The Economic Impact on Georgia of Georgia Tech's Packaging Research Center

GEORGIA RESEARCH ALLIANCE

SRI International

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FOREWORD

About The Study

This study was conducted for the Georgia Research Alliance (GRA) by SRI International's Center for Science, Technology, and Economic Development (CSTED). The SRI Project Team consisted of David Roessner (Project Director), Sushanta Mohapatra, and Quindi Franco. The opinions, findings, and conclusions expressed in this report are those of the project team and do not necessarily represent those of the GRA.

Acknowledgements

The authors wish to thank all those who gave their time and thought to providing the information required to conduct this analysis. Special thanks go to the Packaging Research Center's staff, especially PRC Director Rao Tummala and Associate Directors Carl Rust and Leyla Conrad, to George Harker of the

Georgia Tech Research Corporation, and to representatives of companies affiliated with the PRC who provided additional information on the PRC's activities and impacts.

We also thank the Georgia Research Alliance for providing the opportunity for us to conduct this challenging and important study. The results document a major example of the kinds of economic impacts that can result from public investment in the science and technology infrastructure, particularly investments in fostering university-industry collaboration in key areas of research and education.

Finally, we wish to thank Danielle Hinkley-Abba of CSTED, who designed the cover and internal layout of this report.

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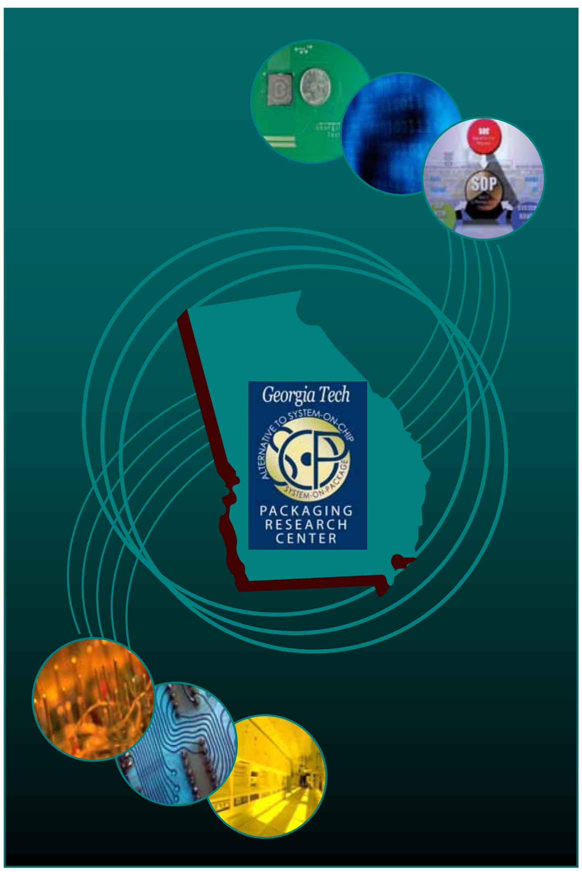


Introduction

The Microsystems Packaging Research Center (PRC) of the Georgia Institute of Technology is a prime example of a cooperative federal-state investment in the nation's science and technology infrastructure. Georgia's financial support of the PRC required an enlightened and long-term view of the kinds of investments that are required to produce long-term, sustainable regional economic growth. Between 1994 and 2004, Georgia invested $32.5 million in the PRC through Georgia Tech and the Georgia Research Alliance (GRA). As a National Science Foundation (NSF) Engineering Research Center, the PRC's base award funding from NSF will cease in 2005, creating a need to look systematically at both the PRC's impact to date and its future outlook.

Accordingly, SRI International, under contract with the Georgia Research Alliance, was asked to conduct an assessment of the economic impact on Georgia of the existence of the PRC. The question was, in effect, what has been the payoff to the taxpayers of Georgia from a decade of state investment in the PRC? This executive summary reports the major highlights and findings from the SRI study. The full report provides details of SRI's methodology, data, assumptions, and results.

Direct Economic Impact of the PRC's Existence

The technical and human resources represented in the PRC have attracted large amounts of cash and in-kind support from sources outside Georgia. The PRC's expenditures on research, education, and related activities have, in turn, led to a variety of direct economic impacts on the state, including numerous benefits to Georgia firms that have interacted with the PRC, and cost savings and other benefits to Georgia firms that have hired PRC graduates. The variety of sources of external support for the PRC and the types of impacts the PRC has had on Georgia are depicted in Figure S.1. ***SRI's analysis of these impacts show a total, quantifiable direct impact on Georgia of nearly $192 million over PRC's ten-year history.*** Figure S.2 illustrates the breakdown of the direct impacts realized.

Figure S.1

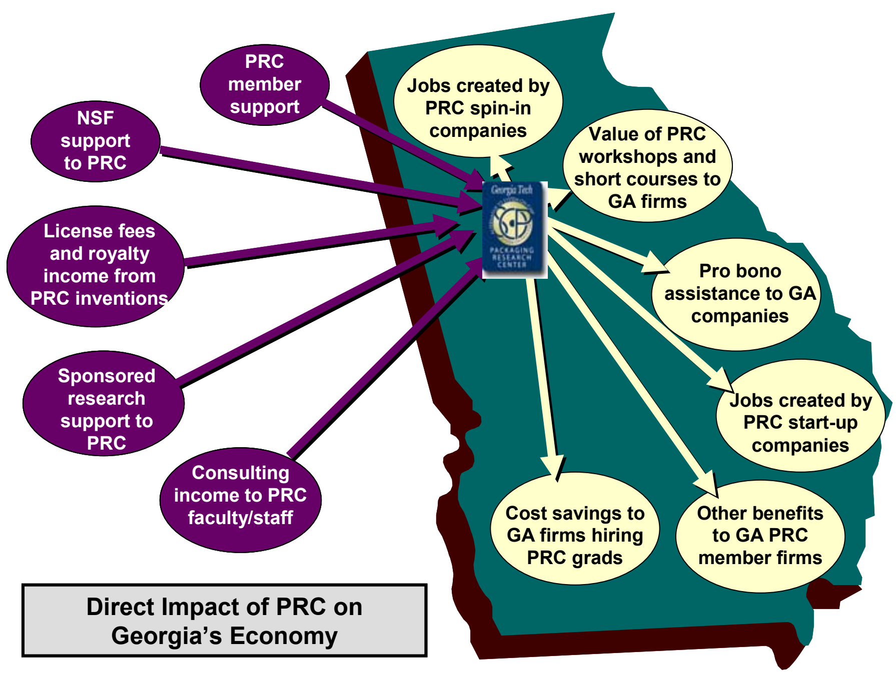
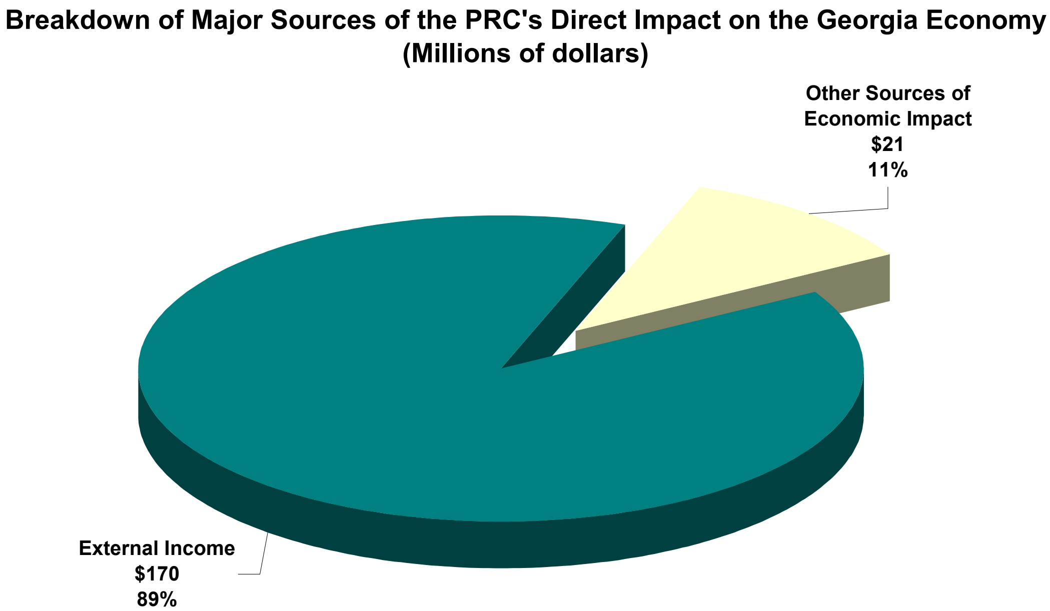


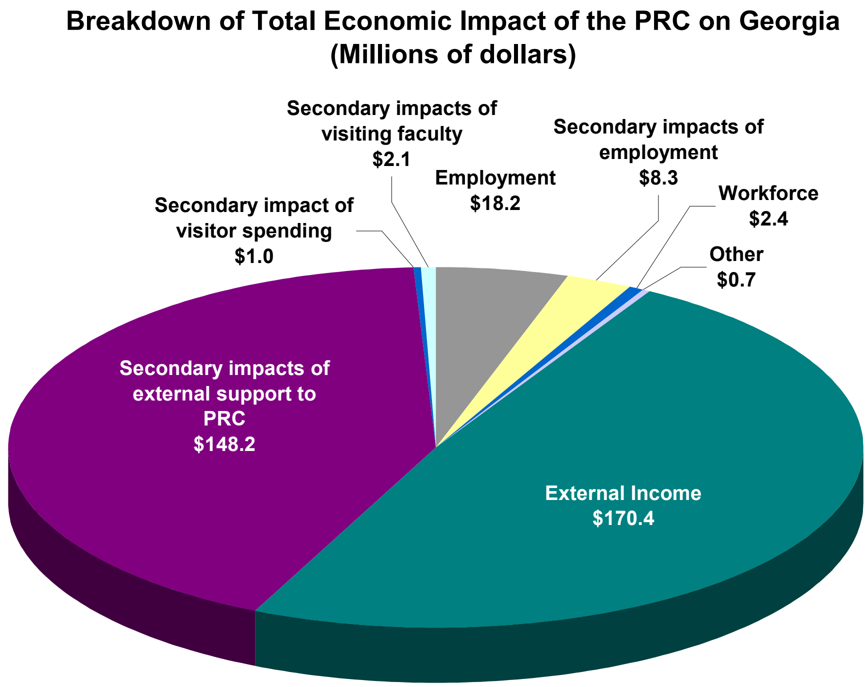
Figure S.2



THE PRC'S SECONDARY AND TOTAL IMPACTS ON GEORGIA

The $192 million of direct impacts of the PRC produce "ripple" effects as they work through Georgia's economy. These ripple effects—indirect and induced impacts—include purchases of goods and services from other firms by businesses that benefit directly from PRC-related activities, and purchases of goods and services in Georgia (food, housing, etc.) by employees whose earnings are derived from PRC-related activities. Ripple effects can be substantial. Using an Input-Output based multiplier model, SRI estimates that the indirect and induced impacts of the PRC have amounted to $159 million, so that ***the total quantifiable impact of the PRC's existence is conservatively estimated to be $351 million over ten years***. Figure S.3 shows the proportional contributions of various sources to the PRC's total economic impact on Georgia.

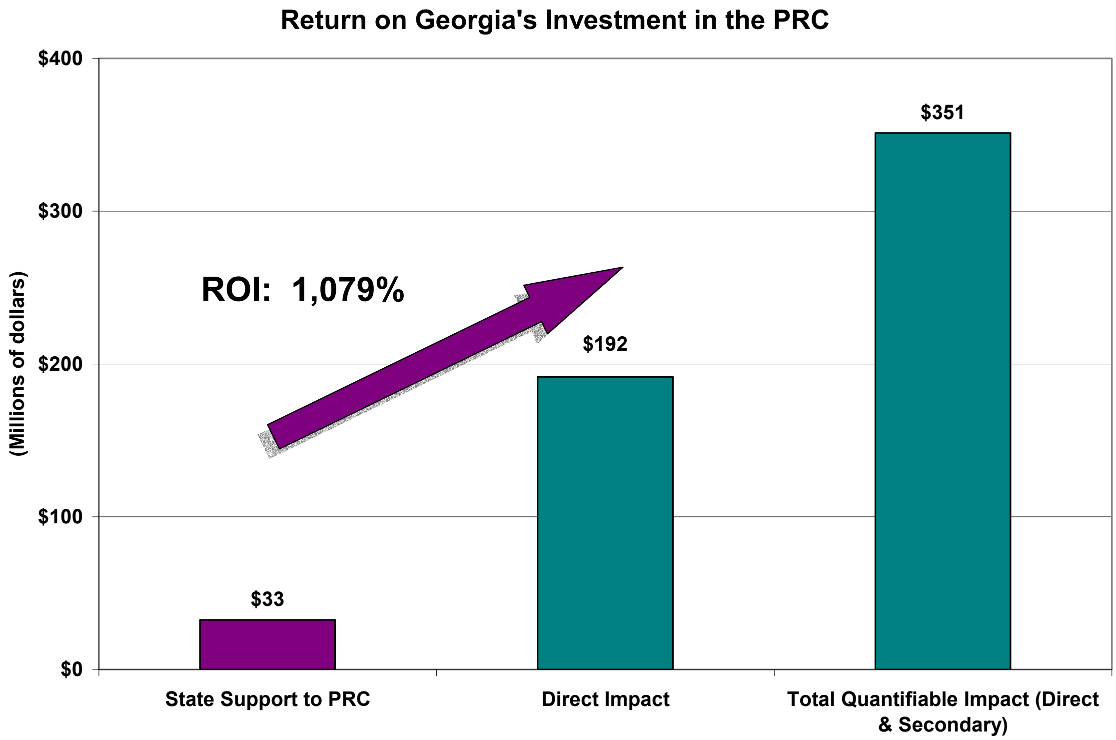
Figure S.3



Return on Investment

As a major funder of the PRC, the state of Georgia is justified in asking what return it has received from its investment in the Center. In purely quantitative economic impact terms, the state's investment of $32.5 million has helped attract external support for activities that had a total economic impact on Georgia of $351 million. ***In other words, every dollar of state investment in the PRC has had a 10 dollar impact on the state economy.*** This represents an impressive leveraging of the state's original investments in the PRC, with a financial "return on investment" (ROI) of 1,079 percent (see Figure S.4).

Figure S.4



Job Creation

Another way to look at the PRC's economic impacts is to consider the number of jobs its activities have created and supported. The PRC directly employs research faculty, support staff, and students. It has also been central in the attraction of several spin-in companies (new ventures by existing companies), and its research has helped create several start-up companies that have located in Georgia. The value of these "direct" jobs, amounting to more than $18 million (396 job-years over ten years), was accounted for as a direct economic impact. But these jobs and the day-to-day operations of the PRC further support other jobs in Georgia that supply goods and services directly or indirectly to the PRC and its employees. SRI estimates that the PRC's activities supported an average of about 343 jobs annually in Georgia over the PRC's ten-year history.

Looking to the Future

SRI's analysis indicates that the PRC has had a very substantial economic impact on Georgia, and that the state's investment in the PRC over its ten-year history has paid off handsomely in myriad ways. Yet investment in the PRC is just beginning to yield valuable results in several areas directly related to sustained regional economic growth: start-ups, spin-ins, intellectual property, and human capital. Over the next decade, the PRC will devote increased attention and resources to fostering start-up companies and realizing the commercial potential of new technologies based on PRC research. In both these areas, positive results began to emerge during the last five years, and there is every indication that their impact will increase as the PRC's earlier investments in "upstream" research yield additional commercial opportunities. (It is typical for commercially promising, university-based research results to require 7-10 years of refinement and development before marketable technologies are produced.) We would also expect the number of students trained in the PRC's industry-friendly environment to increase, and for more Georgia companies to benefit from hiring them. Interactions between Georgia companies and PRC staff are also likely to increase, which should produce lasting benefits for area firms, including cost savings and other benefits such as product improvements. Assuming that the PRC continues to evolve and flourish, we anticipate that by 2014 the PRC's economic impact on Georgia will exhibit a different, more commercially-oriented pattern, and that its value will exceed the $350 million mark established in its first decade.

CHAPTER I: INTRODUCTION AND BACKGROUND

Technology-driven Economic Development in the States

Promotion of economic development has been an important activity of American state governments for as long as states have existed. Subsidies and bounties to construct "strategic" industries such as ironworks date to the colonial period; subsidies to canal and railroad companies were common both before and after the Civil War; state support for the construction of industrial parks became common during the 1950s. By this time, one of the mainstays of state economic development strategies was to offer a wide range of incentives to manufacturing firms to relocate or construct new plants in the home state. The objective of this strategy was to attract new jobs to the state, the more the better.

In the 1980s, however, a number of factors led to a rethinking of state economic development strategies. The economic downturn that many smaller states suffered brought their narrow industrial bases into stark view; in particular, agriculture, energy, and federal installations by themselves could not sustain employment growth during tight economic times. At the same time, the nation was experiencing competitive challenges from abroad, notably from the Pacific Rim, and a number of national commissions identified inadequate levels of scientific and technological innovation as a major cause of the problem. States, picking up this theme, sought to diversify their industrial bases and rejuvenate their existing economies by investing in new strategies that focused in various ways on science and technology. An entirely new array of economic development tools emerged that emphasized the creation of new firms and jobs in rapidly expanding, "high tech" industries. Strategies that sought to recruit existing (usually medium or low tech) firms through relocation subsidies fell from favor. Venture capital funds, incubators, research parks, and university-based centers of advanced technology became staples of state economic development policies. Technological change and innovation were seen as the keys to sustained economic development.

Industry-University Cooperative Research Centers as a State Economic Development Strategy

Over the past two decades both the federal government and the states recognized increasingly that self-sustaining regional economic development is driven by the development, productivity, and employment needs of small, innovative firms and that a central feature of sustained "high-tech" development is the entrepreneurial research university. This recognition has led to federal and state government support of university-industry research centers with provisions that encourage university-based start-ups, and especially to the creation of state organizations such as the Georgia Research Alliance (GRA) that support and encourage university-based entrepreneurs.[1]

By 1991 there were over 1,000 University Industry Research Centers (UIRC) in the U.S., with a total estimated budget of $4.12 billion, of which $2.53 billion was devoted to R&D (most of the balance was for educational activities). Governments provided over 46 percent of UIRC funding (federal - 34.2 percent; state - 12.1 percent) while industrial participants provided 30 percent of the financial contributions (representing over 70 percent of industry's financial support for academia), in addition to providing additional non-cash support. Included among UIRCs are those that receive substantial support from the National Science Foundation (NSF). Although they comprise between 10 and 15 percent of all UIRCs, the size, prominence, and quality of the institutions involved in NSF centers make them a significant force in moving university research results into commercial settings.

The NSF Engineering Research Centers (ERC) Program, initiated in 1985, represents an ambitious effort to stimulate the formation of university-based industrial consortia while at the same time seeking to change the context of engineering research and education. Although one of the key initial political rationales for the creation of ERCs, increased U.S. industrial competitiveness, currently is of lesser concern, other ERC objectives remain salient: promote interdisciplinary research and teaching, promote a team approach to research, and introduce students to industry needs and perspectives. To encourage the conduct of longer-term, high-risk research and the formation of an enduring change in the institutional setting of engineering research and education, NSF supports each ERC for eleven years (subject to intensive reviews every three years) at a level averaging $2.5 million annually for each center. ERCs are supported by a combination of NSF core support, other federal

[1] See, for example, L.G. Tornatzky, P.G. Waugaman, and D.O. Gray, *Innovation U.—New University Roles in a Knowledge Economy.* Research Triangle, NC: Southern Growth Policies Board, 2002; H. Brooks and L. P. Randazzese, "University-Industry Relations: The Next Four Years and Beyond" and C. M. Coburn and D. M. Brown, "State Governments: Partners in Innovation," in L. M. Branscomb and J. H. Keller, eds., *Investing in Innovation*. Cambridge, MA: MIT Press, 1998; S. Slaughter and L L. Leslie, *Academic Capitalism*. Baltimore: The Johns Hopkins University Press, 1997.

agency research grants and contracts, state and/or university money, and industry membership fees, contracts, and in-kind contributions. A typical ERC has 30 industrial members, with full members contributing an average of $20,000 in membership fees. But the average annual budget of an ERC is $10 million, representing support from other parties as well.

The Georgia Research Alliance[2]

The Georgia Research Alliance (GRA) represents the most recent of three significant statewide efforts by Georgia to develop and implement policies to promote science- and technology-based economic development. The first was the Industrial Extension Service, a state-wide network of Georgia Tech field offices established in 1960; the second was the Advanced Technology Development Center, a university-based high technology business incubator created in 1980; and the third was the Georgia Research Alliance, founded in 1990 to foster economic development by improving and leveraging the capabilities of the state's research universities. GRA has become a unique and successful model for fostering cooperation among both public and private universities, while simultaneously strengthening their capabilities to leverage increased research support from federal and industrial sources.

GRA's research support programs are concentrated in three strategic areas: advanced communications, biotechnology, and environmental technologies. To date, the state of Georgia had invested $375 million through the Alliance in research and development programs at its six member universities, matched by $65 million in private funds. This investment has, in turn, helped to attract over $600 million in additional sponsored research. This investment program includes the establishment of endowments for more than 40 eminent scholar chairs, priced at about $3.5 million each.[3] Concrete evidence that GRA's strategy was paying off began to accumulate beginning in 1994, when Georgia Tech won an NSF Engineering Research Center award to create the Packaging Research Center. This was followed by another ERC award to a Georgia Tech-Emory team in 1998, and an NSF Science and Technology Center award to a coalition led by Emory and Georgia State University in 1999. GRA's support for eminent scholars provided the

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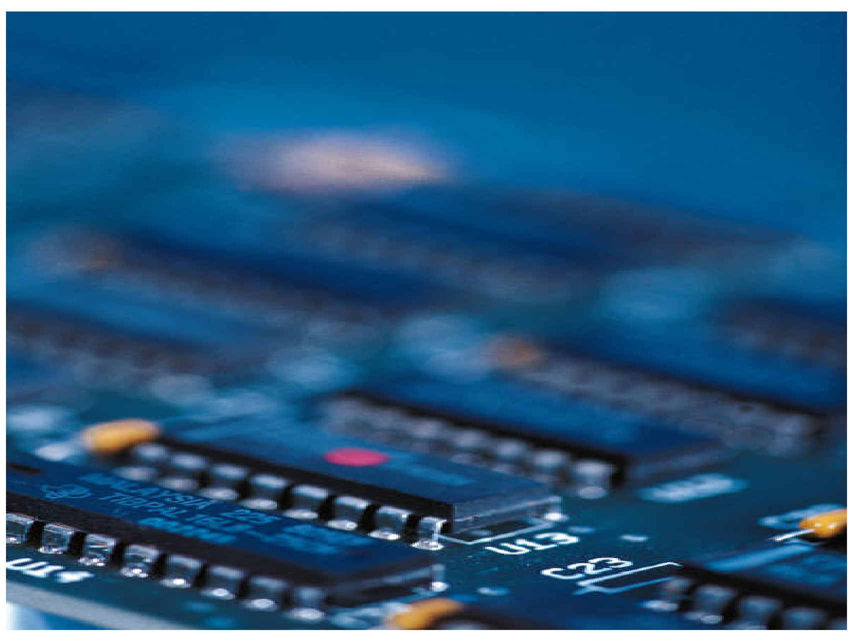
[2] This historical description of the Georgia Research Alliance draws extensively on R.S. Combes and W.J. Todd, *From Henry Grady to the Georgia Research Alliance: A* Case *Study of Science-Based Development in Georgia***.** Atlanta, GA: Georgia Research Alliance, nd. Available at http://www.gra.org/background.html; and W. Henry Lambright, "Catalyzing Research Competitiveness: The Georgia Research Alliance," *Prometheus*, **18**, 4 (2000): 357-372.
[3] http://www.gra.org/background.html

intellectual leadership behind the successful PRC bid, and was instrumental in attracting Dr. Rao Tummala, who would become the PRC's Director, to Georgia Tech.

The Packaging Research Center's Economic Impact on Georgia

The Microsystems Packaging Research Center at Georgia Tech was established in 1994 as a National Science Foundation Engineering Research Center. NSF requires that lead institutions hosting ERCs cost share an amount of at least 20 percent of NSF's support to the ERC. Thus the State of Georgia, through the Georgia Research Alliance and Georgia Tech, has made a sizeable $32.5 million investment in the PRC over its ten-year history. As the date for termination of NSF support for the PRC approaches, it is desirable and appropriate to provide evidence of the payoffs to the taxpayers of Georgia from the state's investment. In response to this need, SRI International (SRI) contracted with the GRA to conduct an evaluation of the impact on Georgia of the PRC over its lifetime. The evaluation was designed to yield an estimate of the economic benefits to the state from its investment in the PRC. The present report describes SRI's approach to, and results obtained from, an assessment of the PRC's economic impact on Georgia.

CHAPTER II: SRI'S APPROACH TO THE ECONOMIC IMPACT ASSESSMENT



Estimating the Economic Impact of the PRC

To assess the net economic impact on Georgia of public investment in the PRC, SRI employed an approach similar to that used in a recent study of the economic impact of Michigan's investment in its state university system.[4] The approach identifies the external (to Georgia) support that the PRC generated; the direct and indirect economic impact of spending by the PRC and its faculty, students, and visitors; cost savings and other benefits to PRC industrial collaborators; the impact of university licensing of PRC technology; the value of PRC-generated employment; and the value of PRC graduates hired by Georgia companies. The net economic impact is the sum of the total net direct and indirect impacts of these outputs and expenditures on Georgia's economy for the period 1995-2004. The approach uses elements of input-output analysis (through the use of multipliers for certain expenditures) in addition to algebraic calculations.

Each category of potential impact is framed in terms of additional money and other resources coming into the Georgia that otherwise would not have occurred, and/or additional value to the state that otherwise would not have occurred, in the absence of the PRC. Table II.1, below, lists the categories of net impact that SRI sought to measure or estimate, including indirect and induced effects.

Table II.1

Categories of Economic Impacts on Georgia from Investment in the Packaging Research Center
NSF support for the PRC.
Industry support from all out-of-state industrial members of the PRC since its inception.
Sponsored research support from outside the state attributable to existence of the PRC.
Consulting income to PRC faculty/staff from outside state attributable to existence of PRC.
Cost savings to firms in Georgia that have hired PRC students and graduates.
Qualitative impacts on Georgia firms that have been members of the PRC.
Economic impact of start-ups based in PRC research that have located in GA.
Licensing fees and royalties for intellectual property generated by PRC research.
Economic impact of spin-ins, companies attracted to GA because of the existence of the PRC.
Value of technical assistance and consultation provided at no cost by PRC faculty and staff to member and non-member firms in GA.
Dynamic effects: the impact of PRC on underlying business attractiveness of GA particularly in industries that are intensive users of PRC services.
Secondary indirect & induced effects: additional economic activity generated by direct increase in in-state expenditures attributable to existence of PRC.

[4] Robert Carr and David Roessner, *Economic Impact of Michigan's State Universities*, Arlington, VA: SRI International, 2002

Data Requirements and Data Collection Strategies

This section provides details of the data sources and data collection strategies employed in conducting the impact assessment. The section is organized around the impact categories listed in the previous table.

NSF support for the PRC, and industry support from all out-of-state industrial members of the PRC since its inception. NSF requires that ERCs report annually all income by source and type of support, so these data were readily available in PRC annual reports and financial records. Included are cash, in-kind support, donated equipment, fees for access to facilities, and grants and contracts.

Sponsored research support from outside the state attributable to existence of the PRC. PRC staff and the Georgia Tech Research Corporation provided data on external research support from all sources.

Consulting income to PRC faculty/staff from sources outside Georgia attributable to the existence of the PRC. In principle, this income should be included in the impact estimate because it increases the incomes of PRC faculty and staff, and some proportion is expended within the state. However, issues involving possible invasion of privacy and the resources required to obtain this information from individual staff and faculty precluded incorporation of this source of income.

Cost savings to firms in GA that have hired PRC students and graduates. As of 2004 the PRC has produced a total of 454 engineers at the BS, MS, and PhD levels.[5] From PRC records and with the help of PRC staff, SRI identified those that were employed by private firms in Georgia upon graduation. Other studies have used reports from center industry members that center graduates could contribute fully to the company one year earlier than could graduates who had not previously participated in industrially-oriented research. Using this approach and adjusting for possible differences in the value of time savings among BS, MS, and PhD graduates, it was possible to estimate the savings to Georgia companies from hiring PRC graduates.

Qualitative impacts on GA firms that have been members of the PRC. SRI has conducted several studies of the impact on industry of participation in ERCs and other NSF university-industry cooperative research centers. In each case, it has proven infeasible to obtain dollar

[5] http://www.prc.gatech.edu/brochure/prc_brochure-lowres.pdf

cost estimates from member firms of the economic benefits derived from center membership. However, survey data from ERC industrial members, including members of the PRC, are available that indicate the effect of center membership on the firm's competitiveness and identify the specific benefits derived from center membership.

Economic impact of start-ups from PRC research that have located in GA. As of 2004, there have been four start-ups from the PRC. All four are in Georgia. The PRC keeps in close contact with its start-ups, so it was not difficult to obtain nonproprietary information from PRC staff on each firm's employment by year. We then estimated the economic impact of these start-ups by multiplying the number of employee-years by a conservative estimate of the annual compensation of technical employees in small, high-tech firms.

Licensing fees and royalties for intellectual property generated by PRC research. The intellectual property produced by most ERCs generally does not generate substantial licensing fees or royalty income, but there are exceptions. Georgia Tech's Office of Technology Licensing keeps records of all income generated by PRC intellectual property, so these data were not difficult to obtain.

Economic impact of spin-ins, companies attracted to GA because of the existence of the PRC. The PRC has been partially responsible for decisions by four companies to initiate new ventures in Georgia. The problem of attribution arose, so it was necessary to interview representatives of these companies to obtain rough estimates of the degree of influence that the existence of the PRC had on these decisions. The economic impact of spin-ins was estimated using the same basic method as for start-ups.

Value of technical assistance and consultation provided at no cost by PRC faculty and staff to non-member firms in GA. Like other ERCs, the faculty and staff of the PRC provide informal technical assistance and consultation to member firms and to (usually local) non-member, small firms as well. (We did not include assistance or consultation provided to PRC member firms in this category of impacts because this is provided as part of the benefits derived from the membership fee.) The value of this uncompensated assistance may be substantial, but is difficult to estimate. PRC staff were able to provide estimates of the number of person-days provided for consultation with

Georgia firms. Multiplication of the number of days times a conservative average daily consulting rate yielded a value for the economic impact.

Value to Georgia of the existence of the PRC, other than via cost savings to Georgia firms from PRC student hires. The PRC provides a variety of educational services to non-students, including short courses, conferences, and workshops. It was infeasible to obtain estimates of the cost savings and other benefits from the Georgia firms sending employees to these kinds of educational activities, so instead we asked PRC staff for records of attendance at these kinds of activities held in Georgia, the duration of each event, and the location of the firm sending participants. We then estimated the economic impact of the additional expenditures made by non-Georgia attendees during the workshop or conference.

Dynamic and secondary effects of the PRC. Research has consistently highlighted the importance of a "critical mass" of business activity and support services for the emergence of vibrant industry clusters.[6] The PRC fundamentally affects Georgia's business environment for industries closely associated with PRC activities by deepening the pool of specialized trained labor, providing targeted business services (consulting), and enhancing the pool of shared specialized knowledge. A full economic modeling effort to estimate directly the dynamic impact of the PRC is beyond the scope of this effort. Instead, SRI reviewed analyses of such dynamic impacts from the existing literature.[7] This involved an assessment of aspects that have been found to be important in enhancing the impact of research centers on industrial development,[8] including the state of specific clusters in Georgia as represented by PRC member companies (systems companies such as IBM; semiconductor manufacturers such as Intel; material, design and process companies; and package and board companies) and the alignment between PRC services and industry needs.

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[6] See, among others: Arthur, B. "Silicon Valley Locational Clusters: When do Increasing Returns Imply Monopoly?" Mathematical Social Sciences,19, 235-51. Athreye, S. "Agglomeration and Growth: A Study of the Cambridge Hi-Tech Cluster." Stanford, CA: Working Paper, Stanford Institute for Economic Policy Research (SIEPR), Stanford University, 2001. Audretsch, D.B. and M.P. Feldman, "Knowledge Spillovers and the Geography of Innovation and Production", American Economic Review, 86(3),630-640: 1996. Masahisa Fujita, Paul Krugman, Anthony J. Venables, The spatial economy: cities, regions and international trade, Cambridge, MA: MIT Press, 1999. Bresnehan, Timothy, Alfonso Gambardella, Annalee Saxenian, "Old Economy" Inputs for "New Economy" Outcomes: Cluster Formation in the New Silicon Valleys. Paper Presented, Copenhagen/Elsinore June 2002.

[7] For example, Martin, Fernand and Marc Trudeau, "The Economic Impact of University Research," *Research File* 2(3). Ontario, Canada: Association of Universities and Colleges of Canada, 1998.

[8] Paytas, Jerry, Robert Gradeck, and Lena Andrews, *Universities and the Development of Industry Clusters.* Pittsburgh PA: Carnegie Mellon University, 2004.

Multiplier effects are the additional economic activities generated by increases in in-state expenditures attributable to the existence of the PRC. Many of the new expenditures attributable to the PRC that are discussed above further work their way through Georgia's economy as firms and employees spend or invest their new earnings (cost savings). Multiplier values vary from economy to economy, based on the unique characteristics of the expenditures and the region's economy. SRI developed a conservative estimate of indirect impacts using an Input-Output based model. Care was taken to develop suitable multipliers and to apply them in such a way as to avoid double counting. Details appear in Chapter IV of this report.

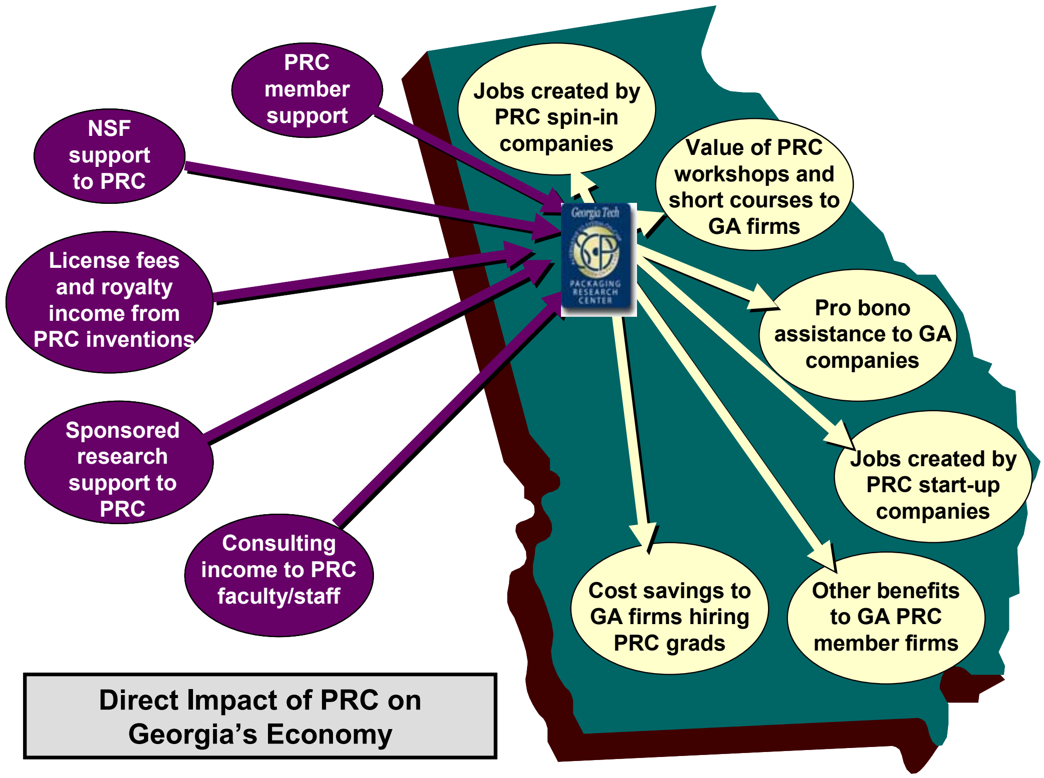
CHAPTER III: THE PRC'S DIRECT ECONOMIC IMPACT ON GEORGIA

This chapter describes the data sources, assumptions, methodology, and estimates of different components of the PRC's direct economic impact on Georgia. Direct economic impacts are those quantifiable and non-quantifiable impacts that accrued to Georgia because of the activities carried out by the researchers, staff, and students of the PRC.

The recruitment of Dr. Rao Tummala as a GRA eminent scholar and the institutional commitments from Georgia Tech and the Georgia Research Alliance led to the establishment of the PRC as an NSF Engineering Research Center in 1994. In the following years, the PRC attracted substantial amounts of federal research support from NSF and other federal agencies. The PRC also formed partnerships with firms in the semiconductor packaging industry, which led to support for PRC research from industry in the form of membership fees, research contracts, and in-kind support from outside Georgia. The PRC's research activities also generated intellectual property in the field of microsystems packaging, and PRC students, graduating with experience in industry-oriented packaging research, brought significant amounts of intellectual capital to the Georgia firms that employed them.

Some of the impacts produced by the PRC's research activities, such as the cash and in-kind support generated by the center, are quantifiable, whereas other impacts, such as the increased competitiveness of Georgia firms collaborating with the PRC and access to new ideas and PRC facilities, are difficult to quantify. An overview of the range of these direct impacts is presented in Figure III-1. For estimation of the quantifiable and non-quantifiable impacts, SRI drew on the PRC's annual reports to NSF, other financial records, and information gathered through interviews with PRC staff, other Georgia Tech officials, and several PRC industry partners. Whenever required, SRI used standard economic data such as the Economic Census published by the U.S. Census Bureau in our estimation of quantifiable impacts.

Figure III.1



The PRC's Quantifiable Direct Economic Impact on Georgia

NSF requires that cash, in-kind support, equipment donations, and fees for access to facilities provided to ERCs from external sources be reported annually to NSF. Therefore, the PRC's tenth year annual report, released in August 2004, formed the basis of our estimate of the Center's quantifiable direct impacts. SRI worked with PRC staff to understand and organize these data into an appropriate analytical framework. We took special care to exclude cash and in-kind support received from Georgia firms from the final estimates of direct impact on the state of Georgia of the PRC. This was done under the premise that funds received by the PRC from in-state sources should be considered as resources circulated within the state, rather than as additional resources flowing into Georgia due to the PRC's existence. The following categories of impacts were quantifiable and captured much, but by no means all, of the PRC's direct impact on Georgia's economy.

NSF support for the PRC since its inception.

The PRC has attracted over $34 million to Georgia in the form of NSF support (Table III.1). These funds include the PRC's base award as an Engineering Research Center as well as other, associated NSF grants.

Table III.1

NSF Cash Support to the PRC	
Type of Cash Support	**Cumulative Support 1995-2004**
NSF ERC Base Award	$27,740,191
NSF ERC Program Special Purpose	$5,030,163
NSF ERC Program Residual Funds	$1,688,808
NSF non-ERC Support	$149,937
Total NSF Support to the PRC	**$34,609,099**

Sponsored research support from outside the state attributable to the existence of the PRC.

The PRC also attracted support from other federal sources and private organizations that funded research and related activities carried out by PRC-affiliated faculty members and students. Such research support amounted to more than $74 million during the first ten years of the PRC's existence (Table III.2). Federal government agencies other than NSF funded the largest proportion of sponsored research support to the PRC—nearly $37 million. Associated contracts, contracts directly related to PRC's area of research and directed by PRC researchers but contracted through other Georgia Tech research units, formed an important component of this sponsored research support. Such contracts brought more than $19 million to the state of Georgia.

PRC staff and the Georgia Tech Research Corporation provided data to SRI on external research support from all sources. When any uncertainty existed about the role of the PRC in winning a contract, the most conservative assumption was made and the contract was dropped from the list of PRC-related awards. Private firms, irrespective of their membership status with the PRC, sponsored approximately $22 million in research through specific research contracts with the PRC during its first ten years. Of this amount, approximately $3.9 million come from contracts with firms located in Georgia. This amount was excluded from our final estimates of sponsored research support from industry, in keeping with our intent to include only non-Georgia sources of support to the PRC.

Table III.2

Sponsored Research Support to the PRC	
Type of Cash Support	Cumulative Support 1995-2004
Associated Contracts	$19,500,000
Industry Support (members+non-members)	$18,125,610
Federal Government Agencies (non-NSF)	$36,877,390
Foreign Government Support	$24,000
Other Sources of Sponsored Research	$257,763
Total Sponsored Research Support to PRC	**$74,784,763**

Member support to the PRC.

A core element of the PRC's mission is to engage interested firms and other related organizations in its research activities through several forms of partnerships and alliances. The PRC invites firms from all over the world to be members of the center on an annual basis. Membership costs each firm between $10,000 and $50,000 per year depending on the level of engagement. Membership offers a series of benefits including royalty-free, non-exclusive licenses to PRC inventions; access to the PRC's facilities, faculty and students; and access to a broad spectrum of intellectual property, workshops, and seminars.

The PRC has partnered with 198 companies over the last ten years, as full members or affiliates at varying levels of engagement and for varying spans of time. Of these, 28 companies are multinationals with headquarters located outside of the United States. These foreign firms contributed in excess of $1.4 million in membership fees. The PRC received over $6.5 million in membership fees from domestic member firms. However, some of these member firms were headquartered in Atlanta, and in other cases the division or subsidiary that formed the partnership with the PRC was located in Georgia. We worked with the PRC staff to identify the locations and the duration of membership of Georgia-based firms.

Georgia firms collectively contributed ten member-years to the PRC, mostly spanning the first five years of the PRC's existence. However, accurate data on the fees collected from these members were difficult to obtain. To be conservative, we assumed full membership for these firms and excluded $50,000 for each member-year, or $500,000, from the total amount of domestic membership fees paid to the PRC. Thus, the total amount of the PRC's income from non-Georgia members amounted to nearly $7.5 million (Table III.3).

Table III.3

Industry Support to the PRC through Membership Fees	
Source of Cash Support	Cumulative Support 1995-2004
U.S. Industry Membership Excluding GA Firms	$6,039,795
Foreign Industry Membership	$1,435,000
Total Member Support to the PRC	**$7,474,795**

In-kind support to the PRC from external sources.

In addition to the cash support received from federal government agencies and national and international industry partners, the PRC also received in-kind support from various sources. Such in-kind support came in two major forms: 1) as equipment, computer software, and hardware donated by firms and other donors and collaborating research organizations; and 2) as visiting researchers hosted by the PRC. These visiting researchers, while on the payroll of their sponsoring companies, contributed significantly to the PRC's research through their direct participation on research teams. Cumulative data on the value of in-kind support were obtained from the PRC's 10th year annual report; the total amounted to more than $52 million (Table III.4).

Table III.4

In-kind Support to the PRC	
Type of In-kind Support	Cumulative Support 1995-2004
Equipment Donations from US Industry Excluding GA Firms	$25,257,965
Other Sources of Equipment Donations	$22,743,549
Value of Personnel Visiting from US Industry Excluding GA Firms	$2,599,272
Value of Personnel Visiting from Foreign Industry	$2,080,124
Total In-kind Support to the PRC	**$52,680,910**

Licensing fees and royalties for intellectual property generated by PRC research.

As noted earlier in this report, Georgia Tech's Office of Technology Licensing keeps records of all income generated directly by PRC intellectual property. However, the interdisciplinary nature of the PRC, the collaborative relationship that exists among PRC researchers and other Georgia Tech researchers, and the complex contracting arrangements with members and non-members that sponsor research at the PRC, make it difficult to identify the extent of the PRC's influence on intellectual property generated in associated fields of research. The PRC documents and reports all inventions conducted and disclosed by PRC researchers, as well as all those inventions that were disclosed by faculty and researchers outside the PRC but influenced to some degree by PRC research.

Whereas compiling licensing income data for inventions disclosed and patented directly from PRC research is straightforward, the problem of attribution arises when compiling licensing income from inventions only partially attributable to PRC research. Licensing income from the three patents fully attributed to the PRC amounted to $15,000, whereas twenty patents partially attributed to the PRC generated $629,500 (Tables III.5 and III.6). Rather than attempt to obtain estimates of the degree of attribution for each of these twenty patents, we decided to exclude all income received from inventions indirectly related and partially attributable to PRC research.

Table III.5

Income from Inventions Directly Attributable to PRC Research

No.	Invention	Patent Number	Year	Licensed? (Yes/No)	Licensing Income Received
1	Low-cost High Performance No-flow Underfills for Flip Chip Devices Applications	1856	1997	Yes	$15,000
2	Characterization of Thin Film Polymer Dielectrics	2560	2001	Yes	0
3	A Thermally Degradable Epoxy System	2873	2003	Yes	0
Total Income from Inventions Directly Attributed to PRC Research					**$15,000**

Source: Georgia Tech Research Corporation

Table III.6

Income from Inventions Partially Attributable to PRC Research					
No.	**Invention**	**Patent Number**	**Year**	**Licensed? (Yes/No)**	**Licensing Income Received**
1	Synthetic Jet Actuators for Cooling Heated Bodies and Environment	1612	1995	Yes	$275,000
2	A Fully Integrated Magnetically Actuated Micromechanical Relay	1670	1995	Yes	$50,000
3	Air Gaps for Electrical Interconnections	1845	1996	Yes	$250,000
4	Inorganic and Organic Insulating Foams	2015	1998	Yes	$51,000
5	A Magnetic Switching System and Method	2052	1998	Yes	0
6	Design of Alternate Tests to Replace the Specification Tests for Analog Circuits	2116	1999	Yes	$1,000
7	Microfluidic and Microelectromechanical devices	2211	1999	Yes	0
8	Multi-Level Metal/ Air Gap Structures	2291	2000	Yes	0
9	Test Generation for High Frequency and RF Circuits	2292	2000	Yes	0
10	Method for Diagnosing Process Parameter Verifications from analog Circuit measurements	2293	2000	Yes	0
11	Method for Reduction of Time Required for Linearity Testing of ADC's	2294	2000	Yes	0
12	Partial Simulation Driven ATPG for Detection and diagnosis of Faults in Analog Circuits	2295	2000	Yes	0
13	Test Synthesis and Calibration for Accurate Prediction of Analog Specification	2296	2000	Yes	0
14	Business Model for Rapid Alternate Test of Analog and Mixed Signal Ics	2307	2000	Yes	0
15	Method for Automatically Generating and Optimizing Tests in Analog Circuits using Behavioral Models	2321	2000	Yes	0
16	Miniature Diaphragm-driven Liquid Pump that Produces a Column of Liquid Droplets	2341	2000	Yes	0
17	Miniature Diaphragm-driven Pulse Liquid Pump that Atomizes Liquid Layers	2342	2000	Yes	0
18	Higher Order Modulation Techniques for Optical Transceivers	2370	2000	Yes	0
19	Advanced Signal encoding/Decoding Techniques for Equalization of Multi-Level Optical Communication Signals	2393	2000	Yes	$2,500
20	Three-dimensional Microfluidic Device Fabrication	2445	2000	Yes	0
Total Income from Inventions Indirectly Related and Partially Attributed to PRC Research					**$629,500**

Source: Georgia Tech Research Corporation

Spending in Georgia by out-of-state attendees at PRC workshops.

The PRC organizes a number of workshops and conferences each year to foster the free exchange of cutting edge research results and to impart technical knowledge to industry and other users. These workshops range from short courses taught by a few professors to major international conferences such as the *International Advanced Flip Chip Workshop* held for four years in Braselton, Georgia, with hundreds of attendees. The conferences draw attendees from across the nation and the world. These out-of-state visitors spend money on lodging, meals, entertainment, transportation, etc., resources that would not have come to Georgia without the PRC.

To estimate the impact of out-of-state visitor spending at PRC workshops and conferences, the SRI study team first estimated the number of workshops held in Georgia in recent years and extrapolated that experience to the ten years of the PRC. We then counted the number of attendees and the number of non-Georgia attendees at a sample of events, and applied those ratios and attendance data to estimate the total number of non-Georgia attendees at workshops and conferences. Assuming an average three-day stay per visitor per conference, and federal government per-diem rates of spending per visitor-day,[9] we estimated that non-Georgia attendees spent approximately $800,000 while in Georgia attending PRC conferences and workshops (Table III.7).

Table III.7

Estimated Spending by Non-Georgia Attendees at PRC Workshops and Conferences held in Georgia	
Number of Workshops in GA	35
Average # Attendees per Workshop	80
Average % Non-GA Attendees	61%
Total # Non-GA Attendees	1,727
Total Attendee Days in GA	5,180
Spending per Visitor Night	$155
Estimated Total Spending	**$802,900**

[9] Federal government per-diem rate is $155 per day in Atlanta. U.S. Government Services Administration, *Domestic Per-Diem Rates,* Available at http://policyworks.gov/org/main/mt/homepage/mtt/perdiem/perd04d.html?menu_id=14 .

Impact of start-ups from PRC research that have located in GA.

As of the summer of 2004, four new companies have been formed based in PRC research: RF Solutions (acquired by Anadigics in 2003), Ardext Technologies, Quellan, and Jacket Micro Devices. Three of these companies are based on PRC technology and one is based on skills that PRC students developed. All four firms are located in metropolitan Atlanta.

A typical approach to estimating the impact on the local economy of start-ups from university-based research is to multiply the number of employees by the sum of the average salary and benefits of technical employees in small, high-tech firms. As Table III.8 shows, with the exception of 2003, total employment for the four PRC start-ups has risen annually and now totals 73. Thus, over a period of eight years since the first start-up was formed in 1997, PRC start-ups have generated 288 employee-years in scientific research and technical services fields. In order to quantify the economic impact of this employment, we used 1997 Economic Census data published by the U.S. Census Bureau. PRC start-ups fit the "Professional, Scientific, and Technical Services" category of the North American Industrial Classification System (NAICS) used by the Census Bureau. Salaries for employees in this category in metropolitan Atlanta average at $45,970 per year. Using this statistic[10], we estimate the total value of employment generated by PRC start-ups to be $13,239,430.

Table III.8

PRC Start-up Companies: Estimated Number of Employees in Georgia, 1995-2004								
Name of Start-Up	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Employee-years**
RF Solutions/Anadigics (1)	3	5	25	39	42	20	25	**159**
Ardext			6	7	4	5	6	**28**
Quellan				6	21	27	32	**86**
Jacket Micro Devices						5	10	**15**
Total	**3**	**5**	**31**	**52**	**67**	**57**	**73**	**288**

[10] This calculation is based on estimates of pre-tax direct salaries. In other words, it does not include other employer paid benefits such as health care and social security contributions. This was done to simplify calculations which otherwise would include estimates of employer-paid fringe benefits minus certain deferred compensations (employer paid benefits such as social security and retirement account contributions do not have a direct or immediate impact on the state economy and so are usually not included in impact analyses). In addition to simplifying the calculation of employment impacts, this also results in a more conservative overall estimate.

Impact of spin-ins, companies attracted to Georgia in part because of the existence of the PRC.

The existence of the PRC has attracted or influenced the relocation decisions of four companies, thereby generating new jobs in the state. From the "parent" company's perspective, these companies were spun out as a business venture. From the state/university perspective, these companies initiated a business venture in Georgia to take advantage of resources (people, tools, ideas) available there. The decision to locate in Georgia was partially, but not necessarily completely, influenced by the presence of the PRC. Employment data on PRC spin-ins, shown in Table III.9, represent the total employment in Georgia for each company, but not all of these jobs can be attributed to the presence of the PRC. To address the problem of attribution, SRI contacted representatives of these companies to obtain estimates of the degree of influence that the existence of the PRC had on these relocation decisions.

SRI learned that Gloconn would not have opened an office in Georgia in the absence of the PRC; therefore the existence of Gloconn and the employment generated in Georgia by the firm was fully attributed to the existence of the PRC. Similarly, SRI's interview with the Siemens/Engent representative indicated that the existence of the PRC had approximately a 75 percent influence on the company's decision to locate in Georgia. Because of the varying degrees of influence of PRC on the location decisions of these spin-in companies in Georgia, SRI used an "influence factor" to weight the number of jobs created by these firms. Applying influence factors of 1 for Gloconn, 0.75 for Engent, and 0.5 each for Lucent and Harima Chemicals, SRI estimated that 108 employee-years were generated in Georgia by these firms because of the existence of the PRC.

The economic impact of these spin-ins, based on the number of employee-years and average salary levels, was estimated using the same method as for start-ups. The resulting estimated value to Georgia of employment from PRC spin-in companies was $4,953,294.

Table III.9

PRC Spin-In Companies: Estimated Number of Employees in Georgia, 1995-2004									
Name of Company	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Weighted Employee-years**
Lucent PRC (1)	5	38	41	20	5	0	0	0	**54.5**
Gloconn/Clo Tech		3	3	3	2	1	0	0	**12**
Siemens/Engent (2)					4	11	14	18	**35.3**
Harima Chemical								12	**6**
Total	**5**	**41**	**44**	**23**	**11**	**12**	**14**	**30**	**107.75**

(1) Lucent PRC was folded into a local business unit in 2001

(2) Siemens Dymatec division set up as separate company in 2002 and changed its name to Engent

Source: PRC staff & SRI estimates

Value of cost savings to firms in Georgia that have hired PRC graduates.

PRC graduates bring advanced technical knowledge and specialized research and development experience to the firms that hire them upon their graduation. Such skills and experience are highly valued in industry, as they significantly reduce the time required for technical training and also reduce the burden on managers of mentoring and supervision. Reduction of training and mentoring translates to cost savings for the hiring firms, with the level of cost savings varying with the new employee's education and research experience.

Over the last ten years, Georgia companies hired 3 PRC graduates with Bachelor's degrees, 8 graduates with Master's degrees and 17 graduates with Ph.Ds. SRI estimates that Georgia firms hiring PRC graduates benefited through one-time cost savings of $50,000 per BS graduate, $70,000 per MS graduate, and $100,000 per PhD. These estimates were based primarily on informal discussions between SRI staff and several ERC industrial liaison officers, and are supported by other studies.[11] Our discussions suggested that a newly-hired ERC PhD graduate requires approximately a year's less mentoring time by a company staff member than a comparable, non-ERC graduate. Based on the above assumptions, the total value of cost savings to Georgia firms hiring PRC graduates was estimated to be $2,410,000.

[11] The cost savings to the hiring firm were estimated to be approximately $100,000 per PhD, using the mentor's annual full compensation as the basis for this estimate. We extrapolated from this to estimate cost savings of $70,000 per ERC MS hire and $50,000 per BS hire. These figures are supported by results of surveys conducted by the Semiconductor Research Corporation (SRC). Companies that hire students supported by SRC contracts estimate cost savings of at least $100,000 per student. See http://www.src.org/member/students/mem_benefits.asp

Value of technical assistance and consultation provided at no cost by PRC faculty and staff to non-member firms in Georgia.

To be included in the set of PRC activities that generate economic impacts in Georgia, the PRC staff's unpaid assistance to firms must draw directly on PRC research, and the beneficiary must be located in Georgia. All of the Georgia-based firms receiving "pro bono" assistance were affiliates of the PRC. Affiliates are firms that have engaged in substantial collaboration with the PRC, and have contributed to Center research, education, or infrastructure without a formal PRC membership agreement. The value of informal assistance or consultation provided to PRC member firms is excluded from this category of impacts.

As noted previously, PRC staff provided SRI with estimates of the value of this pro bono assistance to each PRC affiliate located in Georgia over the Center's ten-year existence. These estimates were developed by first estimating the number of person-days of assistance provided to each firm, and then multiplying this by an average consulting rate, in this case a very conservative $500 per day (typical Georgia Tech faculty consulting rates are more like $1000 per day). Table III.10 lists Georgia affiliates that were provided pro bono services by PRC researchers during 1995-2004, the estimated value of those services for each company, and the total estimated value over the period: $675,000.

Table III.10

Estimated Value of PRC Technical Assistance and Consultation Provided Pro Bono to Georgia-based Companies, 1995-2004		
Company	**Location**	**Estimated Value***
Amoco	GA	$ 50,000
Ardext Technologies	GA	$ 50,000
Bell South	GA	$ 25,000
Circuit Technologies	GA	$ 25,000
Electronic Packaging Services	GA	$ 75,000
Engent (formerly Siemens)	GA	$ 50,000
GloConn	GA	$ 25,000
Harima Chemical-GA	GA	$ 25,000
Jacket Micro Devices	GA	$ 25,000
Lockheed Martin	GA	$ 25,000
Lucent GA	GA	$ 25,000
MicroCoating	GA	$ 75,000
Movaz	GA	$ 25,000
Polymer Aging (formerly Ken Watkins Assoc.)	GA	$ 25,000
Protosystems	GA	$ 25,000
Quellan	GA	$ 50,000
RF Solutions	GA	$ 75,000
Total		**$ 675,000**

* Estimated number of person-days of pro-bono assistance by PRC staff at $500/day for ten years of PRC existence, 1995-2004.

Source: PRC staff

PRC's total direct economic impact.

In summary, the existence of the PRC has led to the inflow of substantial amounts of research funding to Georgia from the private sector and federal government agencies, has created employment in the state, resulted in cost savings to Georgia firms, and generated income from intellectual property. As the following table shows, the total direct economic impact of PRC on Georgia is estimated to be more than $191 million (Table III.11).

Table III.11

The PRC's Total Direct Quantifiable Economic Impact on Georgia	
External Income to Georgia	**Cumulative 1995-2005**
Support to PRC from the National Science Foundation	$34,609,099
Sponsored research support from outside GA to PRC researchers	$74,784,763
PRC membership fees from non-Georgia member firms	$7,474,795
In-kind support from non-Georgia firms	$52,680,910
Intellectual property income from non-Georgia firms for PRC inventions	$15,000
Consulting income to PRC faculty/staff from non-Georgia firms	(not available)
Spending by Non-GA Attendees to PRC workshops in Georgia	$802,900
Total External Income to GA	**$170,367,467**
Value of Increased Employment in Georgia	
Value of employment created by PRC start-up companies located in Georgia	$13,239,430
Value of employment created by new ventures located in Georgia due to the presence of PRC	$4,953,294
Total value of increased employment in Georgia	**$18,192,723**
Improved Quality of Technical Workforce in Georgia	
Value of PRC graduates hired by Georgia firms	$2,410,000
Total value of improved quality of technical workforce in Georgia	**$2,410,000**
Other Benefits to Georgia Firms	
Value of pro bono assistance by PRC researchers to Georgia firms	$675,000
Total (quantifiable) value of other benefits to Georgia firms	**$675,000**
Total Quantifiable Direct Economic Impact	**$191,645,190**

The PRC's Non-quantifiable Economic Impact on Georgia

SRI's studies for the NSF of the impact on industry of member participation in ERCs and other university-based industrial consortia indicate clearly that the less tangible, longer-term, and difficult-to-quantify benefits of membership are substantial, typically exceeding the costs of membership.[12] It is important, therefore, in an impact study such as this to describe the magnitude and variety of non-quantifiable impacts on

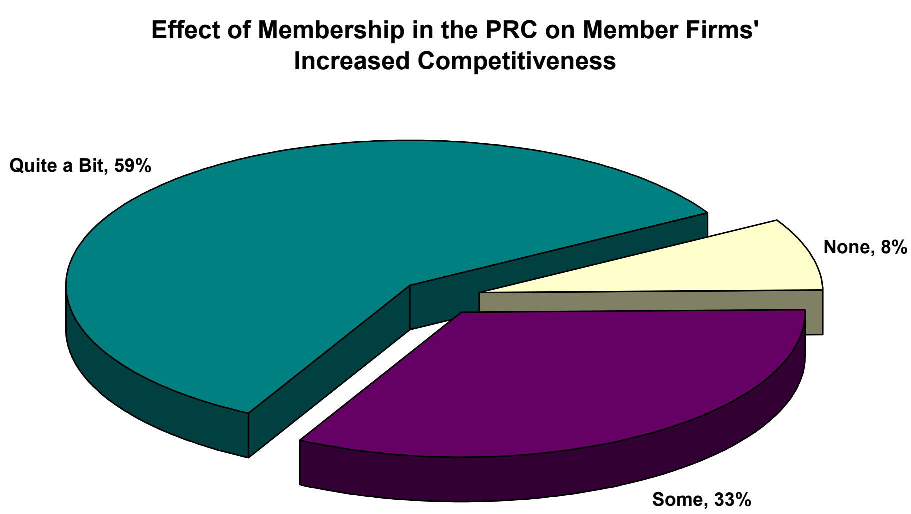
[12] J. David Roessner, David W. Cheney, and H. R. Coward, *Impact on Industry of Interactions with Engineering Research Centers – Repeat Study.* Arlington, VA: SRI International. Final Report to the National Science Foundation, Engineering Education and Centers Division, 2004; David Roessner, *Outcomes and Impacts of the State/Industry University Cooperative Research Centers (S/IUCRC) Program*. Arlington, VA: SRI International, October 2000. Final Report to the National Science Foundation Engineering Education and Centers Division; Catherine P. Ailes, J. David Roessner, and Irwin Feller*. The Impact on Industry of Interaction with Engineering Research Centers*. Arlington, VA: SRI International, January 1997. Final Report prepared for the National Science Foundation, Engineering Education and Centers Division.

Georgia. Examples, some of which were referred to earlier in this chapter, include effects on a company's competitiveness, and a wide range of specific benefits that have positive economic implications for the firm, including access to new ideas and know-how, access to facilities, improved information for suppliers and customers, product and process improvements, and information that influences the firm's R&D agenda.

The PRC's impact on member firms' competitiveness

In 2002, as part of a study of the impact on industry of member firms' participation in ERCs, SRI conducted a survey of all companies that were currently members of eight ERCs that began operations in 1994-96. One of the ERCs whose members were surveyed was the PRC. As a result, we have data from PRC member firms' representatives regarding the effect that PRC membership had on the firm's competitiveness. As Figure III.2 shows, membership in the PRC was reported to have increased the competitiveness of nearly 60 percent of PRC members by "quite a bit," and another 33 percent by at least "some." Only 8 percent reported no impact on competitiveness. Over the PRC's ten-year existence, 17 Georgia firms have collaborated with PRC researchers as either members or affiliates. It is highly likely that the pattern of substantial impacts on firm competitiveness reported by PRC members in our 2002 survey is representative of the impacts that these collaborations have had on the Georgia-based members and affiliates.

Figure III.2



Specific benefits that PRC members realize

As part of its 2002 survey of ERC members, SRI also asked representatives of member firms to identify specific benefits their firm received as a result of participating in the ERC. The thirteen PRC members responding to the survey reported overwhelmingly that they obtained access to new ideas or know-how, that their R&D agendas were influenced, that they were able to provide their customers or suppliers with improved information, and that they improved a product or process (Table III.12). As the table shows, a significant portion of PRC members received other important benefits as well. While the economic value of these benefits could not be specified in quantitative terms, it is apparent that these benefits are both varied and substantial. Again, there is every reason to assume that, over the period of the PRC's existence, Georgia firms that joined the PRC realized these benefits in much the same proportion that PRC members did nationwide.

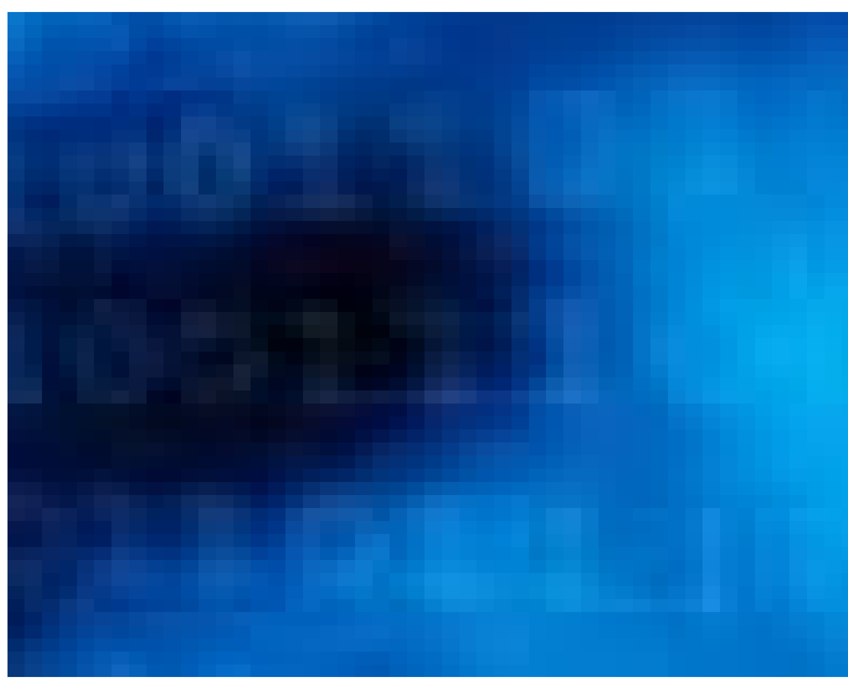
Table III.12

Specific Benefits of Participation in the PRC Reported by PRC Members, 2002

Benefit	per cent responding
We obtained access to new ideas or know-how.	85
Our R&D agenda was influenced.	69
We were able to provide our customers/suppliers with improved technical information.	69
We improved a product(s) or process(es).	62
We developed a new product(s) or process(es).	46
We hired ERC student or graduate	40
We had more interaction than in the past with other ERC firms.	38
We licensed technology or software developed by the ERC.	15
We patented or copyrighted technology or software we developed as a result of interacting with the ERC.	15
We made unexpected operational changes (e.g., equipment or project additions or cancellations).	8

Source: SRI survey, 2002

CHAPTER IV: THE PRC's SECONDARY AND TOTAL IMPACTS ON GEORGIA



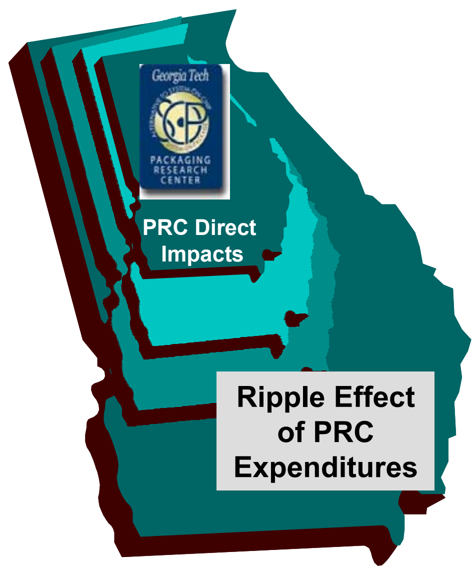
The bulk of this chapter is devoted to discussing the background, assumptions, and methodology SRI used to estimate the secondary indirect and induced impacts of the PRC's activities on Georgia's economy. Following presentation of the results of these secondary impact calculations, we combine the quantifiable direct and secondary impacts to produce an estimate of the total economic impact the PRC has had on Georgia. Additional information is then provided on the PRC's employment impacts on the state, and a financial "return on investment" is calculated that states our results in terms of the returns to Georgia's taxpayers from their $32.5 million investment in the PRC.

Secondary Impacts of the PRC's Activities

Many of the immediate impacts attributable to the PRC that were described in Chapter III will further affect the Georgia economy as firms and employees spend or invest their new earnings (or cost savings) within the state. This ripple effect, as new spending is filtered throughout the economy in subsequent rounds of economic activity, is made up of two components:

- Indirect impacts – Purchases of goods and services from other firms by the businesses that directly benefit from PRC-related activities.

- Induced impacts – Purchases of goods and services (food, housing, transportation, recreation, etc.) by employees whose earnings are derived from PRC-related activities.



In this way, the impact of original spending is amplified as it is re-spent by firms and consumers throughout the economy.

We next review briefly various approaches to estimating indirect and induced impacts and summarize how analysts estimating the impact of similar research centers have tackled this issue. We then describe how indirect and induced impacts were estimated for the PRC and discuss the results.

Review of Similar Impact Studies and Results

Economists have long been concerned with developing methods for assessing the impact of various kinds of projects on area economies. This is a complex issue because the same project may have radically different total impacts in different regions depending on each region's unique economic characteristics. Particularly important is how close the inter-industry relationships are within the region in the sectors being affected. For example, a construction project in an area where most building materials must be imported from outside the region will have a much different impact from the same project in an area where building inputs are produced by local suppliers. In the first case, a large portion of the original spending flows to firms and suppliers outside the region. In the second case, more of the resources circulate in the regional economy as local firms ramp up production, ordering inputs from their local suppliers and creating employment opportunities for area workers.

Since the ripple effect of resources flowing through an economy can be as large as or even larger than the original direct impacts, this calculation can be critical to assessing both the expected worth and actual impact of a given project. In order to estimate these indirect and induced impacts, economists have used a number of approaches:

- Econometric models. The first, and by far the most resource-intensive approach, is to either construct or apply a dynamic econometric model of the regional economy. Such models are complex representations of the current state and behavior of the regional economy. They include estimates of the relationship between key variables such as how the attractiveness of an area for business investment and retention depends on the availability of high-quality human capital. Because such models are very data intensive to create and require analysts to estimate the interactions among many variables, they are not usually created specifically for regional economies. Instead, most analysts rely on generalized models based on quite detailed regional data (mostly from government sources) and estimates of the interactions between these variables based on nation-wide studies.[13] To estimate the impact of a given project or activity, the analyst "models" it within the economic system and observes changes in

[13] An example of this type of model is Regional Economic Models, Inc's, REMI Policy Insight model (www.remi.com).

relevant variables of interest as subsequent spending and investing is carried out within the model.

- Input-Output based models. Input-Output (I-O) matrices are a representation of industrial trade and production. They tell how much each industry must purchase from every other industry in order to produce a dollar of sales. Regional input-output figures tell us how much individuals and businesses spend on different types of goods and services from within a region. Analysts can use regional input-output data to calculate multipliers that relate total impacts to original direct impacts. Fortunately, analysts do not have to resort to generating their own data on regional spending patterns in order to estimate these multipliers since several multiplier models are commercially available. These are predominantly based on the U.S. Department of Commerce's national and regional input-output and trade data.[14]

- Apply a multiplier based on available literature. Where resources are tight and the analysis is of a particular type of project that has been studied extensively in the past, analysts sometimes use a multiplier that is not based on specific data, but rather on a review of what has been used in other, similar studies.

The choice between the above options for estimating total economic impacts depends on the resources available (time, data, and financial resources), and the nature of the project being analyzed. Before initiating an assessment of the secondary impacts of PRC spending, SRI reviewed similar analyses of research centers.

While this is the first impact study of an Engineering Research Center, analysts have estimated the economic impact of research entities more broadly, and there is a wide body of research on the impact of universities. Table IV.1 summarizes the approaches and results of the most relevant of these studies (a more complete list can be found in the Appendix).

- University Impact Studies – University impact studies are normally undertaken by individual universities to quantify their economic impact on the communities in which they operate. Many of these

[14] Minnesota IMPLAN Group's IMPAN model (www.implan.com) and the U.S. Department of Commerce, Bureau of Economic Analysis' Regional Input-Output Modeling System (RIMSII, http://www.bea.gov/bea/regional/rims/) are two prominent examples.

use an impact framework that closely follows that developed by the American Council on Education.[15] This includes salary expenditures by the institution, non-salary purchases by the institution, spending by students, and spending by visitors. A smaller group of these also attempts to calculate the value of universities in terms of improving a region's labor force[16] and their role in fostering start-up companies. The majority of these studies use RIMS II or IMPLAN to develop multipliers for their region.

- Research Center Impact Studies – Like university impact studies, studies of research centers have used an expenditure-based framework to calculate impacts. These have generally focused on three broad expenditure categories: salaries, other institutional spending, and visitor expenditures (particularly for medical centers). While many of these studies do quantify the number of start-ups and intellectual property being generated by the research centers, none assigns an economic impact to these. The majority of these studies use multipliers to estimate total impacts. Unfortunately, it is unclear how most of these multipliers were developed.

[15] Caffrey, John and Herbert Isaacs, "Estimating the Impact of a College or University on the Local Economy" American Council on Education (ACE), 1971.
[16] See, for example, Robert Carr and David Roessner, *Economic Impact of Michigan's State Universities*. Final report to the Michigan Economic Development Corporation, Arlington, VA: SRI International, May 2002.

Table IV.1

Summary Of Relevant Impact Studies			
Study Description	**Impact Area**	**Modeling Approach Used**	**Impact**
University Impact Studies			
University System of Georgia (2002)	Individual GA system host communities	Expenditure framework with multipliers estimated using IMPLAN. Aggregate income multiplier of 1.56 used.	Impact of Georgia system total $8 billion in 2001 on local economies.
Georgia Center for Continuing Education (1996)	10 GA counties	Modification of ACE framework. Aggregate impact multiplier of 1.92.	Total economic impact of $20.2 million on direct effects of $10.5 million.
Emory University (2000)	Atlanta Metro area	Expenditure framework (ACE) with I-O multipliers from RIMS. Aggregate output multiplier of 2.24.	In 1999, Emory had a direct economic impact of $1.5 billion and $3.4 billion total.
Research Center Impact Studies			
Centers for Disease Control (2002)	State (GA)	Expenditure based framework, multipliers from RIMS. Aggregate multiplier of approx. 2 used.	CDC's 1.3 billion spending in GA resulted in $2.5 billion in increased output.
New York Centers for Advanced Technology (1992)	State	Benefit-cost framework of direct impacts – secondary impacts not examined.	State investment of $61 million generated benefits of $190 (low estimate) to $360 million (high estimate).
University of Kentucky Research and External Funding (2004)	State	Expenditure based framework with I-O multipliers from IMPLAN model. "Research multiplier" of 1.8.	State funding of research of $49 million helped generate additional $189 in external funding for research, which had a total impact of $311 million.

SOURCES: Duhant, 2002; Enterprise Canada Research, 2000; Georgia Center for Continuing Education, 1996; Emory University, 2004; University of Kentucky, 2004; SRI International, 1992; KPMG, 2002.

Based on SRI's review of previous studies, several things became clear. First, both universities and research centers consistently have large economic impacts on their relevant regions. Second, total final impacts vary enormously depending in part on the scope of the area being studied – whether it is a metro area, a state, or the whole country.[17] Third, SRI found no studies that were specifically of electronics research entities or of other comparable research groups in Georgia.

[17] In large part, this is simply the result of how economies and multipliers work. A state will always have a larger multiplier than any metro area within it since the state has a broader scope for resources to circulate.

Because of the short time frame available for our analysis and the lack of directly applicable previous studies, SRI used the Bureau of Economic Analysis' Regional Input-Output Modeling System (RIMS II)[18] to estimate secondary impacts. In addition to being readily available and affordable, RIMS II has been shown to produce estimates that are similar to the estimates based on relatively expensive original surveys and models.[19] Because of its affordability and ease of use, RIMS II is most likely the source of many of the multipliers used in the studies referred to above.

Methodology – Applying the RIMS II Model

Applying the RIMS II model involves three basic steps: defining direct impacts that generate secondary effects, selecting appropriate multipliers, and using the multipliers to estimate indirect and induced impacts. For the most part, the direct impacts described in the previous section are used as the main inputs in calculating secondary indirect and induced impacts. However, not all direct impact segments generate secondary impacts. For example, while in-kind contributions of services and materials allow the PRC to perform more effective research with the same research dollars, they do not represent a tangible financial flow. In the same way, pro-bono consulting by PRC researchers provides valuable services to area companies, but does not represent resources that will be subsequently spent throughout the Georgia economy. Therefore, the following direct impact segments were excluded from secondary multiplier calculations:

- In-kind equipment donations,
- Value of PRC graduates hired by Georgia firms, and
- Value of pro bono assistance by PRC researchers to Georgia firms.

SRI purchased RIMS II multipliers for the state of Georgia from the Bureau of Economic Analysis, and identified appropriate detailed industry sector multipliers for each relevant direct impact segment. These are outlined in Table IV.2 below. For those impact segments that represent resources flowing through the PRC (external income from the National Science Foundation, industry membership fees, etc.), the multiplier for the

[18] See: U.S. Department of Commerce, Bureau of Economic Analysis), *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II)*. Washington, DC: US Government Printing Office, 1997.

[19] See: Sharon, Hastings and Latham, "The Variation of Estimated Impacts from Five Regional Input-Output Models", *International Regional Science Review* 13: 119-39, 1990; and Lynch, Tim, "Analyzing the economic Impact of Transportation Projects Using RIMS II, IMPLAN and REMI" Report for U.S. Department of Transportation, Florida State University, 2000.

"scientific research & development services" industry (RIMS Industry number 541700) was used. Implied in this choice is the assumption that the PRC and its employees share a similar spending profile to other scientific research and development services companies in Georgia on which the RIMS II model is based.[20]

For those segments that are income estimates, the multiplier for the household sector was used. This applies to the value of in-kind visitor researcher support (which is essentially visitor salaries for the time they are visiting in Georgia), and the value of employment in Georgia. For spending in Georgia by non-Georgia attendees at PRC workshops, a blended multiplier was created that represents the breakdown of the typical business visitor's spending – 55 percent on accommodations, 25 percent on meals (food services and drinking places), 10 percent on local retail, 5 percent on recreation and entertainment, and 5 percent on ground passenger transportation.

Table IV.2

Multipliers Used To Estimate Secondary Impacts	
Direct Impact Category	**Total Output Multiplier**
EXTERNAL INCOME TO GEORGIA	
Support to PRC from the National Science Foundation	2.268
Sponsored research support from outside GA to PRC researchers	2.268
PRC membership fees from non-Georgia member firms	2.268
In-kind visiting researcher support from non-Georgia firms	1.454
Intellectual property income from non-Georgia firms for PRC inventions	2.268
Spending by Non-GA Attendees to PRC workshops in Georgia	2.187
VALUE OF INCREASED EMPLOYMENT IN GEORGIA	
Value of employment created by PRC start-up companies located in Georgia	1.454
Value of employment created by new ventures located in Georgia due to the presence of PRC	1.454

Results: Indirect and Induced Impacts on Georgia

Given relevant final output multipliers from RIMS II and direct impact estimates, estimating indirect and induced impacts was a straightforward calculation involving multiplication of direct impacts by their corresponding segment multipliers. Total direct impacts of the PRC's activities amounted to $192 million over ten years. These direct impacts generated secondary impacts of $159 million, for an implied aggregate multiplier of

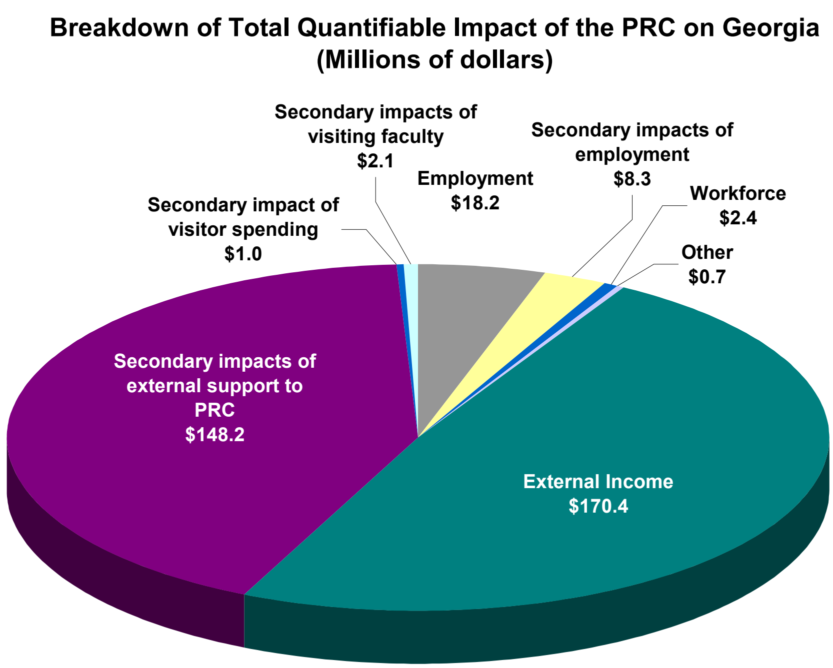
[20] Another approach would be to look at detailed geographic and industry spending by the PRC (how much for salaries, how much for services in Georgia, how much for capital equipment from Georgia firms, etc.). Unfortunately this level data was not available.

1.83.[21] For comparison, the implied aggregate multipliers found in the literature ranged from 1.5 to 2.3.

Total Quantifiable Economic Impacts

The total net quantifiable economic impacts of the PRC's activities on Georgia are the direct impacts detailed in Chapter III plus secondary indirect and induced impacts. The PRC has had a direct impact on the Georgia economy of $192 million, with secondary impacts of $159 million, for a total economic impact of $351 million over ten years (See Table IV.3 on following page). The majority of this impact is from external support that the PRC has attracted from sources outside Georgia, 92 percent of the total (Figure IV.1). The direct and secondary impacts of the employment generated in Georgia as a result of the PRC is the second largest impact segment, 7 percent of the total. Workforce and other impact areas amounted to just 1 percent of the PRC's total quantifiable impact over its ten year existence. As discussed elsewhere in this report, this result does not imply that these impact areas will be unimportant in the longer term.

Figure IV.1



[21] Multipliers are generally specific to certain types of expenditures in the economy. This "aggregate" multiplier refers to total secondary impacts over all direct impacts and is a useful way to compare the importance of secondary impacts across projects or studies.

Table IV.3

Total Quantifiable Economic Impacts of the PRC			
	Direct Impacts	Indirect & Induced Impacts	Total
EXTERNAL INCOME TO GEORGIA			
Support to PRC from the National Science Foundation	$34,609,099	$43,870,494	$78,479,593
Sponsored research support from outside GA to PRC researchers	$74,784,763	$94,797,166	$169,581,929
PRC membership fees from non-Georgia member firms	$7,474,795	$9,475,050	$16,949,845
In-kind support from non-Georgia firms	$52,680,910	$2,124,446	$54,805,356
Intellectual property income from non-Georgia firms for PRC inventions	$15,000	$19,014	$34,014
Spending by Non-GA Attendees to PRC workshops in Georgia	$802,900	$953,307	$1,756,207
Total external income to GA	**$170,367,467**	**$151,239,477**	**$321,606,944**
VALUE OF INCREASED EMPLOYMENT IN GEORGIA			
Value of employment created by PRC start-up companies located in Georgia	$13,239,430	$6,010,701	$19,250,131
Value of employment created by new ventures located in Georgia due to the presence of PRC	$4,953,294	$2,248,795	$7,202,089
Total value of increased employment in Georgia	**$18,192,723**	**$8,259,496**	**$26,452,220**
IMPROVED QUALITY OF TECHNICAL WORKFORCE IN GEORGIA			
Value of PRC graduates hired by Georgia firms	$2,410,000		$2,410,000
OTHER BENEFITS TO GEORGIA FIRMS			
Value of pro bono assistance by PRC researchers to Georgia firms	$675,000		$675,000
TOTAL QUANTIFIABLE IMPACT ON GEORGIA	**$191,645,190**	**$159,498,973**	**$351,144,163**

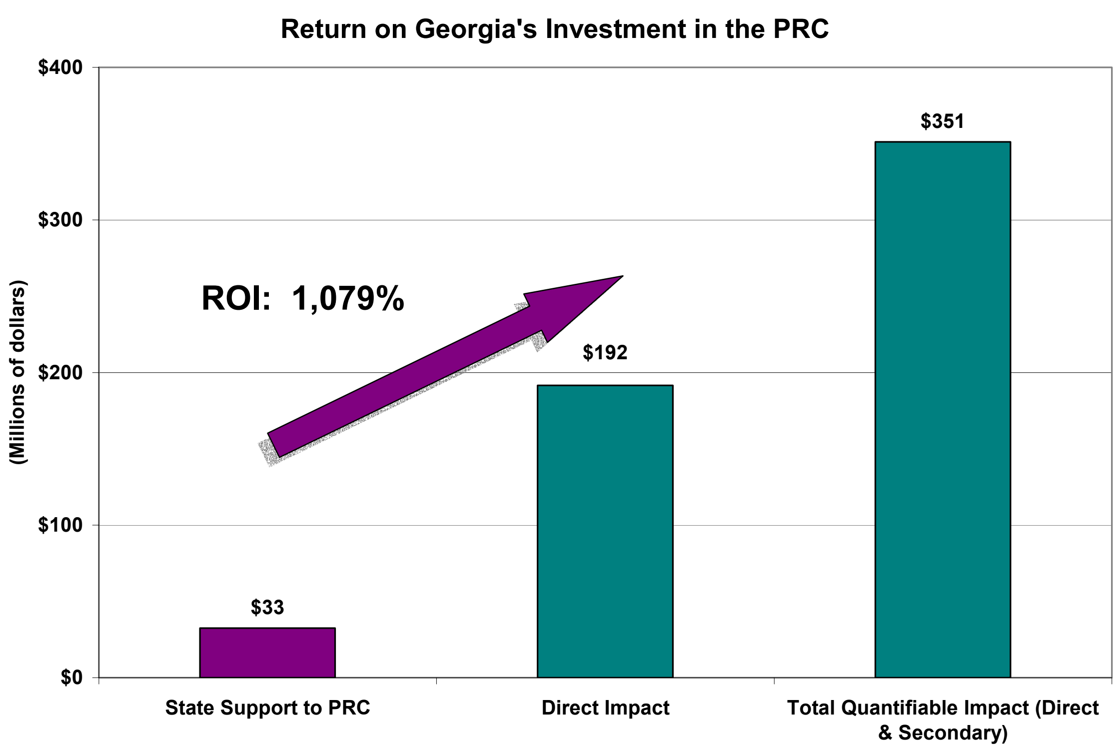
Employment Impacts

Another way to look at economic impacts is to consider jobs created or supported. The PRC directly employs research faculty, support staff, and students. It has also been central in the attraction of several spin-in companies, and its research has helped create several start-up companies in Georgia. But these jobs and the day-to-day operations of the PRC further support other jobs in Georgia that supply goods and services directly or indirectly to the PRC and its employees. Use of the same approach outlined above for the calculation of secondary impacts[22] shows that the PRC's activities supported 343 jobs in Georgia.[23]

Return on Investment

As a major funder of the PRC, the State of Georgia is justified in asking what return it has received from its investment in the Center. In purely quantitative economic impact terms, the state's investment of $32.5 million has helped attract external support for activities that had a total economic impact on Georgia of $351 million. In other words, every dollar of state investment in the PRC has had a 10 dollar impact on the state economy. This represents an impressive leveraging of the state's original investment in the PRC, a financial "return on investment" (ROI) of 1,079 percent. This is depicted graphically in Figure IV.2.

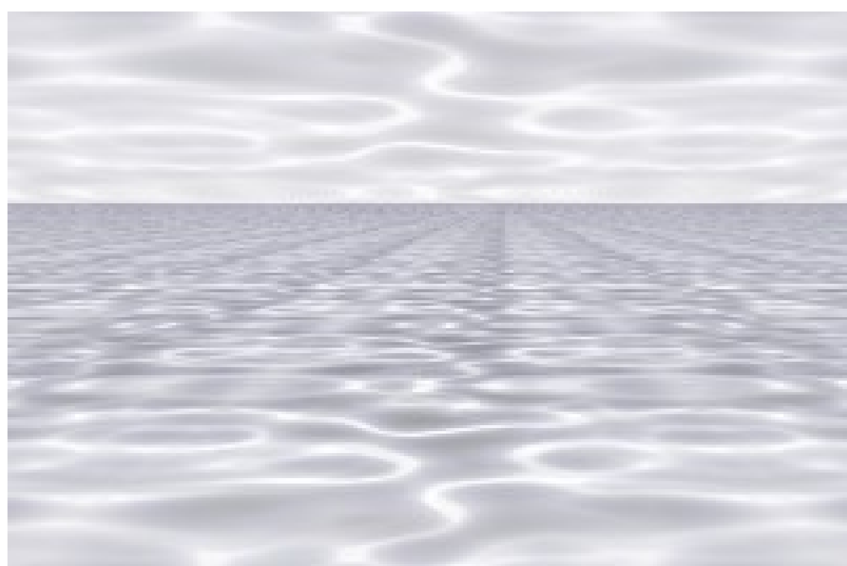
Figure IV.2



[22] Specifically, job-multipliers were used instead of output-multipliers for each relevant impact segment from RIMS II.

[23] Actually, job estimates are calculated in terms of "job-years" created from direct impacts. Thus, PRC's activities have created 3,433 job-years, which SRI converted into an annual average of 343 jobs over the ten year lifetime of the PRC.

CHAPTER V: CONCLUDING OBSERVATIONS AND EXPECTATIONS FOR THE FUTURE



The Packaging Research Center's substantial economic impact on Georgia represents a very high return on the state's investment. In quantifiable terms, Georgia's investment of $32.5 million over ten years yielded a total impact of over $350 million, the sum of direct, indirect, and induced effects. Start-up companies based in PRC research, new ventures initiated in Georgia at least partially influenced by the existence of the PRC, direct employment by the PRC, and jobs induced by PRC expenditures were responsible for an average of more than 340 jobs annually over the period 1995-2004. Through countless informal collaborations between PRC researchers and companies in Georgia, additional benefits to the state's high-tech industry have been realized. Examples of these substantial but difficult-to-quantify benefits to PRC member firms and non-members alike include increased competitiveness, the additional value of PRC-trained students as new hires, access to new ideas and PRC facilities, and improved information for suppliers and customers. Research by SRI and others on programs intended to foster industry-university research collaboration indicates that the value of these kinds of benefits to participating companies considerably exceeds the cost of their memberships. In sum, in assessing the overall economic significance of the PRC, the variety of impacts, the paths by which those impacts are realized, and the importance of both quantifiable and non-quantifiable impacts all stand out as significant ways in which the payoffs to Georgia taxpayers are realized.

Looking to the next ten years, we note that investment in the PRC is just beginning to yield valuable results in several areas directly related to sustained regional economic growth: start-ups, spin-ins, intellectual property, and human capital. Over the next decade, the PRC will devote increased attention and resources to fostering start-up companies and realizing the commercial potential of new technologies based in PRC research. In both these areas, results began to emerge during the last five years, and there is every indication that such outputs will increase as the PRC's earlier investments in "upstream" research yield additional commercial opportunities. (It is typical for commercially promising, university-based research results to require 7-10 years of refinement and development before marketable technologies are produced.) We would also expect the number of BS, MS, and PhD students trained in the PRC's industry-friendly research environment to increase, and for more Georgia companies to benefit from hiring them. Informal interactions between Georgia companies and PRC staff are also likely to increase, producing cost savings and other benefits such as product improvements.

Assuming that the PRC continues to evolve and flourish, we anticipate that by 2014 the PRC's economic impact on Georgia will exhibit a different, more balanced, and more commercially-oriented pattern, and that its value will exceed the $350 million mark established in its first decade.

APPENDIX: SUMMARY OF RELEVANT IMPACT STUDIES

Table A.1

Summary of Relevant Impact Studies			
Study Description	**Impact Area**	**Modeling Approach Used**	**Impact**
University Impact Studies			
University of Massachusetts/ Boston (1993)	State	Expenditure framework with multipliers estimated from Multi-Regional Policy Impact Simulation Model (MRPIS). Income multiplier of 1.341 used.	State government rate of return of 8.9 percent on investment (not counting additional funds attracted to region because of Umass).
Emory University (2000)	Atlanta Metro area	Expenditure framework (ACE) with I-O multipliers from RIMS. Aggregate output multiplier of 2.24.	In 1999, Emory had a direct economic impact of $1.5 billion and $3.4 billion total.
University System of Georgia (2002)	Individual GA system host communities	Expenditure framework with multipliers estimated using IMPLAN. Aggregate income multiplier of 1.56 used.	Impact of Georgia system total $8 billion in 2001 on local economies.
Georgia Center for Continuing Education (1996)	10 GA counties	Modification of ACE framework. Aggregate impact multiplier of 1.92.	Total economic impact of $20.2 million on direct effects of $10.5 million.
San Diego State University (1995-96)		Expenditure focus with I-O based multipliers. Income multiplier of 1.42 used.	
University of Washington (1997)		Expenditure focus with I-O multipliers. Income multiplier of 1.57 used.	
University of Wisconsin (1997)		Expenditure framework (ACE) with I-O multipliers. Income multiplier of 2.34.	
Rensselaer Polytechnic Institute (2001)	NY State	Expenditure model with I-O multipliers from IMPLAN. Implied final output multiplier of 1.56.	Direct impacts of $278 million in 2001 generated total impacts of $435 million on NY State.
West Virginia University (1998)		Expenditure model with I-O multipliers from IMPLAN. Income multiplier of 1.66.	
Connecticut independent colleges & universities (1996)	State	Expenditure model with I-O income multiplier of 2.33.	
Research Center Impact Studies			
New York Centers for Advanced Technology (1992)	State	Benefit-cost framework of direct impacts – secondary impacts not examined.	State investment of $61 million generated benefits of $190 (low estimate) to $360 million (high estimate).
Langley Research Center (2004)	National	Expenditure framework. Unclear how multipliers are estimated. Final output multiplier of 3.04 used.	Langley's $811 million of direct spending creates a total national impact of over $2.47 billion.
UC Medical Center (2003)	Three state region – OH, KY, IN	Expenditure based framework, unclear how multipliers were calculated. Final output multiplier of 2.3 for Ohio State.	Medical Center has a $3.59 billion ultimate impact on the Tri-State area from $1.56 billion of direct impacts.
Durham Research Center, Nebraska (2004)	State	Expenditure based framework, unclear how multipliers estimated. "Research activity" multiplier of 2.25 used.	Since 1998, center's $355 million spending on research has had a total impact of almost $800 million.

Summary of Relevant Impact Studies			
Study Description	**Impact Area**	**Modeling Approach Used**	**Impact**
University of Kentucky Research and External Funding (2004)	State	Expenditure based framework with I-O multipliers from IMPLAN model. "Research multiplier" of 1.8.	State funding of research of $49 million helped generate additional $189 in external funding for research, which had a total impact of $311 million.
Centers for Disease Control (2002)	State (GA)	Expenditure based framework, multipliers from RIMS. Aggregate multiplier of approx. 2 used.	CDC's 1.3 billion spending in GA resulted in $2.5 billion in increased output.

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