The NASA Lewis Research Center:

An Economic Impact Study

Prepared for
The NASA Lewis Research Center
by
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Economic Development Program

February 12, 1996

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The Urban University Program... a unique network linking the resources of Ohio's urban universities with the communities and students they serve, in a cooperative effort to improve the state's urban regions.

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Acknowledgments

The author of this report wishes to recognize the assistance of those working on this project and this report. Zhongcai Zhang, a Ph.D. student at the Levin College of Urban Affairs and a research assistant in The Urban Center's Economic Development Program, provided invaluable assistance in data analysis and in the production of the report's charts and tables. Olinda Paschal provided administrative assistance throughout the nine-month study and Michelle Borlaug assisted with some of the charts.

The author also wants to acknowledge the contribution of the following individuals from NASA Lewis Research Center who provided data, information, and valuable comments to previous drafts: Olga Gonzalez-Sanabria, John Hairston, Ann Heyward, Frank Montegani, Bill Nyerges, Robert Sefcik, and Merry Sherrod. Special thanks are given to Ron Alexander who spent numerous hours coordinating data gathering and review of previous drafts among several staff members of NASA Lewis.

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I. Executive Summary

Introduction

The NASA Lewis Research Center (LeRC), established in 1941, is one of ten NASA research centers in the country. It is situated on 350 acres of land in Cuyahoga County and occupies more than 140 buildings and over 500 specialized research and test facilities. Most of LeRC's facilities are located in the City of Cleveland; some are located within the boundaries of the cities of Fairview Park and Brookpark. LeRC is a lead center for NASA's research, technology, and development in the areas of aeropropulsion and selected space applications. It is a center of excellence for turbomachinery, microgravity fluid and combustion research, and commercial communication. The base research and technology disciplines which serve both aeronautics and space areas include materials and structures, instrumentation and controls, fluid physics, electronics, and computational fluid dynamics.

This study investigates LeRC's economic impact on Northeast Ohio's economy. It was conducted by The Urban Center's Economic Development Program in Cleveland State University's Levin College of Urban Affairs. The study measures LeRC's direct impact on the local economy in terms of jobs, output, payroll, and taxes, as well as the indirect impact of these economic activities when they "ripple" throughout the economy. To fully explain LeRC's overall impact on the region, its contributions in the areas of technology transfer and education are also examined.

The study uses a highly credible and widely accepted research methodology. First, regional economic multipliers based on input-output models were used to estimate the effect of LeRC spending on the Northeast Ohio economy. Second, the economic models were complemented by interviews with industrial, civic, and university leaders to qualitatively assess LeRC's impact in the areas of technology transfer and education.

Major Findings

LeRC's Direct Economic Impact

- LeRC's total full-time employment at the end of FY 1994 was 4,444. Civil-service employees accounted for 58% of the labor force; the rest were employees hired by on- or near-site contractors. By FY 2000, LeRC's total employment is projected to decline by 34%, to 2,943 employees. Civil-service employment is projected to decline by 21%, while employment by on- or near-site contractors is expected to fall more than 50%. By the end of the decade, civil service employment will account for 70% of LeRC's total employment.

- LeRC's direct payroll and benefits exceeded $170 million in FY 1994. Average compensation per work year was $54,500.

- More than half (56%) of LeRC's civil-service employees are scientists and engineers. Another 13% are technicians.

- Almost all (95%) of LeRC's civil-service employees live in the Cleveland metropolitan area. Employees' place of residence is important because they pay taxes and develop a stake in the well-being of the community. Seventy-two percent live in Cuyahoga County, 13% in Lorain, and 10% in Medina.

- During FY 1994, LeRC spent $667.4 million on purchasing goods and services from contractors. Nearly 40% of that was spent in Ohio and 31% was spent in Northeast Ohio. Thus, LeRC purchased $208.4 million of goods and services from Northeast Ohio companies. The prime beneficiaries were companies providing engineering services and business services, which accounted for two-thirds of LeRC's local contract spending ($138 million). Other industries that benefited significantly from LeRC local spending are construction ($39.4 million), utilities ($16 million), and manufacturing ($9.4 million).

- During FY 1994, LeRC awarded $43.1 million in grants to educational institutions. Slightly less than half of this sum went to Ohio institutions and 37% was received by Northeast Ohio educational institutions. Thus, in FY 1994, LeRC awarded $16.1 million in grants to local schools and universities.

- Almost all of LeRC's revenues are derived from federal sources, with the majority provided by NASA. In FY 1994, LeRC's budget was $1,039 million, a 19% increase over FY 1990. Due to budget cuts facing NASA, LeRC's budget is projected to fall drastically by FY 2000. LeRC's budget is projected to decline by over $500 million, or 48%, to only $537.6 million in FY 2000.

- In FY 1994, the City of Cleveland received almost $2 million in tax revenues from NASA civil-service employees, while the City of Fairview Park collected close to $0.5 million. Ohio received nearly $6 million from LeRC's civil-service employees during FY 1994.

LeRC's Total Economic Impact

- LeRC is a major economic catalyst for Northeast Ohio. Consequently, the region would lose if LeRC were to downsize or close in the future.

- LeRC's economic benefit to the regional economy is attested to by its sizable total output impact of $1 billion, employment impact of 12,800, and household earnings impact of $375 million.

- The projected reduction of LeRC's budget will adversely affect its own employees as well as Northeast Ohio. A smaller LeRC budget would decrease its payroll and spending on goods and services purchased from local companies, weakening its positive effect on the regional economy.

A Local Research and Development Resource

- LeRC is a major research and development producer, comprising a crucial part of Northeast Ohio's science and technology base.

- LeRC improves the quality of local universities' scientific research as a capital provider for research.

- LeRC has helped increase the region's supply of highly technical human resources. It employed an average of 1,500 civil-service scientists and engineers per year over the last decade, and its on- and near-site contractors employ many more highly technical employees.

- LeRC has developed specialized high-technology real estate resources, which are valuable to area universities, companies, and other groups.

- LeRC has stimulated the area's information and telecommunication capabilities by serving as the impetus for the installation of fiber-optic lines.

Technology Transfer

- LeRC improves the competitiveness of some of Northeast Ohio's businesses through technology transfer, providing some local companies with innovative technologies to solve real-world industrial problems.

- Historically, LeRC has transferred technology primarily to aeronautics and aerospace companies, which are mostly located outside Northeast Ohio.

- NASA has recently elevated technology transfer to one of its top priorities, causing LeRC to restructure its organization in order to improve and strengthen its transfer of nonaeronautics technologies to a wider range of industries, such as biomedical and manufacturing companies.

- LeRC's Commercial Technology Office (CTO) was recently established to accomplish technology transfer and commercialization and to improve and strengthen collaboration with industry. CTO is LeRC's main liaison to external organizations involved in economic development and technology transfer and commercialization.

- CTO provides one-stop shopping for LeRC industrial customers.

Contributions to Educational Quality

- LeRC's interaction with area schools and universities improves education for K-12 and college students in math, science, and engineering.

- LeRC helps to build a student "pipeline" to science and engineering careers and helps develop innovative approaches to math and science instruction at both the elementary and high-school levels.

- LeRC's university grants provide faculty and graduate students with funding and access to LeRC's staff and its specialized technical facilities, thus enriching the quality of their research and teaching.

Bolstering Northeast Ohio's Favorable Image

- LeRC provides a boost to Northeast Ohio's economic image (a less quantifiable but important benefit).

- The presence of a national research center is beneficial to the area's strategy of high-technology development. LeRC's presence helps attract research and development companies, as well as scientists and engineers, to the region.

Recommendations

The expected downsizing of LeRC requires the Center to use its personnel and facilities more strategically to preserve its current economic impact on Northeast Ohio. Greater collaboration with the local community and industries will help LeRC, and the area, to adjust to future LeRC budget reductions. The Urban Center offers the following recommendations to help in this adjustment process:

1. If possible, LeRC should expand its purchasing from local companies to partially offset spending cutbacks. Local suppliers should be challenged to help LeRC increase its competitive advantages.

2. The community should develop focused strategies to retain LeRC's laid-off technical personnel in the area. Northeast Ohio cannot afford to lose this valuable human capital.

3. LeRC should form new public-private partnerships to strengthen its competitiveness as a technology resource, while conserving scarce government resources.

    a. LeRC should develop full partnerships with industry and academia for technology development, participating as a full and equal partner (not only as a funder).

    b. LeRC should discuss its plans and initiatives with industry and university representatives, allowing them to collaborate during the planning process.

    c. LeRC should hold more sessions focusing on how industry can access and use LeRC's technological expertise for nonaeronautic applications, like the "Technology Dialogue over Lunch" initiative and the "Commercialization Summit" proposed for Fall 1996.

    d. LeRC should work closely with key community organizations like the Greater Cleveland Growth Association, Cleveland Tomorrow and its Technology Leadership Council, Case Western Reserve University, and Cleveland State University.

The next two recommendations are intended to create a demand for the "excess capacity" that would result from LeRC's downsizing:

4. Ask NASA and other federal research laboratories for $100 million to develop and implement new federal-industry partnerships for innovative applications of their technologies to make urban centers, like Cleveland, more technologically advanced and globally competitive.

5. LeRC should examine the feasibility of becoming a contract research center for government and industry clients. Partners could include local universities, hospitals conducting clinical research, and other industries.

I. Statement of Purpose

This report presents the results of a study of the impact of the National Aeronautics and Space Administration's Lewis Research Center (LeRC) on Northeast Ohio's economy. (Northeast Ohio includes the eight counties within the Cleveland and Akron metropolitan areas: Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit.) The study was conducted by The Urban Center at the Levin College of Urban Affairs, Cleveland State University.

Economic impact studies help industry and community leaders understand how an institution affects the economic health of the region. These studies look at the institution's direct impact as well as the benefits that spill over to parties in and around it. Other economic impact studies in the Cleveland area include those of the Playhouse Square Development Project (1987), the Rock and Roll Hall of Fame (1989), the Cleveland Arts Consortium (1991), Cleveland State University (1992), the International Exposition Center (1994), and the Cleveland Clinic Foundation (1995).

The study's purpose is twofold:

1. Provide an independent assessment of LeRC's contribution to the Northeast Ohio economy.

2. Provide LeRC leadership with strategic information to improve its future community outreach strategy.

The study employs two methods to determine LeRC's influence on the local community. The first method uses economic multipliers to estimate the effect of LeRC spending on the Northeast Ohio economy. These standard quantitative measures analyze three levels of economic impact: the effect on the region's total output; the effect on household earnings in the region; and the effect on the number of new jobs created.

The second method uses interviews to make a qualitative assessment of LeRC's impact. Interviews with leaders of the industrial, civic, and university sectors focused on how LeRC affects education and technology transfer, which are significant factors in the region's economic development.

II. NASA Lewis Research Center: Background

The Lewis Research Center is one of ten National Aeronautics and Space Administration (NASA) research and development centers. NASA is undergoing major changes caused by large budget cuts and the downsizing of agency personnel and facilities. Following annual budget increases of 14% from FY 1988 through FY 1992, NASA's administrator, Daniel Goldin, presented his plan in May 1995 to trim the budget by $4.9 billion by the end of the decade. This means that NASA may begin the twenty-first century with a budget just over $13 billion -- $1 billion less than its 1991 budget. The new House budget proposes further cuts to $11.5 billion by the year 2002.

The restructuring of NASA will redefine the roles and mission for each center. It will also streamline the Agency's processes, improve its efficiency, and reduce costs. NASA initiated an internal review, known as the "Zero-Base Review," to streamline its centers and allow each to concentrate on specific aspects of NASA's mission. The proposed changes are intended to reduce overlap, consolidate administrative and research programs, and focus agency resources in five strategic enterprises:

- Mission to Planet Earth Enterprise is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment.
- Aeronautics Enterprise pioneers high-payoff, critical technologies with effective transfer of research and technology products to industry, Department of Defense, and Federal Aviation Administration for application to safe, superior, and environmentally-friendly U.S. civil and military aircraft, and for a safe and efficient National Aviation System.
- Human Exploration and Development of Space Enterprise opens the space frontier by exploring, using, and enabling the development of space.
- Space Science Enterprise contributes to the creation of new scientific knowledge by exploring the solar system and the universe beyond.

- Space Technology Enterprise pioneers, with industry, the development and use of space technology to secure national economic competitiveness, promise industrial growth, and to support space missions.

The Lewis Research Center was established in Cleveland in 1941 by the National Advisory Committee for Aeronautics (NACA) as one of three national research centers. During the next fifteen years, the center developed an international reputation for jet propulsion systems research. In 1958 the NACA centers became the nucleus of a new agency, NASA. The book *Engines and Innovations: Lewis Laboratory and American Propulsion Technology,* by Virginia P. Dawson, provides an insightful account of LeRC activities over the last three decades.

LeRC is situated on 350 acres of land and occupies more than 140 buildings, and over 500 specialized research and test facilities. Lewis is the lead Center for Aeropropulsion and selected space applications. It has been designated as the Center of Excellence for turbomachinery, microgravity fluid and combustion research, and commercial communications. Lewis performs research and technology development in support of aeronautical propulsion, space power, on-board propulsion, and space communication. The aeropropulsion work supports the Aeronautics Enterprise and the microgravity work supports the Human Exploration and Development of Space Enterprise.

The commercial communications, space power, and on-board propulsion work supports all Space Enterprises (Mission to Planet Earth, Human Exploration and Development of Space, and Space Technology.) The space technology is synergistic with the research performed for the Aeronautics Enterprise; the base research and technology disciplines which serve both aeronautics and space areas include materials and structures, instrumentation and controls, fluid physics, electronics, and computational fluid dynamics. LeRC also provides expendable launch services for assigned U.S. space missions supporting the Space Science and Mission to Planet Earth Enterprises. However, this work is scheduled for transition to the Kennedy Space Center after 1998.

Plum Brook, a LeRC field station, is located about 50 miles west of Lewis on 6,400 acres of land. It contains four large and unique aerospace test facilities which are available on a fully cost

reimbursable basis (where users pay all costs) to support major national and international aerospace test programs. One of these facilities, 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 environment similar to that encountered in space including the simulation of vacuum conditions of space up to an altitude of 145 statute miles, very cold and very hot temperatures, and the actual sunlight experienced in space. Another world class test facility is the Spacecraft Propulsion Research Facility where large upper stage rocket vehicles can undergo complete integrated system testing, including engine firing, in a simulated space environment. The third facility, the Cryogenic Propellant Tank, is used to develop the technology for storing and transferring liquid hydrogen in space. To ensure maximum safety, control and data collection operations are located in a separate, remote building. The Hypersonic Tunnel Facility, the fourth major test facility in Plum Brook, is the nation's only non-vitiated, clean air wind tunnel , producing high mass flow rates of high-temperature uncontaminated air, capable of performing large-scale tests in the Mach 5 through 7 range.

LeRC's primary research facilities can be categorized into aeropropulsion, space, and technical support facilities, all providing access to academic, industry, and government researchers for the conduct of experiments. The major aeropropulsion facilities include the wind tunnels (ranging from 1- by- 1 foot to 9- by- 15 foot wind tunnels), the Icing Research Tunnel, the Engine Research Building, and laboratories for propulsion systems and engine components. For example, the 10- by- 10 foot Supersonic Wind Tunnel is designed for testing supersonic propulsion components like inlets and nozzles and the Icing Research Tunnel, the world's largest refrigerated icing tunnel, has been ensuring flight safety in icing conditions since its construction in 1944.

The major space facilities include space experiments and microgravity facilities such as the Zero Gravity facility and drop towers, space propulsion and space power facilities like the Electric Propulsion Laboratory and the Power Systems Facility, and the Plum Brook facilities described previously. LeRC's technical support facilities include central services such as the Research Analysis Center which houses the analytical support for the Center.

LeRC's roles in major NASA programs include, but are not limited to, conducting research for the High Speed Research, Advanced Subsonic Technology, High Performance Computation and Communications, and National Propulsion Simulator Programs in Aeronautics. In the Space arena, current programs include research and development in Microgravity Science, the Advanced Communication Technology Satellite, and power system projects such as Solar Dynamics in support of the International Space Station Program.

Lewis is also involved in many research and development programs vital to the technological and economic development of some of the country's basic industries. Examples of such programs include:

- The High Temperature Engine Materials Technology Program (HITEMP) develops advanced materials and structures technology leading to increased fuel economy, improved reliability, extended life, and reduced operating costs for 21st century civil aviation systems.

- The Enabling Propulsion Materials Program (EPM) develops the engine materials necessary to support High Speed Research Propulsion effort, which will have the greatest impact on the economic and environmental challenges which must be met to achieve a successful Civil Transport System. A key and unique feature of this program is the teaming of General Electric and Pratt & Whitney, two competitors, as joint contractors on this program.

- Solar Dynamic Ground Test Demonstration. LeRC successfully completed a solar dynamic simulator, which is being used to evaluate the potential space station growth, communications and earth-observing satellites, and electric spacecraft propulsion.

- Partnership for a New Generation of Vehicles. Under a Space Act Agreement, LeRC is teamed with the "Big 3" automobile companies as NASA's lead Center in the Low Emission Partnership. LeRC's tasks include developing and validating critical sensor technologies. LeRC is also the program manager for other tasks being carried out at Ames Research Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory.

NASA stands at a critical point in its history as an agency, with diminishing financial and personnel resources. NASA's final budget and its allocation among the research centers, as well as strategic decisions regarding privatization of some agency activities, will determine the future role of each agency center, including LeRC.

III. LeRC Direct Impact: Recent Trends and Projections

The Lewis Research Center is a large economic entity. This section describes its employment, payroll budget, contract and grant spending, taxes, and revenues.[1]

1. Labor Force

LeRC's labor force includes civil-servant employees as well as on-site and near-site contractors. This dual approach is common among federal laboratories where only some of the employees are government workers. Contract workers give LeRC flexibility in the size of its workforce, as their services are determined by the center's needs; hiring civil servants is more complex and more permanent. The sections that follow analyze the LeRC labor force in terms of number of employees, payroll, occupational distribution, and employees' place of residence.

A. Employment

Total full-time equivalent employment at LeRC was 4,444 at the end of FY 1994. Other Northeast Ohio employers with similarly sized labor forces (4,000-5,000 employees) include Centerior Energy Corporation, Finast Supermarkets, University of Akron, General Motors (Parma plant), and Case Western Reserve University. According to the *Greater Cleveland Largest Employers Directory, 1995*, published by the Greater Cleveland Growth Association, LeRC ranks 22nd among the area's largest employers.

The Center's FY 1994 end-of-year labor force included 2,589 civil servants and 1,855 contractors' employees who work for about 27 on-site or near-site contractors (Table 1). Total full-time-

[1]Plum Brook Station, which is considered part of the Lewis Research Center, is located in Erie County, outside the eight-county Northeast Ohio area considered for this study. However, more than 90% of the spending relative to Plum Brook support and operation is with companies located in Northeast Ohio and is thus reflected in LeRC's five-year spending in Northeast Ohio. The number of LeRC civil servants employed directly at Plum Brook was negligible (eight) for the purposes of this study. Plum Brook contractors are employed by on-site/near-site contractors and Northeast Ohio companies.

equivalent employment fell by 5% between FY 1990 and FY 1994, a combination of a 10.5 % decline in civil-servant employment and a 4% increase in employment of on-site and near-site contractors. As a result, the share of civil-servant employees declined from 62% of total employment in FY 1990 to 58% in FY 1994.

Table 1. LeRC End-of-Year Employment, FY 1990-2000			
Year	**Total Employment**	**Civil-Servant Employment**	**On-site/near-site Contractors**
Actual:			
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
Projections:			
1995	4,544	2,479	2,065
1996	4,176	2,385	1,791
1997	3,871	2,330	1,541
1998	3,409	2,194	1,215
1999	3,067	2,038	1,029
2000	2,943	2,038	905

Until the end of the decade, total employment is projected to decline by 34%, with on-site/near-site contractors absorbing the lion's share of job losses. Civil-servant employment is projected to decline by 21%, while employment by on-site/near-site contractors is expected to fall more than 50% between FY 1994 and FY 2000. These projections take into account the severe budget cuts at NASA and the buy-outs offered to civil-servant employees at LeRC. Because of the dramatic pressures on many federal agencies to operate more efficiently with lower budgets, NASA projects that by the end of this decade, LeRC will be a much smaller federal laboratory, with a significantly lower

budget and fewer employees. Obviously, these changes will reduce LeRC's economic impact on the surrounding regional economy.

B. Payroll

Total wages and payroll for civil-servant employees came to $144.5 million in FY 1994, and employee benefits accounted for another $28.6 million.[2] LeRC employs highly skilled workers, including many scientists and engineers, which explains its relatively high average payroll. The average salary per civil-servant work year at LeRC was $54,500 in FY 1994, a 24% increase over the $44,100 in FY 1990. This compares with average 1994 earnings of $35,700 for workers in durable goods manufacturing industries. (If all benefits are included, the average compensation of a civil-servant work year at LeRC was $65,300 in FY 1994; when benefits paid to retirees in FY 1994 are excluded, the average compensation of a civil-servant work year at LeRC drops to $63,150.)

C. Occupations

Civil-servant employees at LeRC fall into five occupational groups: administrative professional (management), clerical, scientists and engineers, technician, and trades. Trends in occupational distributions for the past ten years (FY 1985-FY 1994 end-of-year information) and the projections through the end of the decade are presented in Table 2. While administrative professional and technician positions increased during the past ten years, clerical and trade positions declined among civil servants. Clerical and trade jobs also declined as a share of LeRC employment; however, some of the clerical and maintenance jobs were filled by on-site contractors (Table 3).

Between FY 1994 and FY 2000, civil-servant employment at LeRC is expected to decline by 551 employees, or 21.3%. Almost half of these losses will be among scientists and engineers, the largest category of employees, resulting in a projected decline of 18.5%. These job losses will have a

[2]Of the $28.6 million paid as benefits in FY 1994, $5.6 million are for retiree benefits and other costs which are not attributable to current employees.

significant effect on the Northeast Ohio economy, because LeRC is one of the region's main employers of scientists and engineers, especially in aeronautics and hard sciences.

Table 2. LeRC Civil-Servant End-of-Year Employment, FY 1985-2000

Year	Total	Major Occupational Categories				
		Administrative Professional	Clerical	Scientists & Engineers	Technician	Trades
Actual:						
1985	2,827	253	331	1,343	244	656
1986	2,697	263	297	1,287	235	615
1987	2,777	261	295	1,381	254	586
1988	2,774	266	295	1,411	258	544
1989	2,920	281	298	1,528	274	539
1990	2,894	296	287	1,525	339	447
1991	3,021	321	282	1,642	373	403
1992	2,947	325	263	1,623	373	363
1993	2,851	334	243	1,586	374	314
1994	2,589	309	216	1,437	339	288
Projections:						
1995	2,479	291	200	1,397	309	282
1996	2,385	252	193	1,370	299	271
1997	2,330	245	189	1,339	291	266
1998	2,194	231	178	1,261	274	250
1999	2,038	215	165	1,171	255	232
2000	2,038	215	165	1,171	255	232

One-tenth of LeRC civil servants have a doctoral degree; 21% have a master's; and an additional 35% have a bachelor's degree. Consequently, downsizing LeRC may cause a "brain drain" from Northeast Ohio. The projected employment declines will change the distribution of jobs at LeRC

to reflect NASA's new strategic thinking, which calls for retaining scientists and engineers while cutting overhead costs and streamlining organizational structure. The decline in total civil-servant employment at LeRC will be accompanied by a declining share of administrative professional positions and an increased share of science and engineering occupations as percentages of total LeRC employment.

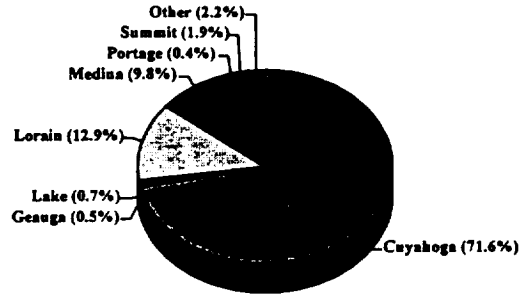
Table 3. LeRC Civil-Servant End-of-Year Employment, FY 1985-2000 (Percents)

Year	Total	Major Occupational Categories				
		Administrative Professional	Clerical	Scientists & Engineers	Technician	Trades
Actual:						
1985	2,827	8.95%	11.71%	47.51%	8.63%	23.20%
1986	2,697	9.75%	11.01%	47.72%	8.71%	22.80%
1987	2,777	9.40%	10.62%	49.73%	9.15%	21.10%
1988	2,774	9.59%	10.63%	50.87%	9.30%	19.61%
1989	2,920	9.62%	10.21%	52.33%	9.38%	18.46%
1990	2,894	10.23%	9.92%	52.70%	11.71%	15.45%
1991	3,021	10.63%	9.33%	54.35%	12.35%	13.34%
1992	2,947	11.03%	8.92%	55.07%	12.66%	12.32%
1993	2,851	11.72%	8.52%	55.63%	13.12%	11.01%
1994	2,589	11.94%	8.34%	55.50%	13.09%	11.12%
Projections:						
1995	2,479	11.74%	8.07%	56.35%	12.48%	11.36%
1996	2,385	10.57%	8.09%	57.44%	12.54%	11.36%
1997	2,330	10.52%	8.11%	57.47%	12.49%	11.42%
1998	2,194	10.53%	8.11%	57.47%	12.49%	11.39%
1999	2,038	10.55%	8.10%	57.46%	12.51%	11.38%
2000	2,038	10.55%	8.10%	57.46%	12.51%	11.38%

D. Where LeRC Employees Live

Most LeRC civil-servant employees reside in Northeast Ohio, 95% in the Cleveland metropolitan area; seven out of ten employees live in Cuyahoga County (Figure 1). LeRC employees are more concentrated in Cuyahoga County than the general population of Northeast Ohio, only 49% of whom live in Cuyahoga County.

Figure1. LeRC Civil-Servant Employment
(By County of Residence)



Over half of the Center's employees reside in ten cities. In order of number of employees, these are North Olmsted, Cleveland, Strongsville, Westlake, Parma, Fairview Park, Berea, Lakewood, Brunswick, and Medina. The first eight are in Cuyahoga County, and the last two are in Medina County. These ten cities combined account for 53% of LeRC's scientists and engineers; almost 12% of all science and engineering employees live in North Olmsted and another 10% live in Strongsville. These employees' place of residence is significant because they pay taxes in their communities and develop a stake in their well-being. Sweeping layoffs of LeRC employees who are concentrated in certain communities can hurt these places.

2. LeRC Spending on Contractors/Suppliers

During FY 1994, LeRC spent a total of $667.4 million on contractors, of which almost 40% was spent in Ohio (Figure 2). In Northeast Ohio, LeRC spent on contractors a total of $208.4 million.

The economic sector in Northeast Ohio where LeRC's contractor spending is highest is engineering and business services, which 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 supports. Payments to engineering and business-service contractors accounted for two-thirds of all contractors' spending (Figure 3).

Figure 2. LeRC Spending on Contractors
(FY 1994)

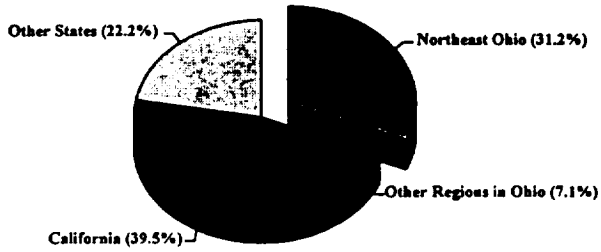
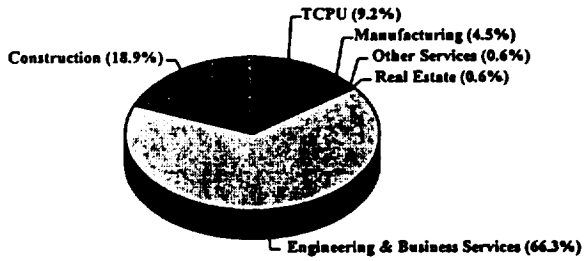


Figure 3. LeRC Spending, FY 1994
(Northeast Ohio Industries)



Northeast Ohio companies providing engineering and business services to LeRC received $138

million during FY 1994. As Table 4 shows, other industries which benefit significantly from LeRC spending are construction - new and maintenance and repair ($39.4 million), utilities ($16 million), and manufacturing industries ($9.4 million).

Table 4. LeRC Spending in Northeast Ohio by Major Supplier Industry, FY 1990-1994, *(in thousands of dollars)*

Industry	1994	1993	1992	1991	1990
Total	208,446	218,255	218,662	203,463	178,867
Construction: New and Repair	39,442	50,310	57,148	46,407	47,475
Manufacturing	9,381	10,312	6,212	7,583	11,157
Transportation	1,781	2,813	2,655	2,093	2,248
Communication	1,280	178	1,049	1,698	1,484
Utilities	16,042	14,524	16,214	14,447	10,945
Real Estate	1,174	1,187	1,044	709	107
Engineering and Business Services	138,172	137,848	133,225	129,421	104,360
Health Services	1,174	1,084	1,117	1,066	1,092
Other Services	1	0	0	38	0

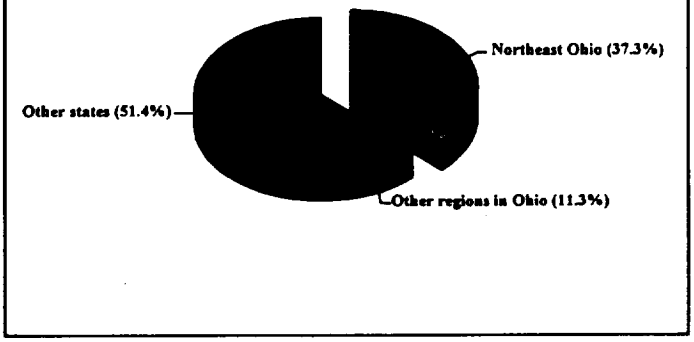
LeRC's purchases of goods and services in Northeast Ohio are especially critical for small businesses. In FY 1994, small businesses accounted for 60% of LeRC's spending in Northeast Ohio. Moreover, 72% of the small business spending went to disadvantaged contractors, defined as minority-owned businesses. During previous years (FY 1990 - FY 1993), about 43% of LeRC's contract spending in Northeast Ohio went to small businesses supplying goods and services to LeRC and about half of that spending went to disadvantaged businesses.

3. LeRC Grants Awarded

LeRC supports research and other educational activities in schools, colleges, and universities, mostly through grants to the educational organizations. During FY 1994, LeRC awarded $43.1

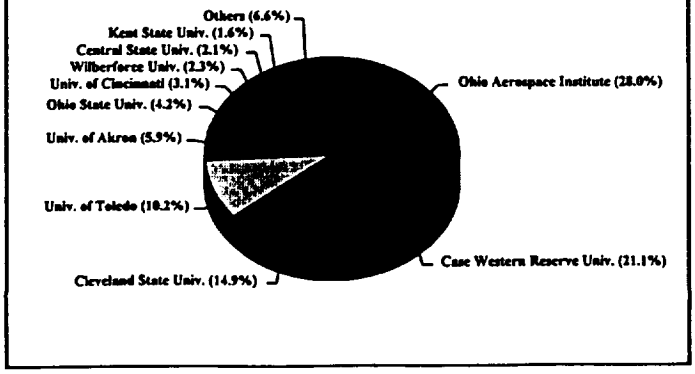
million in grants, of which slightly less than half went to Ohio institutions (Figure 4). LeRC awarded $16.1 million to educational institutions in Northeast Ohio, accounting for 37% of all grants awarded in the United States and for 77% of Ohio's awards (Table 5).

Figure 4. LeRC Spending on Grants
(FY 1994)



The five Ohio universities that received the most grant money in FY 1994 include Case Western Reserve University ($4.4 million), Cleveland State University ($3.1 million), University of Toledo ($2.1 million), University of Akron ($1.2 million), and Ohio State University ($0.9 million). Northeast Ohio universities played a major role in conducting research funded by LeRC. Case Western Reserve University received over one-fifth of all LeRC's grant funding in Ohio (Figure 5),

Figure 5. LeRC Grants for Ohio
(FY 1994)



mainly for research on microgravity, materials structure, mechanical engineering/structural strengths, and applied mathematical modeling. Cleveland State University's College of Engineering is heavily dependent on NASA funding. It receives 15% of LeRC university grants in Ohio to fund projects on materials, fluid mechanics, and electrical engineering and control.

Total grants to educational institutions in Northeast Ohio rose by $4.6 million between FY 1990 and FY 1994 (Table 5).

Table 5. LeRC Educational Grants in Ohio, FY 1990-1994
(in thousands of dollars)

University & School	1994		1993	1992	1991	1990
	Grant	%				
Ohio	20,945	100.0%	19,975	18,914	14,773	14,496
Northeast Ohio	16,085	76.8%	15,239	15,797	11,524	11,477
Ohio Aerospace Institute	5,864	28.0%	5,207	4,670	1,735	573
Case Western Reserve University	4,426	21.1%	4,426	4,433	4,580	6,514
Cleveland State University	3,118	14.9%	3,178	4,296	3,051	2,511
University of Akron	1,236	5.9%	1,295	1,379	1,046	755
Kent State University	344	1.6%	243	217	375	289
Cuyahoga Community College	178	0.9%	142	153	240	528
John Carroll University	176	0.8%	243	231	249	160
Lorain County Community College	11	0.1%	21	21	29	22
Lorain County Vocational Service	82	0.4%	0	0	0	0
Other Universities, Northeast Ohio	590	2.8%	459	396	196	125
High Schools in Northeast Ohio	61	0.3%	25	2	24	0
Universities in Other Ohio Regions	4,859	23.2%	4,736	3,117	3,249	3,019

The major new recipient was the Ohio Aerospace Institute (OAI), which received a tenfold funding increase during this period. Under the leadership of LeRC's director, OAI was established in 1990

to facilitate collaboration on research between Ohio's federal labs, universities, and industry. OAI, a private, nonprofit corporation, is a consortium of nine Ohio universities, LeRC, Wright-Patterson Air Force Base, and technology-driven companies. This consortium is dedicated to research, education, and the application of high technology. OAI's total budget increased from $1.3 million in FY 1990 to $12 million in FY 1995. It channels some of its funding back to Ohio's universities for research and student training. The individual grants reported in Figure 5 and Table 5 include only direct grants from LeRC to the university.

Elementary and high schools receive small grants from LeRC (totaling $61,000 in FY 1994). The main beneficiary is East Tech High School in the City of Cleveland. The grants promote collaborative efforts to empower educators, students, and parents and to improve math and science teaching.[3]

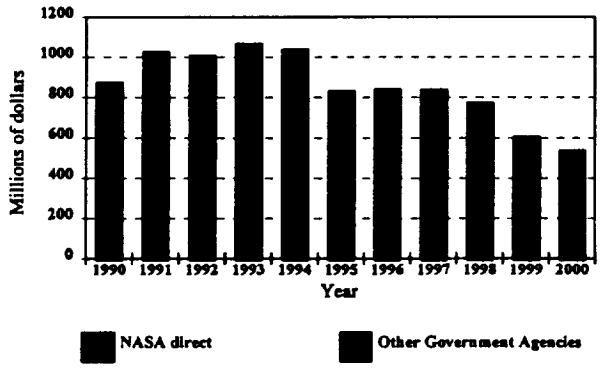
4. LeRC Revenues

Virtually all of LeRC's revenues (sources of income) are derived from federal sources. The majority of LeRC's revenues are provided by NASA; the rest of the revenues (about 5%-13% of the total) are paid by other government agencies and industry for services rendered.

The three primary government agencies that pay for LeRC services are the National Oceanic and Atmospheric Administration, the Department of Defense, and the Department of Energy. Over the period FY 1990 - FY 1994, LeRC's total budget grew by $166.2 million, or 19%, to $1,039.1 million (Figure 6). However, because of budget cuts facing NASA, LeRC's budget is projected to fall drastically, declining by over $500 million, or 48%, to only $537.6 million in FY 2000.

[3] More on the effects of LeRC grants to educational institutions will be found in Section V, "LeRC's Total Impact on the Greater Cleveland community".

Figure 6. LeRC Revenue Sources
(FY 1990-2000)



5. Taxes Paid by LeRC's Employees

The taxes that LeRC 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 a function of the number of civil-servant employees at LeRC as well as their location within LeRC, and are based on their wages and salaries (Table 6). Most of LeRC's employees work at sites located in the City of Cleveland; other LeRC facilities fall within the boundaries of the cities of Fairview Park and Brook Park. Data on Brook Park could not be quantified because taxes are paid through the Regional Income Tax Agency (RITA).

Table 6. Taxes Paid by LeRC Employees, FY 1990 - FY 1994 (in dollars)

Year	City of Cleveland	City of Fairview Park	State of Ohio
5-Year Total	8,923,669	1,080,934	25,996,553
1990	1,617,977	0	4,411,155
1991	1,718,059	0	4,871,469
1992	1,789,942	111,754	5,245,219
1993	1,847,172	503,550	5,522,781
1994	1,950,519	465,630	5,945,929

Over the past five years (FY 1990 - FY 1994), the City of Cleveland received $8.9 million from LeRC employees, while the City of Fairview Park received over $1 million. During FY 1994, the City of Cleveland collected almost $2 million. These taxes are one part of LeRC's direct impact on Northeast Ohio. While the projected downsizing of the LeRC labor force will adversely affect the people employed at the Center, it will also lower the payroll taxes they pay to the cities of Cleveland and Fairview Park.

IV. LeRC Total Impact on the Northeast Ohio Economy

Economic impact studies measure both direct and indirect effects on the economy. The direct impact refers to an institution's spending on goods and services, its sources of income, employment, and taxes. The indirect impact is the effect of the institution's spending and employment on other sectors of the economy. The total economic impact (as used in this section's title) represents in quantitative terms LeRC's combined effects on the region's total output, on total earnings by the region's households, and on total employment in the area. The other parts of this section include two major topics we chose to focus on to describe qualitatively additional contributions by Lewis to Northeast Ohio.[4] The two areas, Technology Transfer and Education, are not fully captured by the economic impact numbers.

1. Economic Impact

A. Methodology

Systematic analysis of economic impacts must take into account interindustry relationships within a region, because these relationships largely determine how a regional economy responds to changes in economic activity. These interindustry relationships are estimated by input-output (I-O) tables, which measure the industrial distributions of inputs purchased and outputs sold by each industry. Thus, it is possible to calculate how the impact of one dollar or one job "ripples" through the local economy, creating additional expenditures and jobs.[5] The economic multiplier measures the ripple effect that an initial expenditure has on the community. Figure 7 describes the process by which LeRC affects the regional economy through its spending in Northeast Ohio.

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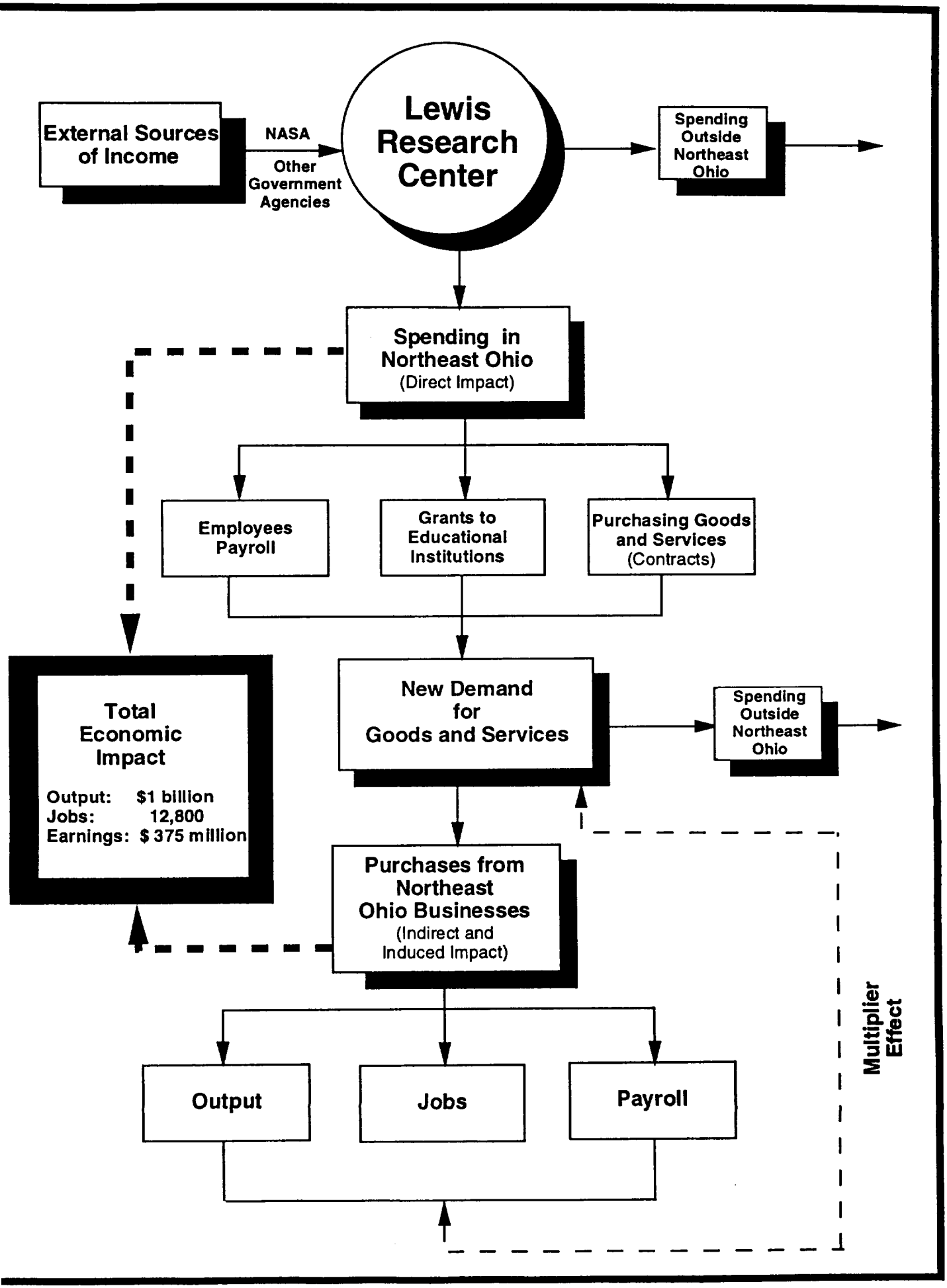
[4]Although examinations of LERC's contribution to technology transfer and education in Northeast Ohio are qualitative in nature, some impact is supported by hard data.

[5]For example, suppose that Company ABC sells $1 million of goods. From the receipts of $1 million, the company takes a profit, pays its suppliers, pays its labor force, and covers other production costs. Once the suppliers and employees receive their payments, they will spend a portion of the money in the local economy for needed goods and services, with another portion of funds going 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 7. Lewis Research Center Economic Impact



This study utilizes regional I-O multipliers from the Regional Industrial Multiplier System (RIMS II) model developed by the U.S. Department of Commerce's Bureau of Economic Analysis. RIMS II provides regional industry multipliers that can be used to estimate the impacts of expenditures by industry on regional output, earnings, and employment. This study uses RIMS II final demand multipliers to estimate LeRC's economic impact on Northeast Ohio based on its pattern of spending in the eight-county area.[6] RIMS II is widely used in both the public and private sectors.

B. Output (Spending) Impact

The final demand multipliers for output measure the effect of LeRC spending on gross receipts or sales in the region. LeRC spending is first divided into spending on goods and services purchased from companies located in Northeast Ohio and spending for goods and services from businesses located elsewhere. Total local spending is then split into major 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 LeRC local spending in each industry (the direct impact) by its corresponding multiplier. For example, as indicated in Table 7, the output impact of LeRC spending on utilities (Electric, Gas, Water, and Sanitary Services) in FY 1994 is $26.9 million ($16 million x 1.6739). The total output impact for each industry is composed of direct impact (LeRC spending on this industry), indirect impact, and induced impact (Table 7 and Figure 8).

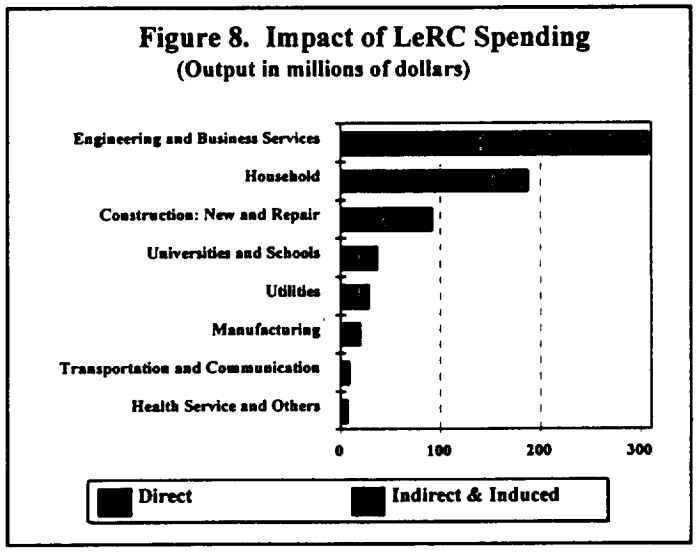
[6]Final demand multipliers reflect three types of impact: direct impact, which represents the initial value of goods and services purchased by LeRC; indirect impact, which represents the value of goods and services purchased by local companies to provide goods and services demanded by LeRC; and induced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

Table 7. Output Impact of LeRC Spending, FY 1994			
Industry	**Spending***	**Multiplier**	**Impact**
Total	**372,167,117**		
Engineering and Business Services	138,171,701	2.2021	304,267,903
Household	149,143,150	1.2397	184,892,763
Construction: New and Repair	39,441,685	2.2412	88,396,704
Colleges, Universities, and Schools	16,086,650	2.2476	36,156,355
Electric, Gas, Water, and Sanitary Services	16,042,332	1.6739	26,853,260
Fabricated Metal Products	4,569,296	2.3142	10,574,265
Miscellaneous Manufacturing Industries	2,900,281	2.0019	5,806,073
Transportation	1,780,576	2.1771	3,876,492
Health Services	1,173,914	2.1677	2,544,693
Communication	1,280,016	1.7831	2,282,397
Real Estate	1,174,410	1.3352	1,568,072
Wholesale Trade**	121,065	1.9155	231,900
Electric and Electronic Equipment	97,793	2.0384	199,341
Machinery, except Electrical	89,817	2.1913	196,816
Instruments and Related Products	93,439	1.9284	180,188
Miscellaneous Services	992	2.2254	2,208
Subtotal (Indirect and Induced Impact)			$668,029,428
Plus Direct Impact			$372,167,117
Total Impact			**$1,040,196,545**

Notes:
* 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 4 includes all spending on manufacturing in Northeast Ohio with no regard to where they were produced.

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

LeRC spending of $372.2 million in Northeast Ohio increases economic output in the region by a total of $668 million. Including its own spending, LeRC's total output impact in FY 1994 amounted to just over $1 billion.



C. Total Impact on Employment

Business activities at LeRC also have a local impact on jobs, beyond employing 2,589 civil servants by the end of FY 1994. The total job impact by industry is detailed in Table 8, where the RIMS II employment multipliers are based on 1992 dollars. For example, each $1 million spent by LeRC on utilities created 11.7 jobs in the regional economy; thus, LeRC's expenditure of $15.2 million (in 1992 dollars) on utilities created 178 jobs throughout the region.

LeRC total spending created almost 10,200 jobs in the Northeast Ohio economy, in addition to its own 2,589 civil-service employees. Thus, LeRC's total employment impact in FY 1994 amounted to 12,781 jobs.

Table 8. Employment Impact of LeRC Spending, FY 1994			
Industry	**Spending*** *(In 1992 dollars)*	**Multiplier**	**Impact**
Total	**$352,572,535**		
Engineering and Business Services	130,898,955	40.9	5,354
Household	141,287,562	18.4	2,600
Construction: New and Repair	37,365,650	29.7	1,110
Colleges, Universities, and Schools	15,239,920	43.5	663
Electric, Gas, Water, and Sanitary Services	15,197,935	11.7	178
Fabricated Metal Products	4,328,789	22.8	99
Miscellaneous Manufacturing Industries	2,747,623	23.7	65
Transportation	1,686,854	29.8	50
Health Services	1,112,124	34.8	39
Communication	1,212,642	15.7	19
Real Estate	1,112,594	6.8	8
Wholesale Trade**	114,693	24.6	3
Machinery, except Electrical	85,089	23.6	2
Instruments and Related Products	88,521	20.3	2
Electric and Electronic Equipment	92,646	20.3	2
Miscellaneous Services	940	34.9	0
Subtotal (Indirect and Induced Impact)			**10,192**
Plus Direct Impact			**2,589**
Total Impact			**12,781**

Notes:
* 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 4 includes all spending on manufacturing in Northeast Ohio with no regard to where they were produced.

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

D. Total Impact on Earnings

Every new job created by LeRC's demand for Northeast Ohio's goods and services generates new earnings for local households. The earnings multipliers for each industry estimate the total change in earnings that occurs in locally-employed households for each additional dollar of goods and services delivered to LeRC (Table 9). For example, the $16 million LeRC spends on utilities creates an additional $5.2 million in earnings by households employed by Northeast Ohio businesses.

LeRC spending on contracts and grants in FY 1994 generated over $226 million in earnings to Northeast Ohio households (in addition to payroll and benefits for its own civil-service employees). LeRC's total earnings impact in Northeast Ohio amounted to $375.3 million in FY 1994.

E. Summary

LeRC's economic activities in FY 1994 produced the following economic impacts.

Total Output Impact:	$1 billion
Total Employment Impact:	12,781 jobs
Total Earnings Impact:	$375.3 million

Table 9. Earnings Impact of LeRC Spending, FY 1994			
Industry	**Spending***	**Multiplier**	**Impact**
Total	**$372,167,117**		
Engineering and Business Services	138,171,701	0.8652	119,546,156
Household	149,143,150	0.3614	53,900,334
Construction: New and Repair	39,441,685	0.6754	26,638,914
Colleges, Universities, and Schools	16,086,650	0.8223	13,228,052
Electric, Gas, Water, and Sanitary Services	16,042,332	0.326	5,229,800
Fabricated Metal Products	4,569,296	0.6199	2,832,507
Miscellaneous Manufacturing Industries	2,900,281	0.5372	1,558,031
Transportation	1,780,576	0.7204	1,282,727
Health Services	1,173,914	0.8628	1,012,853
Communication	1,280,016	0.4344	556,039
Real Estate	1,174,410	0.1098	128,950
Wholesale Trade**	121,065	0.6224	75,351
Machinery, except Electrical	89,817	0.6517	58,534
Electric and Electronic Equipment	97,793	0.5395	52,759
Instruments and Related Products	93,439	0.5414	50,588
Miscellaneous Services	992	0.6234	618
Subtotal (Indirect and Induced Impact)			**$226,152,214**
Plus Direct Impact			$149,143,150
Total Impact			**$375,295,364**

Notes:
* 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 4 includes all spending on manufacturing in Northeast Ohio with no regard to where they were produced.

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

2. LeRC Technology Transfer

This section discusses the process of technology transfer, including changes in national policy and LeRC's reorganization for technology transfer, the efforts of intermediary institutions set up by NASA and others to strengthen technology transfer, and LeRC's level of effort in technology transfer.

A. The Process of Technology Transfer

A.1. Definition of Technology Transfer

Technology transfer is broadly defined as "the transition of scientific or engineering knowledge from one entity to another for a potentially useful purpose."[7] 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: In "technology push" strategies, technologies are developed before commercial applications are sought for them. In "technology pull" strategies, a technology-oriented problem or a new market opportunity leads a private company or industry to seek a solution.

Most of the interviewees believe that the "technology pull" approach is more effective for businesses. Using this approach, the process of technology transfer includes the following steps:

- Identify technology-based problems and target specific technology areas in which the firm wants to pursue additional market opportunities.
- Learn about the resources available to address technology-based problems and opportunities.
- Organize meetings with representatives of technology sources.
- Develop a plan, in collaboration with the technology source, to transfer specific technologies.
- Negotiate and formalize collaborative agreements and contracts, if needed.
- Work with the technology source to apply the technologies.

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[7]J. Creedon, 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.

- Develop business plans to capitalize on the transferred technologies.
- Implement new processes, improve existing plans, or commercialize new products that result from the transfer.

Several interviewees suggested that LeRC has historically followed the technology-push approach, which has been less helpful to Cleveland area businesses. LeRC is currently adapting itself more to technology pull, both through direct contact with firms and in conjunction with intermediary organizations that have been created to facilitate the pull approach by matching a company's needs with a technology source.

There is a need to differentiate between aerospace and nonaerospace types of technology transfer, since each has its own stakeholders. Aerospace technology transfer occurs when LeRC-developed or codeveloped technology directly benefits the U.S. aerospace industry by improving its competitiveness in global markets.[8] Nonaerospace technology transfer occurs when LeRC-developed or codeveloped technology is applied for a nonaerospace purpose, like a manufacturing process or a medical device.

Historically, LeRC's primary area of technology transfer was aeronautics and aerospace. LeRC staff have always worked closely with aerospace companies on research and development as well as technology transfer. However, many of these companies are located outside Northeast Ohio; consequently, aerospace technology transfer is not especially significant to the local economy. For that reason, the rest of this discussion will focus on nonaerospace technology transfer that can contribute significantly to local companies' ability to compete in global markets.

Nonaerospace technology transfer has the potential to affect many more American lives and a much broader segment of the economy.

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[8]Aerospace industries include producers of aircraft, aircraft engines, spacecraft, and launch vehicles, and their respective supplier chains.

A.2. The National Agenda on Technology Transfer

The environment for technology transfer began to change at NASA in 1993. The National Performance Review by the Office of the Vice President, Al Gore, recommended expanding technology-transfer activities that encourage research and development (R&D) partnerships with industry.[9] Recommended measures include providing technology-transfer training to all NASA Centers' employees, devoting 10% to 20% of NASA's budget to R&D partnerships with industry, giving the Centers more flexibility in funding technology-transfer opportunities, developing metrics to measure the results of technology transfer (and not just the levels of activity), and providing small businesses with opportunities to spur technology transfer, in order to accelerate the creation and enhance the competitiveness of small businesses through national and regional technology-transfer centers.

NASA's administrator, Daniel Goldin, made technology transfer one of the Agency's top priorities. He stated that "while meeting its unique mission goals, NASA R&D must also enhance overall U.S. economic security. To ensure that NASA's technology assets and know-how contribute to U.S. economic growth, it is critical that they are quickly and effectively translated into improved production processes and marketable, innovative products." One of the cornerstones of NASA's commercial technology policy is to give Center directors "the authority, flexibility, and discretion they need to proactively foster technology commercialization at their installations."[10]

NASA plans to develop metrics that will evaluate technology-transfer performance in each of its Centers. "Activity" metrics will measure the effort expended; "effectiveness" metrics will measure the results achieved; and the ratio of the two will measure "productivity." It is difficult to measure the benefits of technology transfer because, in many cases, the benefits accrue several years after

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[9] *NASA National Performance Review*, Accompanying Report of the National Performance Review, Office of the Vice President, Washington, DC, September 1993.

[10] *NASA Commercial Technology: Agenda for Change*, July 1994.

R&D is completed. However, NASA is committed to developing the capability necessary to model the long-term economic impact of its technology transfer.

A.3. Reorganization of Technology Transfer at LeRC

Historically, LeRC had some success stories in technology transfer, but they represented only a fraction of the tremendous potential of its technology know-how. Nonaerospace technology transfer was not a priority for past LeRC leadership and until 1992, the LeRC group in charge of technology transfer (the Technology Utilization Office) was understaffed, underfunded, and somewhat isolated from the technology-producing parts of the organization.

Interviews revealed that NASA's past culture and reward system were not conducive to technology transfer, especially for its scientists and engineers. LeRC used to reward researchers for conducting good research and for interacting with other researchers in universities and at R&D departments of large companies; it did not praise them for using their technologies to assist private industry.

Following national policy changes calling for expanded technology-transfer activities, LeRC leaders decided to change their approach to technology transfer and commercialization, becoming more competitive and aggressive in reaching out to meet the needs of other research organizations and private industry. Over the past year, LeRC leaders have developed a new organization to carry out its technology transfer mission more effectively: The Commercial Technology Office (CTO) is being created, in response to NASA's *Agenda for Change,* to improve LeRC's competitive position in technology transfer. It is placed in the Directorate of External Programs, the primary interface between LeRC and the community.

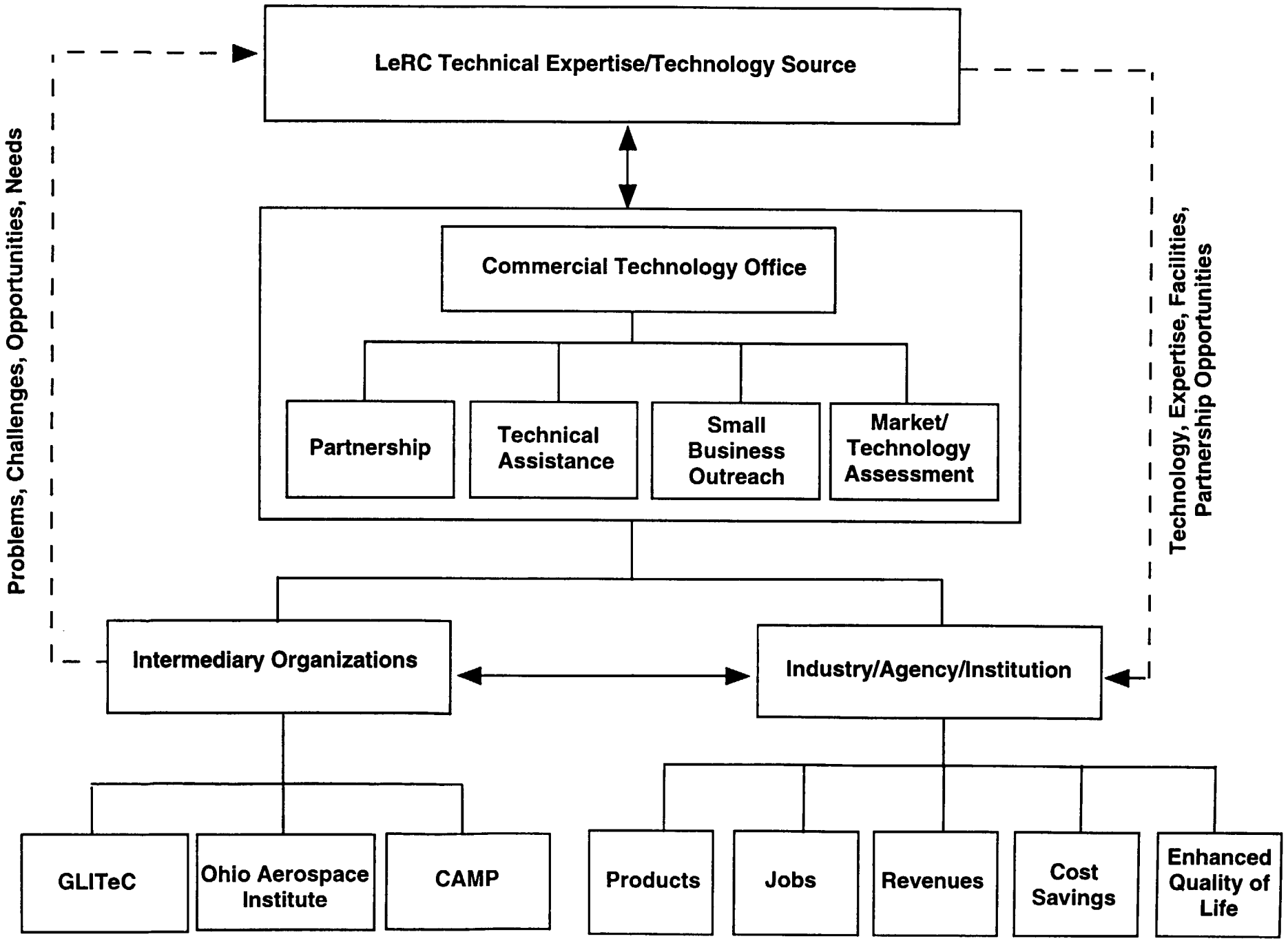
The CTO's purpose is to accomplish technology transfer, technology commercialization, and collaboration with industry and other government agencies. It will be LeRC's main liaison to non-aerospace industries and to external organizations involved in economic development and technology transfer and commercialization. These external organizations include the Ohio Aerospace Institute (OAI), the Great Lakes Industrial Technology Center (GLITeC), the Cleveland

Advanced Manufacturing Program (CAMP), the Edison Centers, the Ohio Department of Development, and additional federal government agencies. To succeed in its mission, the CTO will work to improve relationships and communication among the technology-producing organizations within LeRC, including scientists and engineers whose expertise is required to meet specific technical needs of the private sector.

The CTO is divided into five teams, four primary and one supporting: the marketing and technology evaluation team, the small business outreach team, the technical assistance team, the partnership team, and the project support team. The new office provides one-stop shopping for LeRC industry customers in nonaerospace sectors and also manages the Small Business Innovative Research (SBIR) Program. It also works closely with the Office of the Chief Counsel, which is responsible for managing LeRC's intellectual property, patenting, and licensing. The CTO and its predecessor have recently standardized the language used to draw up Space Act agreements and made it available electronically, thereby reducing the time needed to prepare and approve an agreement from one year to about one month. This improvement significantly increases the number of new Space Act agreements initiated.

Figure 9 describes the process of technology transfer at LeRC, as it is governed by the reorganization. It emphasizes the relationships between the CTO and LeRC's scientists and engineers (who are the technology resource), and the relationships of each CTO team with private industry and research institutions. The CTO will interact with institutions and businesses, either directly or through intermediary organizations that are described later. The CTO is also in the process of forming an external advisory board composed of representatives of local business and industry, regional technology-transfer organizations, economic development organizations, and other regional government agencies. The board will assess LeRC's approaches to technology transfer and advise the CTO on new opportunities for improvement in reaching out to private industry with LeRC's tremendous technological know-how.

Figure 9. Technology Transfer at LeRC



B. Intermediary Organizations

With technology transfer becoming a national priority, NASA and other federal labs have established and funded intermediary organizations throughout the country to expedite the technology-transfer process.

B.1. The Great Lakes Industrial Technology Center

The chief intermediary organization assisting LeRC with technology transfer is the Great Lakes Industrial Technology Center (GLITeC). GLITeC is one of six Regional Technology Transfer Centers (RTTCs) established by NASA to give industry access to federal technology and related capabilities. It serves the Great Lakes region and is managed by the Battelle Memorial Institute. GLITeC maintains an affiliate network that includes the Ohio Aerospace Institute, the Edison Centers, the Council of Great Lakes Governors, and numerous organizations throughout the Great Lakes states. Through the RTTC, companies gain access to technology from NASA and federal, state, and local agencies. Each RTTC's regional focus is enhanced by linkages to individual state initiatives in technical assistance to industry and business. GLITeC services include technical assistance (matching company needs with specific expertise), technology management (providing business with technology planning and evaluations), and technology commercialization (helping companies acquire and adapt federal technology).

The number of companies in Northeast Ohio helped by GLITeC (regardless of the source of technology) are: 83 companies in 1992; 68 in 1993; 77 in 1994; and 39 in the first half of 1995. The companies that had substantial interaction with LeRC through GLITeC assistance numbered eight in 1992; 17 in 1993; 17 in 1994; and ten in the first half of 1995. On the basis of a 10% random sample of GLITeC clients, it is estimated that the average company saved over $14,000 as a result of its interaction with a federal lab.

B.2. The Ohio Aerospace Institute

Another Northeast Ohio organization that serves as an intermediary in technology transfer is the Ohio Aerospace Institute (OAI), a private, nonprofit, university-industry-government consortium

that includes LeRC in Cleveland, Wright-Patterson Air Force Base in Dayton, nine Ohio universities, and technology-driven corporations.[11] 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, university, and government engineers. These groups are established to deliver solutions for industry's needs. Examples include the creation of intelligent manufacturing-workstation processes and the development of fuel-efficient metal matrix composites for the aircraft industry. In most activities sponsored by OAI, both government and industry provide funding to develop technologies for industry's commercial interests.

OAI's technology-transfer activities also include TechNets (Technology Networks), which integrate experts from industry, university, and government to meet key technology challenges. In FY 1994, TechNets held 67 conferences, workshops, short courses, and other meetings, attracting over 1,000 participants. TechNets give OAI members a forum for exploring common research and educational needs. Topics are member-driven and are continually evolving. There are currently 16 TechNets in three general categories: advanced material systems, computer and communication systems, and fluid dynamics and propulsion systems.

B.3. The Cleveland Advanced Manufacturing Program

The Cleveland Advanced Manufacturing Program (CAMP), through its Advanced Manufacturing Center at Cleveland State University, is also an intermediary in technology transfer. LeRC funds a staff position at the Center for a person who is currently working to transfer a specific technology: a membrane to remove metals from liquids. This technology is of potential benefit to local plating companies.

[11]The nine Ohio universities which 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 Cincinnati, The University of Dayton, The University of Toledo, and Wright State University.

C. LeRC's Level of Effort in Technology Transfer

LeRC and NASA as a whole are developing metrics to measure the impact of technology transfer from NASA centers to universities, organizations, and private industry. Without having the benefits of complete metrics at this time to measure the results of LeRC's technology-transfer activities, this section will discuss the number of technical assists to industry, the type of industries affected by LeRC technology transfer (including examples of Northeast Ohio companies assisted by LeRC), and new initiatives designed to improve the technology-transfer process.

C.1. LeRC's Technical Assistance to Industry

During FY 1994-95, LeRC offered *technical assistance* to 1,490 companies in the United States, an 83 percent increase over the previous fiscal year. Two-thirds of these companies are located in Ohio, and one-fifth are located in the eight-county Northeast Ohio area. The number of Northeast Ohio companies assisted by LeRC in FY 1994-95 (290) increased by 75 percent over the previous year. These findings demonstrate the higher priority NASA and LeRC give to technology transfer.

An estimate of the national impact of LeRC's technology transfer over the past five years consists of the following accomplishments:[12]

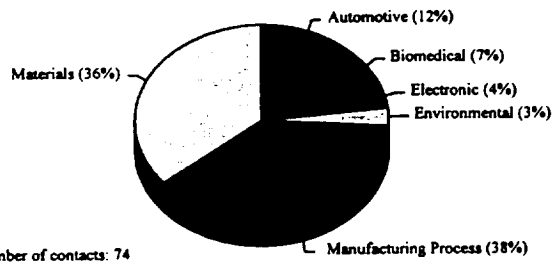
- At least 20 new products were created.
- More than 380 new technologies were reported in the past two years by LeRC contractors and grantees.
- LeRC has the lowest cost-to-technology ratio among all NASA Centers.
- Cost savings to U.S. companies using LeRC technology and expertise are estimated to be at least $200 million.
- Sales for U.S. companies using LeRC technology and expertise are estimated to be at least $30 million.

[12]These estimates were provided by LeRC's staff. Separate figures specific to Ohio or Northeast Ohio are not yet available. LeRC plans to implement a metrics gathering system which would provide this data in the future.

C.2. Examples of LeRC Technology Transfer[13]

LeRC's primary thrusts are aeropropulsion and space technologies. In order to carry out its primary thrusts, LeRC maintains significant capacity in fluid mechanics; surface modification; energy storage systems and thermal transport; materials development and structural design; and electronics, communication, and instrumentation. LeRC offers technology applications, technology transfer, and collaborative research to universities, hospitals, and industry in an array of nonaerospace applications in these fields. Figure 10 describes the distribution of LeRC industrial contacts in the fields described above, by industrial sectors.[14]

Figure 10. LeRC's Industrial Contacts*
Northeast Ohio, FY93 and FY94



* Number of contacts: 74

Source: NASA Lewis Center, the Office of Technology Utilization

Health and medical applications is one field where several cooperative relationships exist between LeRC and Northeast Ohio institutions and companies. Over the past several years, LeRC has collaborated with the biomedical engineering community to produce biologically compatible coatings for implants; structural-modeling computer codes for orthopedic implants; computer-assisted, minimally invasive surgery; acousto-ultrasonic detectors of bone and muscle deterioration;

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[13]The examples in this section are primarily derived from selected letters from Ohio companies that received LeRC's assistance.

[14]"Contacts" represent sustained relationships with companies over a period of time compared with "technical assists" referred to earlier. "Technical Assists" include, in addition to "contacts", referrals to other organizations and one-time quick problem solving that does not require follow up contact. Thus, "industrial contacts" are a subset of "technical assists".

fiber-optic sensors; noninvasive, miniaturized sensors; and improved wheelchair batteries.

In November 1995, NASA Lewis and the Cleveland Clinic Foundation entered into a three-year collaboration on research projects. Researchers from both organizations will engage in mutually beneficial, cooperative research activities to develop products and technologies and solve problems related to such areas as orthopedic and cardiovascular devices, medical imaging, microgravity, and micro-electrical mechanical systems. The agreement will allow the two organizations to share biomedical research data and work together on research grant applications. Individual researchers from LeRC and the Clinic are working on several major projects, including an artificial implantable heart-assist device (using LeRC aeropropulsion research for a heart pump), liquid crystal glasses for more accurate vision testing (using LeRC electronics expertise for vision evaluation), a "smart" wheelchair for developmentally disabled children (using LeRC's expertise in electronics and controls for the "smart" wheelchair), and textured titanium inserts for dental implants (using LeRC expertise in electronics and communication for texturing dental implants).

In addition to the Clinic, LeRC is engaged in collaborative projects in health and medical technologies with other organizations, including University Hospitals, Case Western Reserve University School of Medicine, Ameritech, Metro Health Medical Center, Biomet, and Acromed.

Of the 74 industrial contacts that LeRC initiated during FY 1993 and FY 1994, 38% were for assistance with ***manufacturing processes*** (Figure 10). Various manufacturing companies received help from LeRC scientists in solving technological problems. For example, LTV Steel received LeRC's assistance in measuring velocities and flow patterns in their scale water models of the submerged entry nozzle and mold of a continuous casting machine. The Trauwood Engineering Company, engaged in the design and manufacture of heat-treating equipment for the steel wire and strapping industry, got advice on energy and environmental concerns. The Kirby Company, seeking to improve their products by reducing the noise associated with vacuum cleaner fans, signed a Space Act Agreement with LeRC. Through this agreement, LeRC's Propulsion Systems Branch helped the company understand the performance of vacuum cleaner fans by using software that was

originally developed to simulate the airflow through jet engine fans. LeRC also gave Kirby access to its holography laboratory, where fans are studied with lasers to analyze vibrations that are too subtle to detect by visual inspection. Kirby estimates that cost savings from the software alone were in the range of $10,000 to $50,000.[15]

More than one-third of LeRC's industrial contacts were related to ***materials*** (36%) in FY 1993-FY 1994. Examples include MPTechnologies, Inc., which received assistance in finding a high-temperature barrier material and securing samples for evaluation; Advanced Ceramics Corporation (previously Union Carbide/Praxair Advanced Ceramics) which was interested in LeRC's work on affordable seals, solid lubricants, and high-temperature seals; and Babcock & Wilcox, which has received LeRC's assistance over the past several years in ceramic-composite design technology.

Electronics, another area where LeRC is reaching out to local industry, accounted for 4% of LeRC's industrial contacts. One example is Tenatronics, a Cleveland-based electronics business, which requested LeRC's help in testing and verifying the electrical performance of a cellular antenna they designed and built. The company was bidding on a contract to supply thousands of automotive cellular antennas to a German auto manufacturer. The company lacked the testing facilities to show that their antenna could meet the electrical performance requirements specified by the car maker. The tests that LeRC engineers performed in the microwave systems laboratory indicated that the antenna design was successful. As a result, Tenatronics was awarded the contract to assemble 30,000 antennas in their Cleveland facility, and six jobs were maintained.

Some of LeRC's technology-transfer efforts affect ***quality of life*** for the public at large. Most technology improvements with health and medical applications fall within this category. Another example is LeRC's work with the Cleveland Museum of Art and the Smithsonian Institution which resulted in the development of a safe, effective process for cleaning and restoring damaged works

[15]Additional Northeast Ohio manufacturing companies assisted by LeRC include Nordson Corporation, Parker Aerospace, Picker International, Piping Equipment, Inc., Zircoa, and others.

of art, especially oil paintings. The technique is now being tested for its usefulness in restoring works done with acrylic paints, which are employed by modern artists.

Overall, LeRC has 565 ***cooperative relationships*** with industry, universities, hospitals, and government; over 130 of these are within Ohio. LeRC has cooperative partnerships with 37 Northeast Ohio companies, including TRW, Lubrizol, LTV Steel, Parker Hannifin, the Cleveland Clinic, University Hospitals, and Gencorp.[16] In 1994, LeRC was rated second among NASA Centers in number of cooperative endeavors with external customers.

External awards, such as the "R&D 100", by which *R&D Magazine* recognizes the 100 most significant technology developments of the year, point to the high quality of the technology LeRC produces. Over the history of this award, LeRC has won 63 times, ranking first among NASA centers and fifth among all other research organizations in the world.

C.3. Programs Supporting Technology Transfer

Technology transfer is supported by NASA's ***Small Business Innovation Research Program (SBIR),*** a federal program 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. NASA is one of 11 federal agencies participating through an annual agency-wide solicitation of proposals in the areas of aerospace research and technology.

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[16]Cooperative relationships are a subset of industrial contacts representing more substantial relationships with the company. LeRC's cooperative partners from Northeast Ohio include the following 37 companies and institutions: Acromed, Advanced Ceramics Corporation, Aero Instruments, Ameritech, Baldwin Wallace College, Babcock & Wilcox, B. F. Goodrich, Biomet, Case Western Reserve University, the Cleveland Clinic, The Cleveland Museum of Art, Cleveland State University, Cuyahoga Community College, Dynamic Coatings Inc., Enterprise Development Inc., Flexion Inc., Ford Motor Company, Gencorp, Goodyear Tire & Rubber Company, Kent State University, The Kirby Company, Lorain Community College, LTV Steel, Lubrizol, Metro General Hospital, MPTechnologies Inc., NASA/GLITeC Surface Texturing Consortium, Nordson Corporation, Ohio Aerospace Institute, Parker Hannifin, Piping Equipment Inc., Sterling Manufacturing, TRW, Trauwood Engineering Company, University Hospitals, The University of Akron, and Zircoa Inc.

LeRC currently manages 105 contracts in the country totaling over $31 million; over the past ten years, it awarded 33 SBIR contracts to 19 Ohio companies for a total of $7.3 million. One-fifth of the Ohio awards were to small, disadvantaged companies. The awards to Ohio companies led to commercial products that saved 11 jobs, created 15 new jobs, increased companies' sales by $7.1 million, and resulted in capital investments by these companies totaling $310,000. Since 1983, LeRC has given 13 Northeast Ohio companies 25 awards totaling $5.5 million.[17]

C.4. New Initiatives in Customer-Focused Partnerships and Alliances

In collaboration with intermediary organizations, LeRC has developed two new initiatives to improve and strengthen the process of technology transfer: the Advanced Coatings and Surface Texturing consortium and the Technology Dialogue over Lunch series.

The Advanced Coatings and Surface Texturing consortium was established by LeRC and GLITeC to transfer LeRC's research and technology on space-program materials to private companies. Several methods of advanced coating and surface texturing show promise for commercial applications in many industries and products such as biomedical implants and devices, cutting blades, ophthalmic lenses, abrasion-resistant sunglass lenses, protective head shields, bar-code scanner windows, magnetic recording heads, hard disks for computers, and food packaging. The consortium's objectives are to help companies evaluate and develop the surface treatment or coating most likely to benefit their products and to transfer government-related technology to the private sector. Consortium members pay a fee for a set of deliverables including consultation on the advanced texturing processes and coatings most suited to their needs, the coating and texturing of member-supplied samples to evaluate new approaches and applications, and consultation on member-performed evaluations of samples. The consortium, which has operated since April 1994, now has six members at $10,000 each and another ten members at lower fees.

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[17]Local companies that received SBIR awards from LeRC include Advanced Ceramic Corporation, AI Ware, Inc., B&C Engineering, Deformation Control Technology, Inc., Essential Research, Inc., Expert Systems Applications, Inc., NASTEC, Inc., Research 2000, Inc., Rhenium Alloys, Inc., Sorbent Technologies Corporation, Technology Management, Inc., Transmission Research (a division of NASTEC), and Sun Valley Technology, Inc.

The Technology Dialogue over Lunch series is a new outreach program designed by LeRC and GLITeC to begin discussions between local companies and LeRC's scientists and engineers in an informal setting. Invitations are sent with specific information about the technologies to be discussed. Market research guides the selection of invitees, to assure their interest in the technology being presented. The following technologies were discussed at the first four pilot lunches: advanced ceramics, real-time process control, emerging measurement technologies, and surface modification in biomedical applications. Representatives from 37 Northeast Ohio companies attended the four pilot technology dialogues. The industries best represented in these dialogues include instruments and related products, industrial machinery and equipment, chemicals and allied products, and research and testing services.

Each dialogue is opened by a LeRC scientist or engineer who presents a technology available for industrial application. An industry representative presents an available technology or a problem requiring a solution. The dialogue among participants stimulates open communication, innovative thinking, and mutual learning. As a result of its first four dialogues, LeRC established a formal partnership with one company to examine the development of affordable composite materials. LeRC, jointly with GLITeC, is currently expanding the program throughout Ohio.

D. Summary

In response to changes in national policy, including new directions in the president's agenda for science and technology, the National Performance Review, and NASA's Agenda for Change, LeRC continues to improve and strengthen its technology-transfer and commercialization activities. LeRC is undergoing a change in its technology transfer organization: The Commercial Technology Office was created with enhanced structure, policies, and mechanisms to reach LeRC's various stakeholders. LeRC, collaborating with its intermediary organizations for technology transfer, is now better positioned to form partnerships with other research organizations, and to transfer LeRC's technologies to private industry in order to bring new and improved products to the marketplace and raise industry's global competitiveness.

3. LeRC Contributions to the Quality of Education in Northeast Ohio

One of the industrial sectors that benefit from having LeRC in Northeast Ohio is the educational sector. As described earlier (Section III. C.), LeRC gives grants to numerous U.S. colleges and universities, many of them in Ohio. However, LeRC's contribution to local faculty and students reaches beyond the amount of its research funding. The present section discusses LeRC's contributions to education in Northeast Ohio at both the university and K-12 levels.

A. Higher Education

We conducted interviews with the deans of engineering, research, and graduate studies at all universities associated with the Ohio Aerospace Institute, as well as with LeRC's Office of University Programs. Most interviewees emphasized the importance of a federal facility such as LeRC to their universities, citing benefits that can be divided into the following areas:

- Research funding: direct grants awarded by LeRC to fund faculty, graduate students, and full-time research associates.
- Access to high-tech facilities and equipment for conducting experiments that cannot be done on campus.
- Access to LeRC's scientists and engineers and their expertise.
- Exchange of ideas between faculty, students, and LeRC employees.
- Improved and enriched curricula resulting from research done at LeRC facilities. New and advanced techniques learned at LeRC are incorporated into the classrooms.
- Placement of graduates at LeRC at the B.Sc., Master's, and Ph.D. levels. This is especially important to universities with departments of aerospace engineering such as Ohio State University.

The Summer Faculty Fellowship Program is executed through grants from NASA headquarters and LeRC to OAI. The program provides science and engineering faculty the opportunity to participate in research for a ten-week period in the summer. Faculty are chosen to participate in the program

because their expertise matches LeRC's needs, and each participant works closely with an assigned LeRC colleague. NASA does not consider this a summer job program, but rather a means of continuously introducing new faculty into the NASA system and giving them an opportunity to develop mutually beneficial professional relationships. Short-term benefits to faculty take the form of summer funding. However, long-term benefits to faculty and their universities include enhanced research skills, improved prospects for future research grants, and better classroom curricula. The program is advertised nationally and applicants are drawn from all states, but the geographic effect of proximity to a NASA Center is apparent at LeRC as well as at other centers. Except for last year, about one-fourth of all faculty participants at LeRC came from the eight-county Northeast Ohio area (Table 10).

Table 10. Summer Faculty Fellowship Program Participation at LeRC

Year	Number of Participants		Northeast Ohio as a Percent of U.S.
	Northeast Ohio	U.S.	
1990	15	65	23%
1991	16	59	27%
1992	15	60	25%
1993	12	51	24%
1994	6	52	11%

The Graduate Student Researchers Program provides up to three year's support to full-time students working toward advanced degrees. Each participant works closely with a LeRC advisor and spends a significant part of his or her time at LeRC. The program's direct benefit is to provide financial support for graduate students. However, it also creates opportunities for students who pursue academic careers and promotes interaction between the student's academic advisor and the NASA advisor, which often leads to a substantive professional relationship between them. In each of the

past five years, the program supported between two and seven Northeast Ohio students.

Another relationship with area universities is the collaborative on-site graduate engineering program at LeRC. The program, which is administered by OAI under a contract with LeRC, provides opportunities for working engineers to pursue master's degrees and doctorates on-site. Several universities participate by sending faculty to teach on-site (mainly from local universities) or by interactive television (from other Ohio universities).

A unique contribution to the education level in Ohio (although not in Northeast Ohio) is LeRC's grant to Wilberforce University, a historically black college, for undergraduate studies. The $1.3 million three-year grant supports several faculty and students and it helped to establish an electronic design lab for students. Interaction among LeRC, Wilberforce University, and Kent State University created an enhanced engineering physics curriculum at Wilberforce University that enables graduates to continue to a master's degree at Kent State University. The LeRC grant also helps support a summer program to strengthen incoming freshmen's math and science skills.

B. K-12 Education

LeRC's outreach activities with students and teachers in K-12 grades are designed to capture the interest of students, to channel that interest into substantive involvement with LeRC resources, and to enhance teachers' skills in using aerospace education for teaching science and math. LeRC's involvement helps prepare the next generation of scientists and engineers, especially minority students who have traditionally avoided these types of professional careers. The LeRC programs relevant to pre-college education can be divided into five clusters:

- On-Site Student Internship and Apprenticeship Programs, which are held primarily during the summer months, include 300-400 students each year. These programs, marked by increased participation of students with disabilities and by female and minority students, build a student "pipeline" to science and engineering education.

- Volunteer Feeder Programs capture and channel the interest of average and high-achieving students, guided by LeRC mentors who provide personal interaction with students and

encourage parental involvement. In one of the projects (New Approach to Self Achievement), more than 85 inner-city students participated over the past two summers. In another project, Explorers, 19 out of 30 participants were minority and/or female.

- Community School Programs: The T-34 Star Program utilized a T-34 aircraft to train educators in using aeronautics to stimulate students' interest in math and science through practical applications of concepts. The NASA Lewis Empowerment of Educators Program (LEEP) identifies and recruits teachers throughout the six-state region to act as liaisons with the Lewis Office of Educational Programs. The Cleveland-area National Engineers Week (NEW) Program combines educational and public affairs activities. During February 1995, 120 schools and 10,000 students in Northeast Ohio were visited by LeRC and other area engineers under the guidance of the LeRC NEW team.

- School Partnerships are collaborative efforts designed to empower educators, students, and parents. One example is a unique partnership between LeRC and the Anton Grdina School, an elementary school located in an underserved community in the City of Cleveland. The project involves students, school personnel, parents, and officials of the nearby housing authority. About 3,300 students were involved over the past four years. Success has been measured in improved test scores and attendance, decreased student discipline problems, and increased family and community involvement. Another unique example is the partnership between LeRC and East Tech High School in the City of Cleveland. It features LeRC assistance in tutoring and science fairs, as well as student participation in on-site LeRC programs, and affects many of the school's students. Moreover, East Tech has about 100 students in its pre-engineering program, an important pipeline into science and engineering professions. LeRC also hires East Tech graduates, about 30 of whom currently work there.

- On-site and Outreach Programs for Teachers: A nationwide program, NEWEST, gives competitively selected elementary-school educators the opportunity to experience NASA'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. The Telereach Program arranged for 73 telereach conferences since 1990. A telereach session, including a discussion and a question-and- answer period on a specific topic, is held between educators, students, and LeRC staff.

In sum, LeRC has a wide influence on education at the K-12 level. About 32,000 students and 1,500 teachers in Ohio were involved in on-site activities at LeRC between 1990 and 1994, and 11,500 Ohio students and teachers were affected by partnerships. In addition, over 58,000 people were affected by educational outreach activities, conducted by LeRC between 1990 and 1994 (separate data on Northeast Ohio are not available).

A new LeRC initiative in the area of K-12 education is SEMAA, the Science, Engineering, Mathematics, and Aerospace Academy. SEMAA reaches underrepresented, underserved, and minority students in Cleveland, East Cleveland, Euclid, Cleveland Heights, Warrensville Heights, and Shaker Heights. Its primary goal is "to provide academic enrichment and career awareness programs to encourage K-12 students to acquire a strong academic background in science and math education to prepare them to pursue undergraduate programs in science, mathematics, engineering, and technology." In addition to meeting residency requirements, in order to participate in SEMAA students must express interest in math and science, be willing to attend and participate in sessions regularly, and maintain good conduct. Parental commitment to the program is encouraged but not mandatory.

SEMAA supports schools by offering science and math enrichment to complement schools' instructional programs and to encourage student interest and success in science, math, engineering, and technology. Students who participate in SEMAA programs are channeled from one program activity to another. The programs are divided into five components, depending on the age and interests of participants: K-4, 5th and 6th grades, 7th and 8th grades, and two for high school--one affiliated with Cleveland State University and one with Case Western Reserve University. Most of the programs include sessions during the school year (after-school and/or Saturday), augmented by summer sessions.

SEMAA received a $500,000 grant from LeRC. This year, about 1,400 students participated, including 500 in summer programs. Although SEMAA is a new initiative, it has already achieved some success. Pre- and post-testing of student participants shows a significant increase in scores. Participation in SEMAA programs is very high; 90 percent of the students show up for the Saturday program, and the summer programs had to turn away many qualified applicants.

V. Conclusions and Recommendations

1. Why is LeRC a Major Economic Catalyst for Northeast Ohio?

This study has examined the Lewis Research Center's (LeRC) economic impact on Northeast Ohio. LeRC has a special impact on the regional economy for several reasons.

1) All of its revenues are derived from federal sources, which are external to the region. This makes LeRC a special economic catalyst that brings back home federal tax dollars that Greater Cleveland taxpayers sent to Washington. One major consequence of LeRC's downsizing is that it will bring fewer tax dollars into the region.

2) LeRC is a major research and development producer, and therefore comprises a crucial part of Northeast Ohio's science and technology base. As a capital provider for research, it improves the quality of local universities' scientific research. LeRC has helped increase the region's supply of highly technical human resources by employing an average of 1,500 civil-service scientists and engineers per year over the last decade. In addition, its on-site and near-site contractors employ many more highly technical employees. LeRC has developed specialized high-technology real estate resources which are valuable to area universities, companies, and other groups. It has also stimulated the area's information and telecommunication capabilities by serving as the impetus for the installation of fiber-optic lines.

3) LeRC has given the region a quiet but steady and significant infusion of economic resources. It has produced these benefits quietly in the sense that it has not sought great visibility as its researchers worked to help NASA reach its space exploration goals. LeRC's economic benefit to the regional economy is attested by its sizable total output impact of $1 billion, employment impact of 12,800, and an earnings impact of $ 375 million. Therefore, the

projected downsizing of LeRC's budget and labor force will adversely affect its own employees and will also jeopardize these output, employment, and earnings impacts. LeRC's economic impact is a function of its spending in the local economy; a smaller LeRC budget could reduce its spending on goods and services purchased from Northeast Ohio companies and weaken its positive effect on the regional economy.

4) LeRC improves Northeast Ohio's business competitiveness through technology transfer, which provides area companies with innovative technologies and facilitates the solving of real-world industrial problems by LeRC scientists and engineers. Historically, LeRC has transferred technology primarily to aeronautical and aerospace companies. However, NASA has recently elevated technology transfer to one of its top priorities, causing LeRC to restructure its organization in order to improve and strengthen its transfer of nonaeronautics technologies to a wider range of industries, such as biomedical and manufacturing companies.

5) Northeast Ohio also benefits from LeRC's presence through the center's interaction with area schools and universities, which improves education for K-12 and college students in such fields as mathematics, science, and engineering. LeRC's staff helps to build a student "pipeline" to science and engineering careers and helps develop innovative approaches to math and science instruction. LeRC's university grants provide funding for faculty and graduate student research. The grants also give faculty and graduate students access to LeRC's staff and its specialized technical facilities, thus enriching the quality of their research and teaching.

6) A less quantifiable benefit to Northeast Ohio is the boost LeRC provides to the area's image. The presence of this national research center is beneficial to the area's strategy of high-technology development. LeRC's presence helps attract research and development companies, as well as scientists and engineers, to the region.

These six reasons explain why the Lewis Research Center is a strategic economic resource for Northeast Ohio. They show that LeRC is a catalyst for regional economic growth. They also identify what the region could lose if the Center downsizes or closes in the future.

2. What Actions Would Strengthen LeRC in the Future?

The expected downsizing of LeRC makes it necessary for the center to use its personnel and facilities more strategically to preserve its current economic impact on Northeast Ohio. Greater integration with the local community and the area's industries will help LeRC and the area adjust to future LeRC budget reductions. The Urban Center offers the following set of recommendations to help in this adjustment process:

1) Nearly one-third of LeRC's spending for FY 1994 occurred in Northeast Ohio, a higher share than in previous years. It is recommended that, if possible, LeRC will expand its local purchasing commitment to partially offset spending cutbacks. A "win-win" strategy for LeRC and the local community needs to be identified, in which LeRC would work with local companies to increase their competitiveness as future LeRC suppliers, and the local suppliers would make LeRC more competitive among other NASA centers and federal labs.

2) The community must develop strategies to retain LeRC's laid-off technical personnel in the area. These personnel can join existing companies, start new businesses, or move to areas outside Northeast Ohio. Highly skilled employees enrich the area's labor market and they should be strategically redeployed where possible. Plans to assist these individuals in establishing new start-up companies should be made. Developing a high-tech business incubator and providing businesses with managerial and financial assistance could be keys to business development and retention of personnel. Possible assistance could come from Enterprise Development Inc. (EDI) and the Greater Cleveland Growth Association's Council of Smaller Enterprises (COSE).

3) The aerospace industry has been targeted for intensive development by the Ohio Department of Development and the Greater Cleveland Growth Association, but LeRC's downsizing could hurt the industry's local development potential. These economic development groups should identify ways to retain and expand the LeRC operation. Helping LeRC's laid-off but highly skilled personnel remain in Northeast Ohio, and renting LeRC facilities to the private sector are two possibilities.

4) In the area of privatizing government functions, LeRC should form new public-private partnerships to strengthen LeRC competitiveness as a technology resource while conserving scarce government resources. Partnerships with industry and academia are vital to preserving LeRC's technological capacity, especially in light of declining financial resources. The following are examples of such partnerships:

a) LeRC should develop full partnerships with industry for technology development. For example, the High Speed Civil Transport (HSCT), the second-generation supersonic airplane, is being jointly developed by NASA, Boeing, General Electric Aircraft Engines, McDonnell Douglas, and Pratt & Whitney. Another example would be a private-public partnership to establish a research institute in an area where LeRC is designated as a Center of Excellence. Instead of just funding research and technology development, LeRC should participate with industry and academia as a full and equal partner.

b) It is recommended that LeRC discuss its plans and initiatives with industry and university representatives during the planning stages to allow them to influence the plan and its timing. A good model to follow is Wright-Patterson Air Force Base's "Road Map Review," a two-day workshop where laboratory managers speak with industry and university representatives about their program initiatives and implementations. This workshop allows industry and universities to interact with the

federal lab during its planning stages, to influence the plan and its timing, and to collaborate on the implementation.

c) To improve the process of technology transfer to companies in Northeast Ohio, especially in nonaeronautics technologies, LeRC should hold more sessions on how industry could work with NASA and find technological expertise at LeRC. Also, by placing staff in local "industry internships," LeRC could develop its relationship with local companies and gain knowledge of their technical strengths and weaknesses, and of the technology they must have to remain competitive in global markets.

d) LeRC should work more closely with key community organizations such as Cleveland Tomorrow and its Technology Leadership Council, the Greater Cleveland Growth Association, and the Ohio Science and Technology Commission.

5) Ask NASA and other federal research laboratories for $100 million to develop and implement a set of new federal-industry partnerships for innovative applications of NASA and other federal labs' technologies to make urban centers like Cleveland more technologically advanced and globally competitive. Partnerships should reach across federal agencies and ensure the matching of federal dollars with private industry money. LeRC could work with industry and federal partners to initiate a national program to develop new technological solutions to urban environmental, transportation, and other infrastructure problems. One such initiative could focus on new cost-effective remediation technologies for brownfield and Superfund site cleanup. The governmental partner in this case could be the U.S. EPA's Regional Research Laboratory in Cincinnati.

6) LeRC should examine the feasibility of becoming a contract research center for government and industry clients on the applications of aeronautics and space technologies to nonaerospace industries. Partners could include local universities, hospitals, and other industries.

The last two of these recommendations are intended to create a demand for the "excess capacity" that would result from LeRC's downsizing.

Appendix: List of Persons Interviewed for the Study

The following persons were interviewed to gather information and insights for this study:[18]

Person	Organization
Edward Asikele, Ph.D. Assoc. Professor, Engineering/Computer Science	Wilberforce University
W.A. Baeslack, Ph.D. Assoc. Dean for Research, College of Engineering	Ohio State University
Dorothy Baunach Senior Associate, Technology Leadership Council	Cleveland Tomorrow
William Bryant Former President (retired), Greater Cleveland Growth Association	Ohio Aerospace Council
Terry Butler Principal	East Tech High School, City of Cleveland
Carol Cash Manager, Cleveland Office	Cleveland Aerospace Professional Representatives Association (CAPRA), G.E. Marketing Representative, Aircraft Engines
Christopher Coburn Executive Director	Great Lakes Industrial Technology Center
Lonzo Coleman Chairman	ColeJon Corporation
George Coulman, Ph.D. Dean of Engineering	Cleveland State University

[18]Face-to-face interviews were conducted with individuals in the Cleveland area. Interviews with faculty and university administrators in Ohio universities located outside the Cleveland area were conducted by phone. Thus, out of 27 interviews, 19 were conducted in person and eight by phone.

Person	Organization
Priscilla Diem Client Services	Great Lakes Industrial Technology Center
Stephen Gage, Ph.D. President	Cleveland Advanced Manufacturing Program (CAMP)
Lawrence Gooch, Ph.D. President and Chief Operating Officer	Analex Corporation
Richard Irey, Ph.D. Associate Dean for Research and Graduate Study	University of Toledo
Ravi Jain, Ph.D. Associate Dean of Research	University of Cincinnati
Andrew Kelton Director of Development	Chelm Management Company
Jerry Lee, Ph.D. Vice President, Aerospace Division Research	BFGoodrich
Thomas McManamon Director	Science, Engineering, Mathematics and Aerospace Academy (SEMAA), Unified Technology Center
Thomas Moss Dean of Research and Graduate Studies	Case Western Reserve University
Dominic Ozanne President	Ozanne Construction
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Richard Robe, Ph.D. Dean of Engineering	Ohio University
Michael Salkind President	Ohio Aerospace Institute, OAI

Person	Organization
Gordon Sargent, Ph.D. Vice President	University of Dayton
Frederick Schoenig, Ph.D. Director	Advanced Manufacturing Center of CAMP
Joseph Thomas, Ph.D. Associate Provost for Research	Wright State University
Max Willis, Ph.D. Associate Dean, College of Engineering	University of Akron
Pierrette Woodford Deputy Director	Great Lakes Industrial Technology Center