroom that allows middle and high school students to explore and discover aeronautics and microgravity situations. At an AEL, a state-of-the-art classroom, students can simulate a cross-country flight using NASA's aeronautics as a theme. The AEL has ten workstations, including an operating wind tunnel and a virtual reality station. GRC has provided funding to install an AEL at Cuyahoga Community College in Cleveland and at Sinclair Community College in Dayton at a cost of about $200,000 each. Beginning in fall 1999, SEMAA students across the country will be able to work simultaneously on projects via the Internet in their respective AELs. Planned projects include positioning a large telescope to view constellations and an automated electron microscope to analyze substances.

SEMAA's national office is located at Cleveland's Cuyahoga Community College. The national office ensures that SEMAA's curriculum for grades K-12 meets national standards in math and science and is currently available on CD-ROM. The national office shares technological updates with all sites and helps to establish partnerships in each location to ensure the future sustainability of local programs.

SEMAA's success is evident in its replication across the country. Ohio's sites in Cleveland, Ashtabula (a Cleveland Extension), and Dayton reached 1,750 students in FY 1998 and about 2,500 in FY 1999. The success of the program is due partly to outstanding leadership support from GRC. GRC's staff participates in SEMAA's programs by serving as mentors and guest speakers. GRC's Office of Educational Programs contributed to curriculum development and oversight.

[21] This information was taken from *SEMAA 1999 Annual Report*.

[22] The AEL is the stationary version of NASA's successful Mobile Aeronautics Education Laboratory (MAEL), which is described later in this section.

SCHOOL PARTNERSHIPS

School partnerships are collaborative efforts designed to empower educators, students, and parents. One example, which has been in place for ten years, is the partnership between GRC and East Technical High School in the City of Cleveland. The partnership includes GRC's staff assistance in one-to-one tutoring of students during the year and for science fairs, as well as student participation in on-site GRC programs.

The East Tech Technical Academy, part of the partnership between East Technical High School and GRC, uses a curriculum developed jointly by staff from East Tech and GRC. It provides students entering the 9th grade the opportunity to study and be exposed to engineering and technical occupations. Designed for urban at-risk students, the program aims to improve academic achievement and attendance and to facilitate decisions regarding careers in science, engineering, and technology. In FY 1999, 120 students participated. Although this program targets entering 9th graders, it plans to track those cohorts throughout their tenure at East Tech. GRC also donates many computers and helps sponsor the year-end awards ceremony at the school.

One of the highlights of the partnership between East Tech high School and GRC was the financial and technical support of the school's robotic team for the past six years. The East Tech High-School robotic team participated in FIRST (For Inspiration and Recognition of Science and Technology), a national program that promotes science and math. FIRST is a national engineering contest that immerses high school students in the world of engineering. In six weeks, students and NASA engineers and technicians work together intensely to brainstorm, design, construct, and test their "robot champion" and then compete with other teams. Approximately 25-30 students from Cleveland's East Technical High School are involved each year and have won regional and national awards.

In 1998, East Tech won a national invitational competition as well as the Great Lakes Regional Xerox Creativity Award. In 1999, the team placed 118 out of 207 in a national FIRST competition. However, they won the Chairman award in that competition, an award given for displaying the best working relationship among team members, relationship with the sponsor, and community support. The robot is built at GRC, where team members work on it after school and on weekends. GRC has a core staff that works

with the students throughout the project, and others that join when appropriate. Every year, the robotic team creates a lot of excitement at the school, where the team of 25-30 students is chosen from 150-200 applicants. For the selection presentation, students work in teams of three and prepare a creative presentation. Both the high school and GRC staff participate in the team's selection. In FY 2000, GRC will fund FIRST teams from two Cleveland high schools, East Tech and James Rhodes, as well as a team from a consortium of urban schools in Columbus.

OTHER EDUCATIONAL PROGRAMS SUPPORTED BY GRC

The following is a short description of several other programs supported by GRC to improve and enhance education for students in grades K-12.

- The **Aeronautics in Mathematics and Science** program provides a motivational approach to aeronautics-related careers as well as an introduction to aeronautics. In FY 1999, the presentations conducted under the auspices of this program reached about 530 teachers, students, and parents.

- The **Mobile Aeronautics Education Laboratory** (MAEL) is a mobile, state-of-the-art classroom that brings aeronautics-based technology to schools and communities. The MAEL trailer and program were created through a partnership between Cuyahoga Community College and GRC. The MAEL reached about 3,400 Ohio students and educators in FY 1998 and FY 1999. The MAEL was replicated at stationary sites (AEL) as part of the SEMAA program, described above.

- The **Educator Resource Center** provides supplemental teaching materials. Educators and parents can get curriculum guides, lithographs, posters, and activities and can copy videotapes and slides at no charge. Educators can borrow actual lunar and meteorite samples after completing certification. The Educator Resource Center assists about 1,000 Ohioans every year.

- The **New Approach to Self-Achievement Program** assists students entering grades seven to nine. During the summers of 1998 and 1999, more than 85 inner-city students participated, improving their math and science skills through classroom instruction and field trips. The program aims to increase students' interest in engineering careers.

- As part of **National Engineers Week**, every year during the month of February GRC engineers visit schools**.** In FY 1998 and FY 1999, GRC's engineers reached 12,772 students and educators. The presenters use age-appropriate hands-on activities to generate excitement and interest among the students. Presentations by women engineers demonstrate to the students that the engineering field is open to both men and women.

- The on-site **Glenn Summer Internship and Fellowship Program** involves 150-200 high school, undergraduate, and graduate students and 5-10 teachers each year. (This program was also summarized above in the section on GRC's contribution to higher education.) Participants are assigned a mentor and receive a stipend for the summer. In FY 1998, 141 Ohioans participated; 147 participated in FY 1999. The high school internships demonstrate the importance of attending college and encourage students to study science or engineering.

- The **Shadowing Program** offers students an opportunity to spend time with GRC employees in both the trades and professional positions. In FY 1998, 77 students participated, increasing to 114 in FY 1999. The number of minority students more than doubled over the past year, while the number of disabled students also increased.

- The **Explorers Program** collaborates with the Boy Scouts of America to provide students ages 14 to 20 with career exploration opportunities focused on aeronautics and computer science. GRC volunteers serve as Exploring Advisors; they lead activity groups that meet one weekday evening a week during the school year to work on group projects. A total of 122 students participated in FY 1998 and FY 1999.

Conclusions

NASA has been experiencing budget cuts since the mid-1990s and will begin the 21th century with a budget almost a billion dollars smaller than it began this decade. NASA is dealing with the cuts primarily through programmatic changes. Some of the agency-wide consolidations resulted in a loss of programs for GRC, which led to lower budgets and smaller numbers of civil service employees. GRC is rebuilding itself in response to these external forces.

This report describes in detail GRC's labor force trends, spending on contractors, grants awarded, and revenues received. The declining GRC budgets, triggered by external forces, resulted in a smaller labor force and a reduction in GRC spending on contractors. Not surprisingly, GRC's impact on Northeast Ohio declined somewhat over the past five years, although it remained significant. The total economic impact of GRC in Ohio shows that in FY1998, the Center generated $1,155 million in spending (output produced), created 12,062 jobs, and while increasing household earnings by $384 million.

Moreover, as the qualitative sections on technology transfer and education suggest, GRC continues to significantly contribute to the quality of education locally and throughout the state and has increased its ties with companies located in Northeast Ohio and the rest of the state through technology transfer activities.

We recommend that GRC continue to build on its relationships and partnerships with industry and educational institutions located in Ohio. The Center should continue to seek more matches between GRC's needs and Ohio talent. In the same way, GRC should continue to improve its working relations with Ohio companies through more transfer of its research and technology. GRC use of intermediaries has grown over the past several years to benefit both industry and academia; we recommend that the Center continue to work with intermediary organizations and leverage its revenues with other partners and stakeholders. Examples of such new partnerships are the GLENNAN Initiative, the Garrett Morgan Initiative, and the LIFT Incubator. Older partners include the Ohio Areospace

Institute (OAI), the Great Lakes Industrial Technology Center (GLITeC), the Aerospace Council, the Ohio Department of Development, and Wright Patterson Air Force Base.

Given the fact that revenues and workforce have been reduced, we believe that GRC should continue to build on its relationships with the Center's partners and stakeholders to increase its impact on Ohio's economy and quality of life. Despite recent reductions in revenue and workforce, the Center is doing a more effective job of leveraging its resources with other organizations and industry. GRC's projections of increased revenues suggest the opportunity for the Center to strategically increase its economic impact on the region and the State of Ohio.

APPENDIX 1: GRC SPENDING

TABLE A-1. GRC SPENDING ON GRANTS AND CONTRACTS BY STATES, FY 1998

STATE	CONTRACT	GRANT	TOTAL
ALABAMA	734,080	4,719,715	5,453,795
ALASKA	317,710	0	317,710
ARIZONA	2,948,201	613,352	3,561,553
ARKANSAS	0	0	0
CALIFORNIA	116,988,968	5,053,784	122,042,752
CANAL ZONE	0	0	0
COLORADO	51,346,119	1,287,095	52,633,214
CONNECTICUT	18,071,023	1,066,106	19,137,129
DELAWARE	489,369	170,215	659,584
FLORIDA	4,850,877	1,166,682	6,017,559
FOREIGN	412,897	1,847,268	2,260,165
GEORGIA	790,831	1,869,804	2,660,635
HAWAII	0	26,593	26,593
IDAHO	186,851	0	186,851
ILLINOIS	1,499,328	2,550,944	4,050,272
INDIANA	3,785,848	1,244,702	5,030,550
IOWA	0	150,611	150,611
KANSAS	97,552	444,319	541,871
KENTUCKY	27,456	134,871	162,327
LOUISIANA	0	712,208	712,208
MAINE	67,743	0	67,743
MARYLAND	20,143,660	1,690,121	21,833,781
MASSACHUSETTS	5,558,153	1,843,713	7,401,866
MICHIGAN	18,292,483	1,440,965	19,733,448
MINNESOTA	320,197	444,806	765,003
MISSISSIPPI	15,701	365,800	381,501
MISSOURI	532,890	474,780	1,007,670
MONTANA	176,946	0	176,946
NEBRASKA	0	30,229	30,229
NEVADA	0	18,340	18,340
NEW HAMPSHIRE	1,672,694	(7,728)	1,664,966
NEW JERSEY	3,456,981	632,314	4,089,295
NEW MEXICO	679,878	234,762	914,640
NEW YORK	2,595,769	2,034,130	4,629,899
NORTH CAROLINA	282,517	565,863	848,380
NORTH DAKOTA	0	129,361	129,361
OHIO	242,705,920	15,052,125	257,758,045
OKLAHOMA	4,434	194,355	198,789
OREGON	645,652	68,947	714,599
PENNSYLVANIA	2,078,127	1,702,003	3,780,130
PUERTO RICO	0	0	0
RHODE ISLAND	32,550	314,135	346,685
SOUTH CAROLINA	38	47,101	47,139

TABLE A-1. GRC SPENDING ON GRANTS AND CONTRACTS BY STATES, FY 1998 (continued)

STATE	CONTRACT	GRANT	TOTAL
SOUTH DAKOTA	0	34,049	34,049
TENNESSEE	565,872	908,617	1,474,489
TEXAS	3,654,286	3,409,477	7,063,763
UTAH	334,120	18,726	352,846
VERMONT	190,894	0	190,894
VIRGINIA	3,235,123	3,691,672	6,926,795
WASHINGTON	2,648,232	962,752	3,610,984
WASHINGTON DC	470,074	1,637,816	2,107,890
WEST VIRGINIA	539,540	104,814	644,354
WISCONSIN	506,157	158,767	664,924
WYOMING	0	0	0
TOTAL	513,953,741	61,261,081	575,214,822