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IMPACT ON INDUSTRY OF INTERACTIONS WITH ENGINEERING RESEARCH CENTERS – REPEAT STUDY

Summary Report

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EXECUTIVE SUMMARY

Background

The National Science Foundation (NSF) created the Engineering Research Centers (ERC) Program in 1985 to develop a government-industry-university partnership to strengthen the competitive position of U.S. firms in world trade. During 1994-1997, NSF contracted with SRI International to study the effects on industry of membership in the first 18 ERCs. This study examined patterns of interaction that had emerged between the centers and industry as a consequence of the Program and the overall impact of the interactions on industry. More specifically, the study identified the types of results or outcomes of ERC-industry interactions, the frequency with which those results occur, and the relative value or benefit of reported interactions and results of interaction from the perspective of the companies involved. "Value" was defined more broadly than just financial terms.

Even as the data were being collected for the first ERC industry impact study, a new cohort of ERCs began operation: four were funded during 1994-95 and four more in 1996. The nation's economic climate had changed considerably since the first ERCs were funded ten years earlier, such that the ability of the United States to compete internationally was no longer in serious doubt. Also, R&D activities in private firms had shifted in organizational locus and in emphasis, and both universities and private firms had learned a great deal about how to collaborate effectively in research. All of these changes, plus others reflecting some changes in the ERC Program, meant that the ERCs initiated in the mid- and late 1990s began operating in a very different context from that of their earlier counterparts. NSF staff were well aware that the second generation centers were different in numerous ways from those in the first generation, and wished to obtain systematic information about how new emphases in the Program and different economic circumstances had affected ERC interactions with member firms and non-member small firms, and what the results of these interactions were on firms.

Accordingly, in 2001 NSF again contracted with SRI to conduct a new study that would address many of the same questions posed in the first study, anticipating that at least some of the results would differ from those that reflected the experiences of industry members of the first cohort of ERCs. The newer study, whose results are summarized in this report, repeated the original study in modified form. The primary objectives of this study were to:

- Determine the extent to which industrial ERC members use different ERC activities and resources, including fundamental research, enabling technology research, and research equipment/facilities (including testbeds) and technical advice/consulting with faculty;

- Determine the specific benefits members receive from their use of these ERC activities and resources;

- Compare the value to the members of the various kinds of benefits they receive from ERC membership;

- Identify the capabilities and value to member firms of ERC student/graduate hires compared with other student/graduate hires who were not exposed to ERC research or education programs; and

- Provide measures of the overall impact on firms of their ERC membership.

These objectives were met via a 2002 survey of the 182 primary representatives of private sector firms with membership during 1999-2000 in the eight ERCs included in the study. In addition, a set of secondary objectives for the study were to:

- Identify ways in which ERCs work with small, non-member companies that seek assistance from the centers and with firms that are start-ups based on ERC technology; and

- Determine the extent to which the nature of the involvement of such start-ups and other small companies with the ERCs and the benefits they receive are similar to or different from what is the case with larger firms.

To address these latter objectives, SRI conducted interviews with Industrial Liaison Officers (ILOs) in each ERC, and, in selected cases, with representatives of those businesses as well. SRI also conducted a bibliometric analysis of the publications of the centers included in the study. Finally, SRI compared selected results from the earlier study with those from the newer study to identify how the changing context in which the second generation of ERCs operates has affected their interactions with, and impact on, industry members.

Selected Results of the Survey and Analysis

The study analyzed member firm use of center activities and resources in five categories:

- Use of the results of fundamental research;
- Use of the results of enabling technology research;
- Use of technical advice/consulting services from center faculty;
- Use of center equipment/facilities/testbeds; and
- Hiring of students or graduates.

Member firm use of center activities and resources was not concentrated in any one category but was spread fairly evenly among the categories. A greater proportion of member representatives (53 percent) reported obtaining technical advice/consulting services compared with the proportion reporting use of the results of other types of center activities and resources (about 40 percent for each of these other four categories).

The frequency with which member representatives reported that their units realized specific benefits varied widely. Ninety percent reported gaining access to ideas and know-how; 60 percent reported improving or developing new products and processes; 15 percent reported licensing center-produced technology or software.

Forty percent of respondents reported hiring center students or graduates. Among those who received benefits, respondents rated the value of hiring students or graduates more highly than any other benefits studied. On every one of a wide range of performance criteria, a large majority of ERC students or graduates hired were rated "somewhat better" or "much better" than comparable non-ERC hires.

Member representatives were generally positive about the benefits their firm received. Seventy-four percent of respondents reported that the value of benefits matched or exceeded the costs. Nearly three-fourths (74 percent) reported that membership had increased their firm's competitiveness by at least "some." Seventy-nine percent of respondents expected their firm to renew its membership for the coming year, compared with five percent that did not expect renewal.

Member representatives were asked to estimate the relative importance of specific reasons for their firm joining the ERC. The most important reason given was access to new ideas and know-how, rated by 78 percent of respondents as "very important" or "extremely important," followed by access to faculty and to ERC technology, and then by prior connections or relationships with individuals at the ERC. The least important reasons given, those rated either "not at all important" or "somewhat important," were the ability to license inventions or software developed by the ERC, access to equipment, facilities, and/or testbeds, and the ability to leverage the firm's research investment with money from other ERC sponsors.

Member representatives were asked about barriers to receiving benefits from ERC membership. The overall pattern of responses indicates that none of the barriers presented extreme difficulties for most members. "Other company matters" and "difference conceptions of time," were the most significant barriers, with 45 percent and 38 percent, respectively, responding that these were "quite" or "extremely" significant barriers. Representatives were also asked to identify and rate the importance of a variety of factors that might contribute to the benefits their company derived from ERC participation. The five factors that were rated as "very important" or "extremely important" by the highest proportion of representatives (between 48 and 53 percent) were:

- The continuous existence of a strong ERC "champion" in the company unit;
- Management support of the ERC within our company;
- The closeness between the ERC's specific technical focus and ours;
- Responsiveness of ERC faculty/researchers to our needs; and
- The ERC's efforts to communicate and stay in contact with sponsors.

Least important were the ability to establish proprietary rights, the commercialization potential of ERC research, the integration of research and education, and the ERC's engineered systems goals. Still, nearly a third of the representatives rated each of these factors as very or extremely important.

SRI conducted a variety of statistical analyses of the relationships between types of firms and centers, use of center activities and resources, types of benefits obtained, and overall impact on member firms. Some selected results of these analyses are:

- Representatives of small businesses reported a significantly higher average net benefit rating than did larger firms, but they were no more likely than representatives of larger firms to report that they expected to renew in 2003.

- There were no significant differences between U.S. and foreign member firms in terms of their representatives' assessments of the net benefits of membership, the likelihood of renewal in 2003, or their use of center activities and resources.

- Representatives of firms with membership in pre-paradigmatic centers did not differ from representatives of member firms in paradigmatic centers in their assessment of the net benefits of membership or of the likelihood of renewing membership in 2003.

- Member firms use of the results of fundamental research and enabling technology research increased with increased years of center membership, but their use of facilities and receipt of technical advice/consulting services from faculty did not. Also, the number of center student and graduate hires increased with years of center membership.

- Student hiring was strongly correlated with use of the results of fundamental research and enabling technology research, but not with the use of equipment/facilities or technical advice/consulting services.

- Use of technical advice/consulting services was the category of center activities/resources whose use was most strongly predictive of the intention to renew membership in 2003.

- Member representatives' assessments of the likelihood that their firm will renew its membership in 2003 were positively and strongly related both to their assessments of whether center membership had increased the firm's competitiveness, and to their assessments of the overall benefits vs. costs of membership.

- Firms whose research agenda was influenced by participation in an ERC were most likely (compared to firms receiving other benefits) to report a positive benefit/cost rating and most likely to expect continued membership in the center in 2003. Product or process improvements were also associated with high benefit/cost ratings as well as with greater likelihood of renewal for 2003.

- Obtaining technical advice/consulting services from center faculty, using the results of fundamental research and enabling technology research, and hiring students and graduates were all predictive of higher benefit/cost ratings.

ERC Interactions with Small Businesses

SRI's interviews with ILOs revealed as many differences as similarities among the eight ERCs regarding their interactions with small businesses. Many interactions with ERC-based start-ups and small, non-member firms are heavily influenced by factors over which center managers have little or no control. These include state laws, university policies, university culture, the resources available to the university technology licensing office (TLO), tensions inherent in the long-term research focus of centers and the short-term needs of start-ups, the center's technical focus, and the dynamism of the industry served by the center. Yet it is clear that the second generation ERCs are interacting with small firms in a variety of ways that mutually benefit the centers and their host universities, the small firms involved, and the center's full members.

ERC Publications: Patterns and Impact

To supplement the survey aspect central to this study, an analysis of publication and citation patterns was undertaken using individual databases for each of the eight ERCs studied. The databases were assembled by extracting from the citation indexes of the Institute for Scientific Information (ISI) center-specific lists of publications submitted to SRI by each ERC containing all peer-reviewed articles about center research published since the center's inception. Each database identified as many as possible of the following:

- "source" publications (i.e., papers published in ISI-covered journals by the ERC);
- all publications "*cited*" by the source publications (i.e., the contents of the reference lists of the source papers); and
- the publications that had referenced the ERC source papers subsequent to their publication (i.e., the "*citing*" papers).

The source papers were characterized by types of collaborations with industry and researchers outside the U.S. The relative inclination of the ERC to cite its own university's papers compared to outside work was examined for possible insight into its dependence on its own research versus its openness to outside work. The list of the top ten citing organizations was similarly characterized by the number of international and industrial firms appearing in it. In addition, the percentage turnover between the two lists was calculated as a possible indicator of the dynamics of development in each ERC's research field.[1]

The data did not seem to lend themselves to many broad or general conclusions. Each ERC is sufficiently unique that any pattern that seems to apply to half of them does not apply to

[1] Turnover from list A to list B is the proportion of new entries in list B that were not on list A.

the other half. No consistent patterns were found in any of the variables examined. Neither could any pattern be discerned that distinguished pre-paradigmatic from paradigmatic centers.[2]

While the data suggest that these ERCs are having a significant impact on research in their fields, the type of impact varies from one to another. Overall, the only generalization that emerges from this study of ERC publication and citation patterns is that these eight centers are sufficiently different from one another that their publication and citation practices vary according to individual needs. Whether more rigorous publication data from the ERCs would – or would not – produce more evident patterns cannot be judged at this time.

Conclusions, Observations, and Implications for NSF

The basic patterns of benefits and impacts realized by center members from participation in ERCs do not appear to have changed dramatically from the first to the second generation centers. Access to ideas, know-how, and the ability to hire center students and graduates continue to top the list of most valuable benefits, while licensing ERC software and technology continues to be least important to member firms. A significantly higher proportion of member firms from the more recent study reported receiving a number of important benefits, notably product and process improvements and new products or processes. Factors considered important for realizing these ERC-derived benefits are numerous and include company issues (e.g., management support of the ERC and the existence of a "champion"), ERC-specific features (e.g., responsiveness of ERC faculty/researchers to company needs), and the nature of ERC-member interaction (e.g., ERC efforts to communicate with members). Highly favorable assessments by member representatives of the net benefits of participation in ERCs continue, as does the match between expectations of benefits from membership and the benefits actually experienced. And finally, barriers to the realization of benefits by member firms are not serious, and they continue to relate mostly to firm policies and environments, not ERC activities.

The importance of research universities for regional economic growth has become widely recognized over the past two decades, and government programs at all levels reflect this change. Successful, innovative, research-based businesses are accepted as one of the keys to sustainable regional growth, and university-based start-ups are an important ingredient in the recipe. Industrial liaison officers of the second generation of ERCs are well aware of this and act knowledgeably and aggressively to help create, develop, and nurture center relationships with small, research-based firms in their regions. They also work closely with university technology licensing offices to foster the creation and growth of start-up firms based in ERC research. While probably more a matter of degree than of kind, this emphasis represents a significant change in ERC-industry relationships since the late 1980s and early 1990s.

Our findings do not suggest that fundamental changes have occurred in ERC-industry relationships that point to the need for revisions in ERC Program policies or practices. If anything, our results show the need for Program flexibility to continue, allowing Directors, ILOs,

[2] Preparadigmatic centers are ones whose research focuses on areas that are moving in entirely new directions from the state-of-the-art, where there is also normally no recognized discipline. Paradigmatic centers are ones whose research builds on existing disciplines or fields of research and is more incremental and heavily grounded in accepted theory-based paradigms.

and other members of center management teams to adjust to different conditions, e.g., changes over time and variations in policies among ERC host institutions and their environments.

In the next cohort of ERCs, relationships with small businesses, especially start-ups, are likely to continue to grow in importance. ILOs will need to manage a delicate balancing act, one that enables centers to help foster internal start-ups, nurture them, and work effectively with non-member small firms in the region, while at the same time attending to the recruitment and retention of fee-paying members and encouraging lower-level participants to become full members. Here, flexibility in member fee and benefit structures and in the membership agreement are especially critical. ILOs will need to continue to share experiences and best practices among themselves to the greatest extent possible.

IMPACT ON INDUSTRY OF INTERACTIONS WITH ENGINEERING RESEARCH CENTERS – REPEAT STUDY

SUMMARY

PART 1: BACKGROUND, STUDY OBJECTIVES, AND STUDY DESIGN

Background

The National Science Foundation (NSF) created the Engineering Research Centers (ERC) Program in 1985 to develop a government-industry-university partnership to strengthen the competitive position of U.S. firms in world trade.[3] By 1994, 18 ERCs were in operation and the oldest were nearing the end of their ERC Program funding. At this time, the ERC Program management contracted with SRI International to study the effects on industry of their membership in Engineering Research Centers.[4] This study, completed in 1997, focused on the private-sector firms that had paid fees to a given center for annual membership in the center.

The study whose results are summarized in this report repeats that original study with a second generation of ERCs that began operation in 1994-1996. This second cohort of ERCs began operation under a somewhat different environment than the first cohort. The nation's economic climate had changed considerably since the first ERCs were funded ten years earlier, and the ability of the United States to compete internationally was no longer as serious of a concern. Also, R&D activities in private firms had shifted in organizational locus and in emphasis, and both universities and private firms had learned a great deal about how to collaborate effectively in research. In addition, other changes occurred in the ERC Program and were reflected in the program announcements for the first two sets of second-generation ERCs. There were several specific changes that led ERC Program management to expect different results.[5] First, the education component of ERCs was expanded in the second generation centers, with pre-college outreach and impact on university curriculum becoming explicit objectives. Evidence of this change included new degree programs, certification programs, and pre-college outreach that was not explicitly expected or developed by first generation ERCs. The importance of students to the realization of ERC goals was further signified by the formation of Student Leadership Councils, now a feature of all new ERCs. Second, while the criteria for industrial collaboration had remained constant, such involvement had become more standardized through center-specific, formal membership agreements between each center and its member firms. Industrial liaison officers (ILO) had become more activist and more effective in building firm membership bases and expanding to user organizations not previously involved in ERCs, e.g., hospitals and similar practitioner organizations. Third, center management had become less hierarchical, reflecting a more horizontal and participatory mode of leadership. Fourth,

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[3]Parker, Linda, *The Engineering Research Centers (ERC) Program: An Assessment of Benefits and Outcomes*. Arlington, VA: National Science Foundation, Directorate for Engineering, Engineering Education and Centers Division. December 1997. Available online at: http://www.nsf.gov/pubs/1998/nsf9840/nsf9840.htm#table

[4]Ailes, Catherine P., J. David Roessner, and Irwin Feller. *The Impact on Industry of Interaction with Engineering Research Centers*. Arlington, VA: SRI International. January 1997. Available online athttp://www.sri.com/policy/stp/erc/.

[5] The perceived changes discussed here reflect extensive discussions between SRI and NSF staff in the fall of 2001.

university start-ups had become more important in research-intensive universities as vehicles for commercializing technology, and ERC-derived start-ups were a relatively new phenomenon when the second generation ERCs began. Finally, the newer ERCs were required to develop and employ formal strategic plans showing how the systems goals of the ERC "drive and integrate its major research goals and test beds to realize the systems-level vision."[6] These changes made it desirable to repeat the first study with a different set of centers to determine if the effects on industry of center membership had changed. NSF wished to obtain systematic information about how new emphases in the ERC Program and different economic circumstances had affected ERC interactions with member firms and non-member small firms, and what the results of these interactions were on firms.

At the outset of the present study in the fall of 2001, the ERC Program was supporting 18 ERCs. Of those 18 centers, the 8 oldest had received ERC Program support for between five and seven years, a sufficiently long period for firms with membership in these centers to begin experiencing results from their involvement with an ERC. The 8 Centers that were the subjects of this study and their lead institutions are:

1994/5 Cohort	Lead Institution
Center for Neuromorphic Systems Engineering	California Institute of Technology
ERC for Particle Science and Technology	University of Florida
Packaging Research Center	Georgia Institute of Technology
Biotechnology Process Engineering Center	Massachusetts Institute of Technology

1996 Cohort	Lead Institution
ERC for Environmentally Benign Semiconductor Manufacturing	University of Arizona
ERC for Reconfigurable Machining Systems	University of Michigan
Integrated Media Systems Center	University of Southern California
Biomaterials Engineering Research Center	University of Washington

[6] http://www.nsf.gov/pubs/2004/nsf04570/nsf04570.htm

Study Objectives and Approach

The primary objectives of the study were the following:

- Determine the extent to which industrial ERC members use different ERC activities and resources, including fundamental research, enabling technology research, research equipment/facilities (including testbeds), and technical advice/consulting with faculty;
- Determine the specific benefits members receive from their use of these ERC activities and resources;
- Compare the value to the members of the various kinds of benefits the receive from ERC membership;
- Identify the capabilities and value to member firms of ERC student/graduate hires compared with other student/graduate hires who were not exposed to ERC research or education programs; and
- Provide measures of the overall impact on firms of their ERC membership

These objectives were met primarily via a 2002 survey of the 182 primary representatives of private sector firms with membership during 1999-2000 in the eight ERCs included in the study.

In addition, NSF identified a set of secondary objectives for the study:

- Identify ways in which ERCs work with small, non-member companies that seek assistance from the centers and with firms that are start-ups based on ERC technology; and

- Determine the extent to which the nature of the involvement of such start-ups and other small companies with the ERCs and the benefits they receive are similar to or different from what is the case with larger firms.

SRI addressed these secondary objectives by interviewing, either by telephone or in person, the Industrial Liaison Officers (ILOs) in the eight ERCs, and, in selected cases, representatives of small businesses as well. Information was obtained about both start-ups originating with center knowledge or technology, and other small, non-member firms that interacted with center staff.

In addition to the survey and interview data, SRI conducted a bibliometric analysis of the publications of the eight centers studied. Its purpose was to identify patterns in ERC publications that would suggest the amount and nature of collaborations among universities, other research institutions, and industry; and provide evidence of the impact that each ERC's research was having in its field.

Finally, SRI analyzed selected data from both the earlier and more recent member surveys in a comparative format to elicit specific findings concerning possible changes in the ways ERC member firms interacted with centers, the expectations and actual benefits derived

from membership, and the value associated with specific benefits realized from center interactions. The comparative analysis is presented following a summary of the results of the more recent study, which begins immediately below.

Survey Design

SRI surveyed each member firm's representative to a center using the Primary Participant survey instrument. In addition, each Primary Participant was asked to provide names and contact information for others in the firm who were knowledgeable about interactions with the ERC. These people received the Secondary Participant survey instrument.

To facilitate comparative analysis of results of the present study and those from the previous ERC industry impact study, a number of questions were taken directly from the instrument used in that study. In addition, the survey instrument drew extensively upon SRI's recent evaluation of the NSF State/Industry University Cooperative Research Centers (S/IUCRC) Program.[7] The survey instrument and subsequent data analyses were structured according to the categories shown in Table S-1.

[7] 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.

Table S-1: Analytic Framework for Survey and Analysis

Member Use of Center Activities and Resources	Benefits to Member Firms	Indicators of Impacts on Member Firms
Use of results of fundamental research	We obtained access to new ideas or know-how.	Expectation of renewed membership in ERC
Use of results of enabling technology research	Our R&D agenda was influenced.	Summary assessment of benefits and costs of membership
Use of technical advice/consulting services	We licensed technology or software developed by the ERC.	Assessment of impact of membership on firm competitiveness
Use of research equipment, facilities, and testbeds	We patented or copyrighted technology or software we developed as a result of interacting with the ERC.	
Hiring of ERC students or graduates	We improved a product(s) or process(es).	
	We developed a new product(s) or process(es).	
	We had more interaction than in the past with other ERC firms.	
	We were able to provide our customers/suppliers with improved technical information.	
	We made unexpected operational changes (e.g., equipment or project additions or cancellations).	
	Benefits from student or graduate hiring.	

Source: SRI International

The survey sought information about the benefits and impact on member firms as a result of use of five categories of center activities and resources. The five categories are:

- *The conduct of fundamental research*: projects designed to accomplish focused yet fundamental, non-proprietary research objectives in the center's strategic plan;
- *The conduct of enabling technology research*: research intended to produce new devices, processes, components, control algorithms, materials, and/or other technologies that, when integrated into an engineered system, enable a function to be delivered;
- Making ERC *research equipment/facilities/testbeds* available to member organizations;
- Providing *technical advice or consulting services* by center faculty to member organizations (via technical consultation in person, by phone, or other means).
- *Educating and training students*.

For the first four of these activities and resources, the survey instrument asked respondents about the extent of their use of each. For each category, the survey instrument then asked what specific benefits the firms received from that use. It also asked how valuable these benefit were. For the fifth category, educating and training students, the survey instrument asked respondents about the firm's hiring of students and graduates associated with the ERC, and about the capabilities of these hires compared to non-ERC hires. Finally, the survey instrument sought information about the overall impact of membership on member firms. These included assessments of the overall benefits versus costs of membership, the effect on the competitiveness of the firm, and the expectation of continued membership.

SRI contracted with InfoPoll, Inc., to place the survey on the Web. The survey was initiated in mid-June 2002; three follow-up notices were sent to initial non-respondents to the survey. This resulted in a final response rate of 64 percent.

Structural Features of ERCs Studied

This study focused on selected structural and environmental features of centers, such as the type of research conducted, membership profile, technology field, and level and types of industry support; characteristics of responding member firms, such as the length of time as a center member, the tenure of the member representative, and the size of the member firm; member expectations about the benefits of membership; and the perceived barriers to realizing those benefits.

Table S-2, below, presents a number of descriptive features of the eight centers studied, all of which varied considerably across the centers.

Table S-2: Structural Features of the Eight ERCs Included in the Study

Center Name	Lead Institution	Type of research	Number of Full Members	Number of Small Firms	Technology Field	Total Industry Support FY 2001 (dollars)
Center for Neuromorphic Systems Engineering	Cal Tech.	Pre-paradigmatic	10	2	Microelectronics	738,694
ERC for Particle Science and Technology	University of Florida	Paradigmatic	39	36	Design/ Manufacturing	1,947,651
Packaging Research Center	Georgia Tech	Paradigmatic	22	5	Microelectronics	7,955,478
Biotechnology Process Engineering Center	MIT	Pre-Paradigmatic	18	N/A	Biotechnology	745,153
ERC for Environmentally Benign Semiconductor Manufacturing	University of Arizona	Paradigmatic	31	0	Design/ Manufacturing	6,297,415
ERC for Reconfigurable Manufacturing Systems	University of Michigan	Paradigmatic	16	6	Design/ Manufacturing	3,620,717
Integrated Media Systems Center	USC	Pre-paradigmatic	24	4	Microelectronics	2,165,477
Engineered Biomaterials Engineering Research Center	University of Washington	Pre-paradigmatic	27	4	Biotechnology	618,124

Source: SRI International

PART 2: RESULTS

Reasons for Deciding to Participate as Member of Center

Member representatives were asked to estimate the relative importance, in the case of their firm, of specific reasons for joining an ERC. The most important reason given was access to new ideas and know-how, rated by 78 percent of respondents as "very important" or "extremely important," followed by access to faculty and to ERC technology, and then by prior connections or relationships with individuals at the ERC (Table S-3). The least important reasons given, those rated either "not at all important" or "somewhat important," were the ability to license inventions or software developed by the ERC, access to equipment, facilities, and/or testbeds, and the ability to leverage the firm's research investment with money from other ERC sponsors.

Table S-3: Importance of Alternative Reasons for Deciding to Participate in Center (percent responding)

	Degree of Importance		
Reason to Participate	**Not Important or Somewhat Important**	**Quite Important**	**Very Important or Extremely Important**
Access to new ideas and know-how	6.0	14.7	77.6
Access to equipment, facilities, and/or testbeds at the ERC	46.2	16.2	34.2
Access to ERC students as prospective new hires	38.8	25.0	33.6
Access to specific ERC faculty	20.7	21.6	55.2
Access to ERC technology	19.0	22.4	55.2
Opportunity for joint projects	22.4	27.6	48.3
Opportunity for cross-disciplinary research	24.8	26.5	46.2
Ability to leverage our research investment with money from other ERC sponsors	41.9	19.7	35.9
Opportunity to interact with other companies affiliated with the ERC	26.1	29.6	42.6
Ability to license inventions and/or software development by the ERC	53.4	19.0	25.9

Source: SRI International

Table S-3: Importance of Alternative Reasons for Deciding to Participate in Center (percent responding) continued...

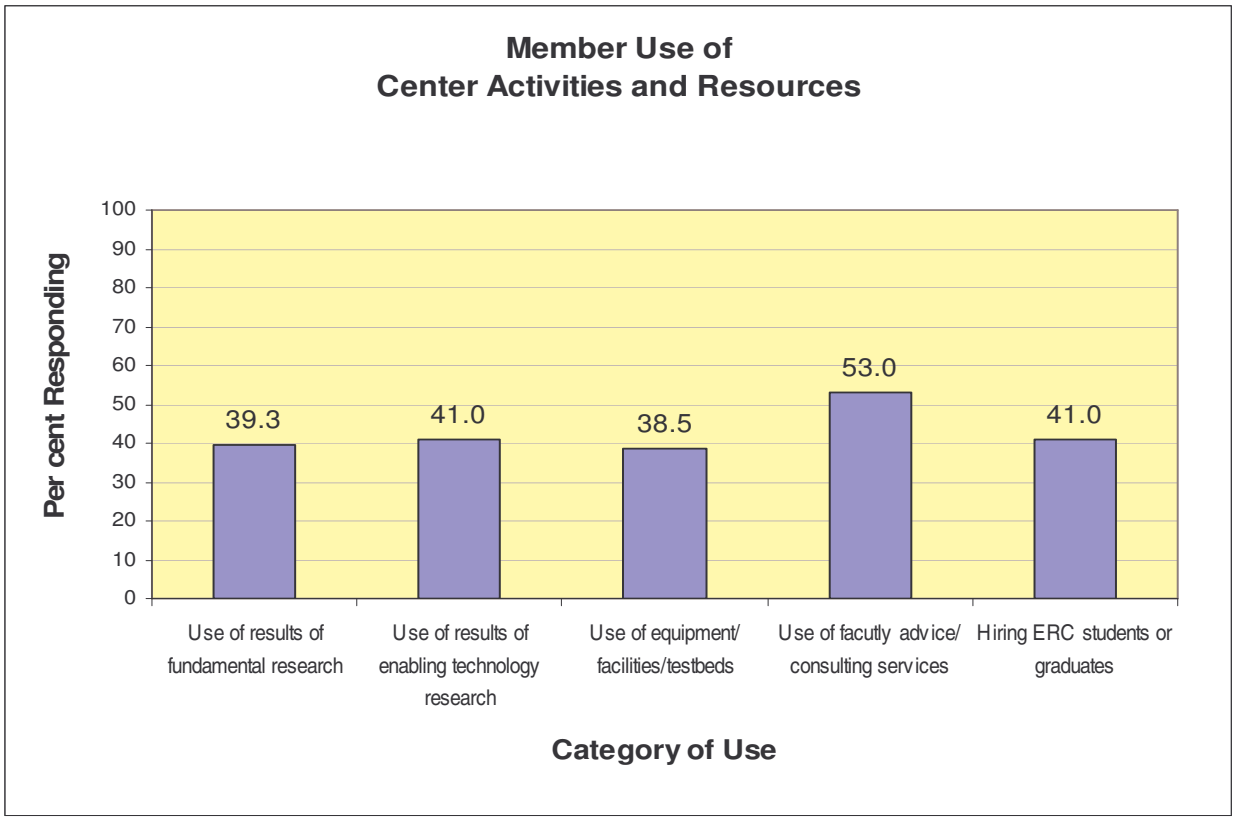
	Degree of Importance		
Reason to Participate	**Not Important or Somewhat Important**	**Quite Important**	**Very Important or Extremely Important**
The ERC's engineered system goals	26.5	31.6	33.3
Technological/research focus at ERC matched our interests	6.8	23.1	67.5
The ERC's integration of research and education	38.8	24.1	35.3

Source: SRI International

Member Use of Center Activities/Resources, Benefits Realized, and Overall Impacts of Participation in ERCs

Each ERC member firm's representative was asked whether his or her unit made use of each of five center activities and resources: results of fundamental, generic research; results of enabling technology research; research equipment/facilities/testbeds; technical advice or consulting services, and hiring students or graduates. Figure S-1 illustrates these results.

Figure S-1: Member Use of Center Activities and Resources

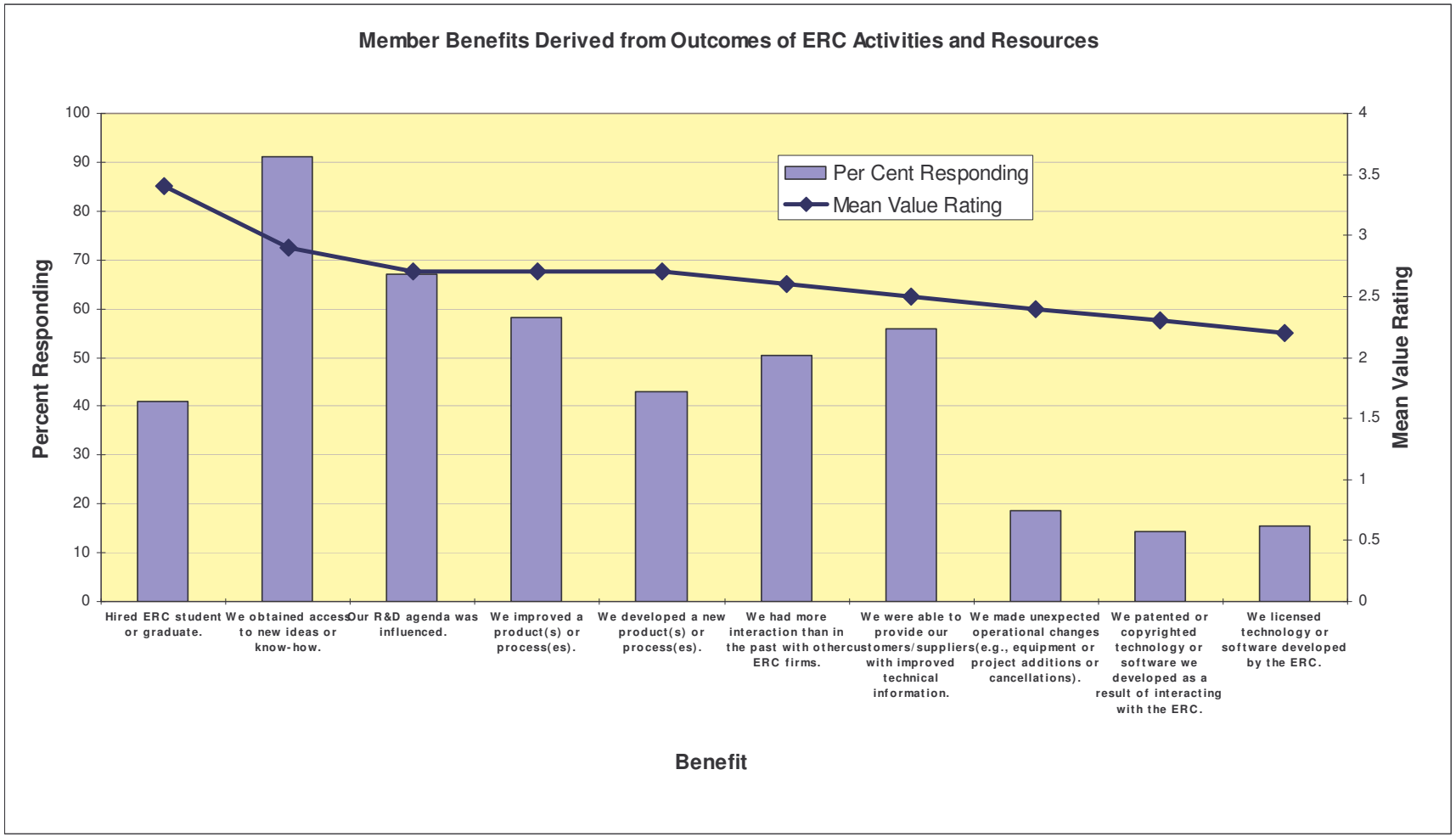


Source: SRI International

Ninety-seven of the 117 respondents (83 percent) reported that their unit had used at least one of the five activities or resources. Use of advice and consulting services was the most frequent. Other center activities and resource were used approximately equally.

Figure S-2 shows the specific benefits obtained from member participation in center activities. It shows both the percentage of respondents that received specific benefits and the mean value of each benefit realized, rated by respondents on a scale of 1 to 4 (1=none, 2=some, 3=quite a bit, 4=a great deal). Nearly all (91 percent) reported that their unit obtained access to new ideas or know-how. Two-thirds reported that their unit's R&D agenda was influenced, and just under 60 percent reported that their use of center activities and resources led to product or process improvement. Only about 15 percent reported that their unit licensed ERC technology or software, and the same proportion of members patented or copyrighted technology developed internally as a result of interacting with the center. Hiring a center student or graduate was the most highly valued of all types of benefits.

Figure S-2: Member Benefits Derived from Outcomes of ERC Activities and Resources



Source: SRI International

Approximately 40 percent of the member representatives reported that their unit had hired at least one ERC student or graduate as a summer or regular employee. About 12 percent had hired three or more ERC students or graduates. As shown in table S-4, on every one of a wide range of performance criteria, a large majority of ERC students or graduates hired were rated "somewhat better" or "much better" than comparable non-center hires. More than half of the student or graduate hires were rated as performing "much better" than comparable students in their breadth of technical knowledge (53 percent) and in their ability to work in interdisciplinary teams (55 percent). Fully 87 percent were regarded as performing better than comparable hires in their overall preparedness for working in industry.

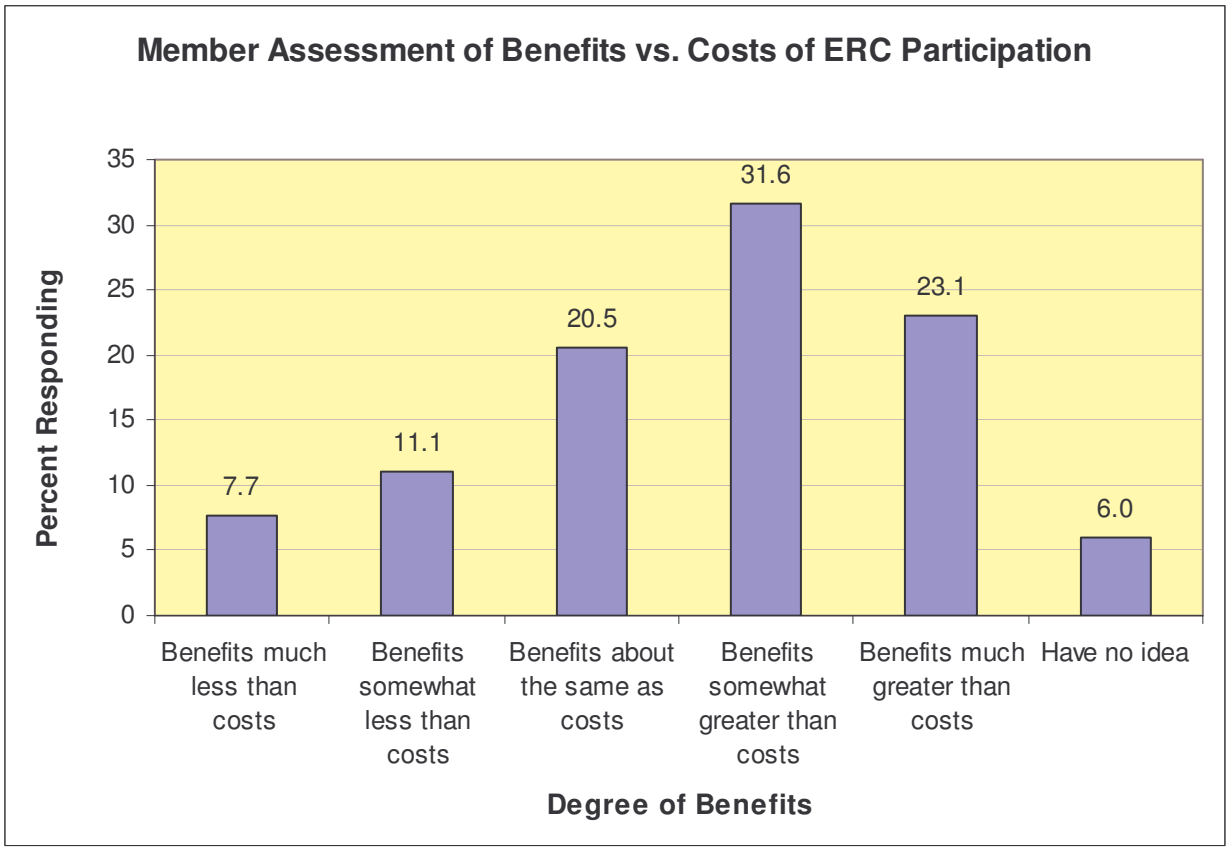
Table S–4: Comparison by Member Firms of Performance of Center Hires with Comparable non-Center Hires (percent responding)

	Performance Rating		
Performance Dimension	**Much Worse or Somewhat Worse**	**About the same**	**Somewhat better or Much Better**
Depth of technical knowledge.	0.0	18.8	79.2
Breadth of technical knowledge.	0.0	14.9	83.0
Contribution to the firm's technical work.	2.2	15.2	80.4
Firm-funded training required before they became a net contributor to the firm's work.	0.0	26.7	64.4
Ability to apply knowledge from different disciplines and use technologies in an integrated fashion to solve problems.	0.0	17.4	78.3
Ability to solve problems within constraints of time, money, and human resources.	0.0	29.8	66.0
Ability to work in interdisciplinary teams.	0.0	12.8	83.0
Ability to apply engineered systems perspective.	0.0	23.4	72.3
Ability to use knowledge to develop technology.	0.0	19.6	73.9
Overall preparedness for working in industry.	2.1	8.5	87.2

Source: SRI International

To assess the overall impact of their participation in ERC activities, member representatives were asked whether the benefits of participating in an ERC were much greater than the costs, somewhat greater, about the same, somewhat less, or much less. Figure S-3 shows these results. The majority of respondents (55 percent) reported that the benefits of participation were either much greater or somewhat greater than the costs, and three-quarters (74 percent) reported that the value of benefits matched or exceeded the costs. Just under 8 percent of the member representatives responding (9 of 117) considered that their unit's benefits were much less than the costs of membership in the ERC.

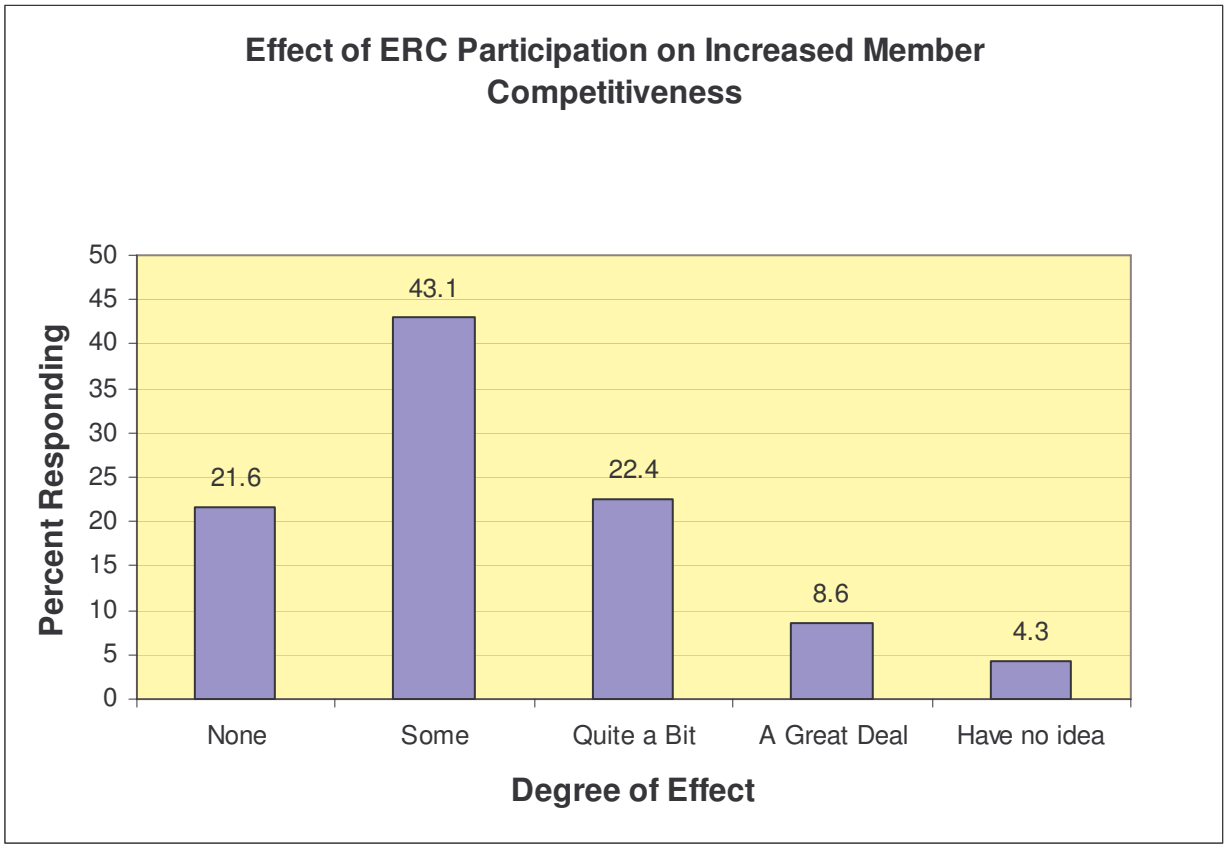
Figure S-3: Member Assessment of Benefits vs. Costs of ERC Participation



Source: SRI International

Member representatives were asked the extent to which their firm has increased its competitiveness as a result of center participation. A large proportion reported that center membership had increased the firm's competitiveness (figure S-4): nearly three-fourths (74 percent) reported that membership had increased competitiveness by at least "some;" of this group, 22 percent responded that their firm had increased competitiveness by "quite a bit," and 9 percent said it had increased a "great deal."

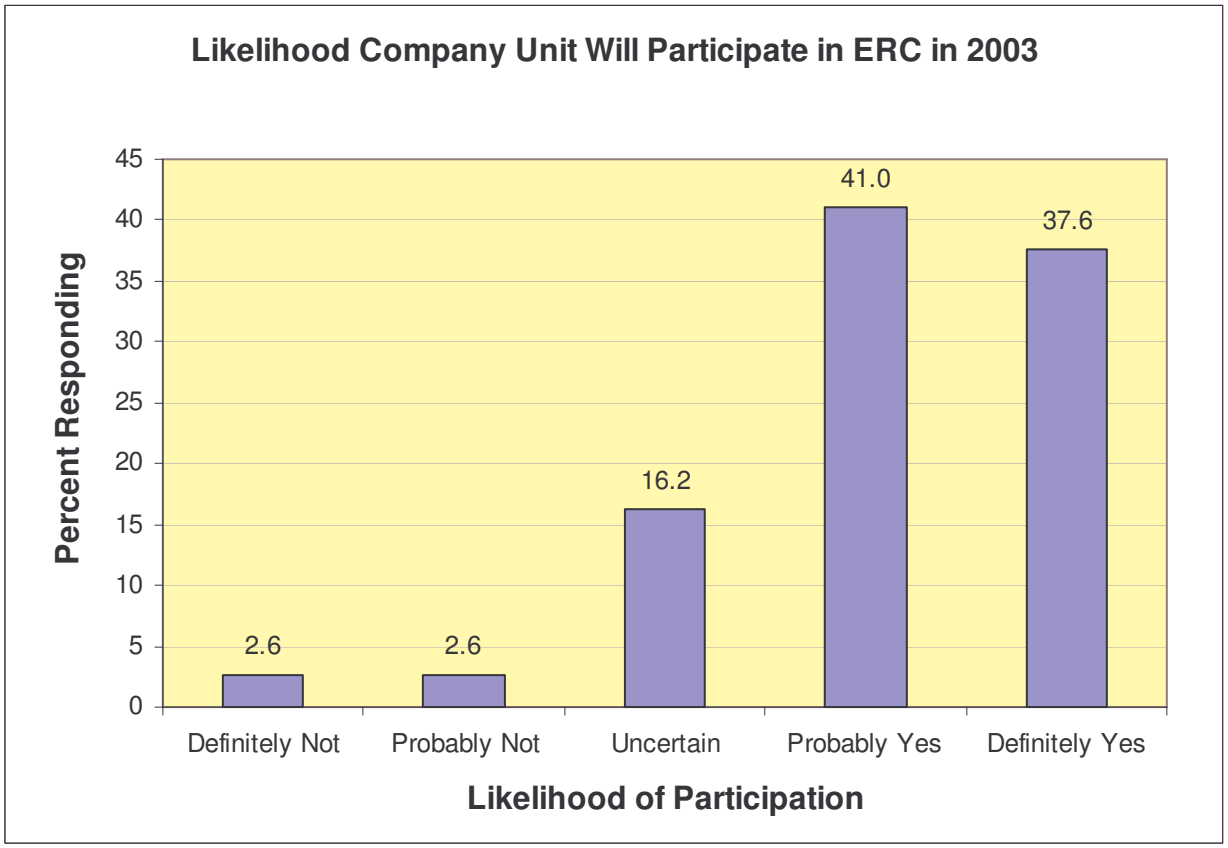
Figure S-4: Effects of ERC Participation on Increased Member Competitiveness



Source: SRI International

Member representatives were also asked whether the firm expected to renew its membership in 2003, and in 2004. Figure S-5 shows the results for 2003. The great majority of member representatives predicted that their firm would renew its membership in 2003 (79 percent said "probably yes" or "definitely yes") and also in 2004 (69 percent said "probably yes" or "definitely yes).

Figure S-5: Likelihood Company Unit Will Participate in ERC in 2003



Source: SRI International

Factors Expected to Influence Impact of Participation in Centers on Member Organizations

There are several categories of factors that can influence member representatives' assessment of the impacts on the firm of membership in Engineering Research Centers:

- **Features of individual centers**, such as leadership style and quality, levels and types of financial support and staffing, research or technology field, characteristics of the academic setting, number of center members, and size profile of member firms;

- **Characteristics of member firms and their representatives**, such as firm size, industry or industries represented, length of time as a center member, and length of time as member representative to a center;

- **Characteristics of the interactions and communication** between centers and members, and among center members themselves, which are undoubtedly related to either or both of the above factors.

Membership Characteristics

A majority of responding representatives (58 percent) indicated that their firm had been a member of an ERC for four years or more, with only 9 in their first year of membership. Turnover among member representatives is higher, with just over half (56 percent) reporting that they had served as the firm's representative for three years or less.

Barriers to Realizing Benefits of Center Membership

Member respondents were asked to judge the significance of several barriers to obtaining the full benefits of center membership. For each barrier, the level of significance was rated on a scale from "not at all significant" to "extremely significant." The overall pattern of responses indicates that none of the barriers presented extreme difficulties for most members. "Other company matters" and "difference conceptions of time," were the most significant barriers, with 45 percent and 38 percent, respectively, responding that these were "quite" or "extremely" significant barriers (Table S-5).

Table S-5: Significance of Alternative Barriers to Realizing Benefits of Member Participation in Centers (percent responding)

	Degree of Significance	
Barrier	Not Significant or Somewhat Significant	Quite Significant or Extremely Significant
Differences between the ERC and my company in values, mission, or priorities (e.g., academic vs. corporate values)	67.2	31.0
Intellectual property issues	63.3	30.8
Different conceptions of appropriate time between project initiation and completion	57.3	37.6
Poor communication between the ERC and us	68.4	24.8
Lack of awareness about the ERC within my company	65.8	30.7
Internal company "politics" or requirements	73.1	23.5
Other company matters preempt increased involvement with the ERC	45.3	44.5

Source: SRI International

Factors Contributing to ERC-Derived Benefits

Member representatives were also asked to rate a wide range of factors in terms of each factor's contribution to realizing the benefits derived from participation in the ERC. The factors included internal company matters, characteristics and actions of the ERC, and the nature of ERC-member interactions. As Table S-6 shows, factors associated with all three of these categories were considered to be at least "quite important" by a large majority of member

representatives. Indeed, it is notable that company matters such as the existence of an ERC champion and management support, ERC characteristics and actions such as responsiveness to member needs efforts to communicate with them, and match between ERC and company research foci are all regarded by about half the respondents as very or extremely important to the realization of ERC-derived benefits. Clearly, a wide range of factors pertaining to both the ERC and the company are considered to be at work.

Table S-6: Factors Contributing to ERC-Derived Benefits

	Percent Responding			
Factor	**Not at All or Somewhat Important**	**Quite Important**	**Very Important or Extremely Important**	**Mean Rating***
Continuous existence of a strong ERC "champion" in the company unit	22.1	25.0	52.9	3.5
Management support of the ERC within our company	25.7	25.7	48.6	3.4
The closeness between the ERC's specific technical focus and ours	21.1	31.2	47.7	3.4
Responsiveness of ERC faculty/researchers to our needs	24.3	24.3	51.4	3.3
The ERC's efforts to communicate and stay in contact with sponsors	25.2	27.0	47.8	3.3
The ERC's emphasis on cross-disciplinary research	27.8	30.6	41.7	3.2
Receptivity of company technical staff to ERC ideas and/or results	30.6	33.3	36.1	3.1
Our ability to influence the ERC's research agenda	36.5	30.8	32.7	2.9
The ERC's engineered systems goals	43.1	23.5	33.3	2.8
Integration of research and education	46.1	24.5	29.4	2.8
The commercialization potential of ERC research	43.3	26.0	30.8	2.8
Our ability to establish proprietary rights	51.6	17.2	31.2	2.7

Source: SRI International
*Items were rated on a 5-point scale, with 1=not at all important, 2=somewhat important 3=quite important (moderately important in 1994-5 scale), 4=very important, 5=extremely important. The midpoint is 3.0.

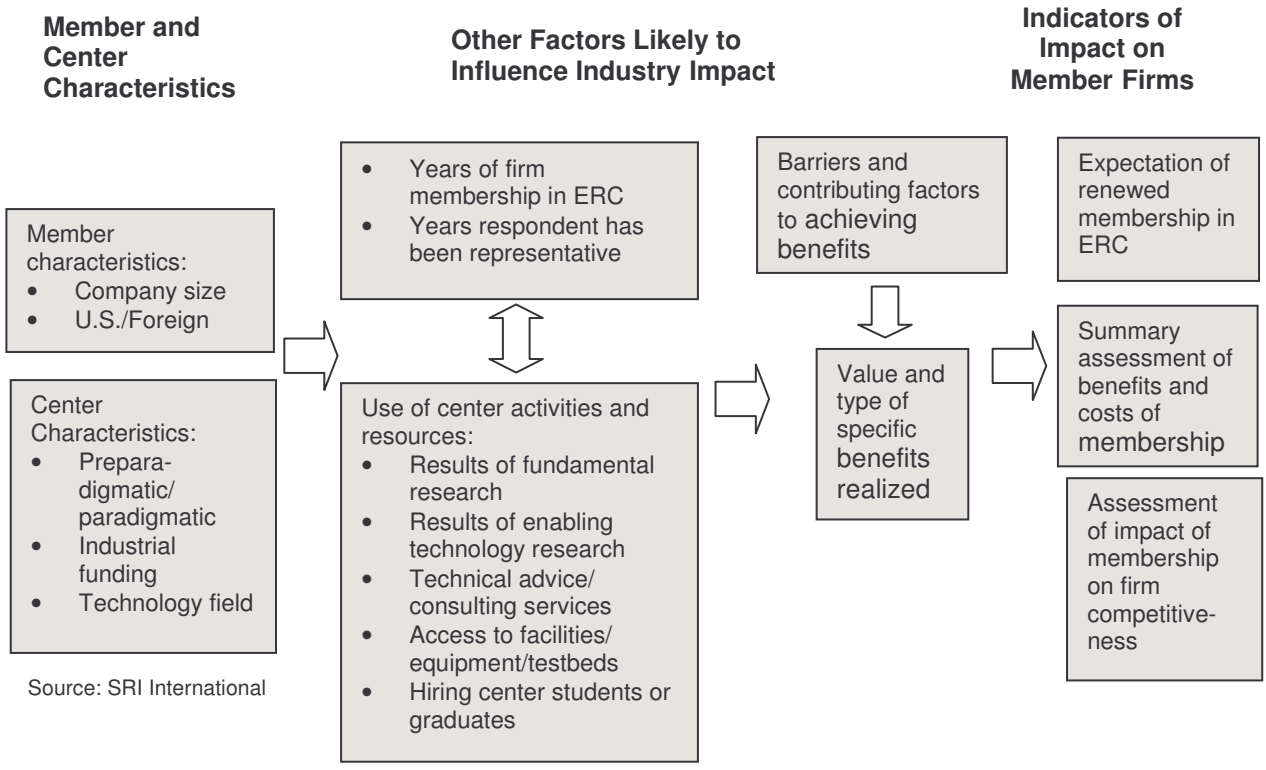
Explaining Variations in Impacts

Figure S-6 depicts a model of the hypothesized causal relationships among ERC activities, resources, benefits, and industry impacts analyzed for in this study. The model illustrates that there are several independent factors, such as center and firm characteristics, as well as a large number of other influences, such use of center activities and length of firm membership in the center, that interact in a complex fashion. All of these factors are presumed to influence the level and type of impacts that member firms experience from participation in centers, which in turn affect their representatives' overall assessments of the benefits of membership compared with costs, the likelihood of membership renewal, and the effect of center participation on firms' competitiveness.

The factors examined in this study that may relate to variations in reported impacts include:

- Center characteristics (technology field, type and amount of industrial funding, pre-paradigmatic versus paradigmatic research focus);
- Member characteristics (company size and nationality);
- Membership characteristics (years of membership, tenure of current representative);
- Use of center activities and resources, including student/graduate hiring;
- Center and firm barriers to achieving benefits; and
- Center and firm characteristics that influence the achievement of benefits.

Figure S-6: Conceptual Model of Factors Expected to Influence Impact on Member Firms of Participation in ERCs



Source: SRI International

The conceptual model presented above guided our analytic approach. Two indicators of the overall impact on firms were used in the analysis: member representatives' assessment of the likelihood that their firm will renew membership in 2003, and their rating of the overall relationship of benefits to costs of center membership.

Due to the small number of respondents in the survey, it was difficult to obtain statistically significant results for complex relationships. In most cases we reported only results that are significant at the 95 percent confidence level (e.g., there is less than 5 percent probability that an apparent relationship is due to chance alone). However, for a few relationships we reported results that do not quite achieve that level of significance. In these instances results should not be considered conclusive, but rather suggestive of questions for further study.

A number of interesting results emerged from crosstabular and regression analysis of the factors in the model:

- Representatives of small businesses reported a significantly higher average net benefit rating than did larger firms, but they were no more likely than representatives of larger firms to report that they expected to renew in 2003.

- Small businesses did not use any one of the four primary center activities and resources, relative to the others, more frequently than did larger firms.

- There were no significant differences between U.S. and foreign member firms in terms of their representatives' assessments of the net benefits of membership, the likelihood of renewal in 2003, or use of center activities and resources.

- Representatives of firms with membership in pre-paradigmatic centers did not differ from representatives of member firms in paradigmatic centers in their assessment of the net benefits of membership or of the likelihood of renewing membership in 2003. In addition, there were no significant differences in the extent to which these firms used the four primary center activities and resources. However, representatives of pre-paradigmatic centers' member firms were significantly less likely to report that center participation enabled them to provide improved technical information to their customers and/or suppliers.

- Members of microelectronics centers made more extensive use of the results of enabling technology research and of faculty technical advice/consulting services than did members in design/manufacturing and bioengineering centers.

- Members of biotechnology centers made less use of the results of enabling technology research, and probably of fundamental research, than did members of centers in other fields. However, the technology field of the center was not

significantly related to the two impact indicators, net benefit ratings, or estimates of the likelihood of renewal in 2003.

- The total amount of industrial funding of centers was not significantly related to the two impact indicators or to the patterns of member use of the four primary center activities and resources. Members of centers with larger amounts of industrial funding did not receive significantly different benefits than members of centers with smaller amounts of industrial funding.

- Member firms' use of the results of fundamental research and enabling technology research increased with increased years of center membership, but their use of facilities/equipment/testbeds and of technical advice/consulting services from faculty did not. Also, the number of center student and graduate hired increased with years of center membership.

- Length of center membership and net benefit ratings were positively related, but were just short of being statistically significant. This was also the case for the likelihood of membership renewal in 2003.

- Student hiring was strongly correlated with use of the results of fundamental research and enabling technology research, but not with the use of equipment/facilities/testbeds or technical advice/consulting services.

- Use of technical advice/consulting services was the category of center activities and resources that was most strongly predictive of the intention to renew membership in 2003.

ERC Interactions with Small Businesses

This study addressed two questions posed by NSF that involve ERC interactions with small businesses:

- In what ways do ERCs work with small, non-member companies that seek assistance from the centers and with firms that are start-ups originating with ERC technology?

- How are the interactions with ERCs of such start-up and other small companies, and the benefits they receive from center interaction, similar to or different from ERC interactions with larger, member firms?

SRI discussed ERC interactions with small businesses with the Industrial Liaison Officer (ILO) at each of the eight ERCs included in the study using in-person and telephone interviews. SRI also interviewed the CEO or COO of three start-ups to discuss the origins of the company; center interactions with the firm before and after its creation; benefits received by the firm before and after its creation; and interactions with center member firms.

Interactions Between ERCs and Start-ups Based in ERC Research or Technology

ERC staff interacted more frequently with faculty and student entrepreneurs intending to initiate a start-up than with start-up principals after the start-up begins functioning outside university walls. However, the types of interactions during the initial stages of a start-up's life span are relatively narrow, in contrast to the post-initiation period, during which the range of interactions expands considerably. In most cases, an ERC-based start-up originates with a faculty member or student working on ERC research. In many cases, ERCs work closely with their university's technology licensing office (TLO) to help the potential entrepreneur obtain necessary advice and support during the filing of an invention disclosure, patent application, searching for venture capital support, obtaining business assistance, and so on. In some universities with very strong entrepreneurial cultures, the TLO has had years of experience and success in moving university intellectual property into existing firms as well as putting all the pieces together for launching start-ups initiated by students and faculty. In centers based in universities with strong, successful TLOs, the latter play the major role, taking on this supporting function at an early stage and minimizing the ERC's role. In universities with weaker entrepreneurial cultures (often associated with small, understaffed TLOs), the ERC can assume a much larger entrepreneurial role.

Interactions between ERCs and start-ups are less frequent and intense following the formative stages, but include a wider range of activities, both formal and informal: research collaboration, continuing nurturing, use of ERC facilities, and hiring of students and graduates or interns as permanent employees. Often, companies formed on the basis of "raw" center-derived technology still require some research or research support to bring it to a commercializable state. Since the fledgling company may not have the facilities to carry this out, it may continue working with the ERC through an active project partly or fully funded by the start-up. Software-based companies that require less capital or specialized equipment are more independent.

ERC start-ups enjoy a number of benefits that result from their interactions with the ERC, many of which are shared with member firms. (It is relatively rare for an ERC start-up to become an ERC member, at least during the time frame in which ERC Program support for the center continues. There are several reasons for this, including the cost of membership, the short-term focus of the start-up, and the lack of need for broad and continued access to center intellectual property.) Some of these benefits are suggested by the types of interactions described above, e.g., access to students, informal advice, nurturing, access to smart people. However, one of the most significant benefits is the synergistic relationship that exists among ERC start-ups and full member firms. Aspects of this synergy were mentioned prominently in every interview SRI held with ILOs and start-up principals.

Rather than regarding start-ups as competitors, ERC member companies consider start-ups as sources of new technology through licensing, as potential partners, and as potential targets for acquisition. Most ERC members are large companies, unthreatened by start-ups. If anything, the early and intimate look that member companies get at start-up technologies provides valuable insight into possible directions that their core technologies might take, giving them plenty of time to consider whether a countering strategy is needed. In other cases, members represent the

original equipment manufacturers to which start-ups can sell their products, so they get an early window on new supplier technologies that could increase their sales and market share. Start-ups, in turn, benefit from access to potential customers, market information, and even financing.

ERC Interactions with Non-member Small Businesses

ERC interactions with non-member small businesses fall mostly into three categories:

- interactions based on a formal affiliation with the ERC that does not meet the center's definition of full membership;
- interactions based on deliberate efforts by the ERC to attract the attention of small businesses, often with an eye toward recruiting them as future members, affiliates, or contributing firms; and
- a variety of short-term, often one-time interactions based on the benefits that one party to the interactions can offer the other.

Most ERCs have established a tiered membership fee structure, with fees proportional to firm size or sales. Usually these categories of membership also provide for varying levels of other ERC benefits such as access to center intellectual property. A primary purpose of this is to increase the center's interaction with small businesses, and more generally to increase the number of firms with some formal connection to the center other than via formal membership. Clearly the mutual advantages offered to centers and their member, affiliate, and contributing firms increase with the number of involved firms.

Small business relationships with ERCs are often local. Many centers recognize the economic development impact of small, innovative firms and actively seek them out for a variety of types of interaction. Many ERCs have joint projects with small companies, some of which involve test facilities to which these companies otherwise would not have access. In some centers, member companies will bring a small business (subcontractor or company with a joint project) to the university, seeking the university's partnership in preparing an SBIR or STTR proposal.

Although most small businesses with which ERCs interact are either members, affiliates, or contributing firms, there are also significant and widely varying interactions between centers and small companies with no official relationship with the center. Facilities-based ERCs can, for a fee, test a device, run failure analyses, validate tools developed in projects, and so on. Centers may involve small, local companies in producing prototypes for testing a device in numbers too large for the center itself to produce.

ILOs said that the attraction of their centers to small firms is a mix of access to brains and to facilities. Some small firms come to a center to do some pilot work, from concept to commercialization. Centers charge the usual rate for use of facilities, but use the occasion to build credibility with the firm in the hopes of establishing a relationship that will lead to a more formal, longer term arrangement. Centers also brainstorm with small firms for no charge,

perhaps over lunch, again with an eye toward establishing credibility and opening the path to a future relationship. This is not to say that ERCs spend an inordinate amount of time working with small firms. ILOs are well aware of the balance that has to be maintained among serving existing members, large and small; attracting new members, affiliates, and contributing firms; and working with local, non-member firms on a short-term, as needed basis. Some ILOs acknowledge this delicate balancing act by admitting that they do not market the ERC too openly, instead relying substantially on contacts made via the network of full and affiliate members.

Tensions and Limits

ERCs and the ERC Program face a number of issues that shape the extent and types of relationships that centers have with small firms, including start-ups. Variations in state law, university policies and cultures, the technical focus of the center, and the industry or industries involved all influence what can and cannot be done with small firms. ERCs may face restrictions on their ability to work with small non-sponsoring companies, restrictions that may appear in the center's sponsorship agreement. For example, one ERC's agreement forbids the center to work with companies that do not join as full members. State conflict of interest laws may limit the involvement of a faculty member in a start-up originating by university research, thus dampening the entrepreneurial spirit among faculty. In at least one state, law forbids a professor to be an officer, to serve on the Board of Directors, or be the scientific advisor of a start-up. As a partial solution, students become the vehicle for start-ups.

Another issue concerns the inherent tension between the long-term, strategic focus of most center research and the needs of small businesses, especially start-ups. New, small firms must be profit-focused, and centers that generate a large number of start-ups must resist becoming a job shop, deluged with near-term problems and failing to conduct longer range research. To be successful, start-ups must cross the "valley of death," the gap between an idea and a workable prototype or proof-of-concept. With the possible exception of software-based start-ups, a center start-up often remains dependent on center staff and facilities as it attempts to cross the valley of death. Center managers and ILOs must remain vigilant to avoid devoting too much attention to the needs of start-ups at the expense of the fundamental, core research that is the essence of the center's *raison d'être*.

Finally, some ERCs face fundamental constraints on their ability to generate start-ups because of the nature of the industries they serve and/or the technologies they develop. In less dynamic, mature industries, potential start-ups face even more problems than in fast-moving, research-intensive industries such as biotechnology. Venture capital is scarce, technological opportunities are rare, and potential markets are especially uncertain. Some technologies such as discrete software modules (rather than integrated packages) do not lend themselves to start-ups—member firms integrate elements of the center-developed, discrete software into their own software. In some ERCs, members get nonexclusive, royalty-free licenses to software, thus limiting the potential market for center-based start-ups.

Major Results from Bibliometric Analysis

To supplement the survey aspect central to this study, an analysis of publication and citation patterns was undertaken using individual databases for each of the eight ERCs. The databases were extracted from the citation indexes of the Institute for Scientific Information (ISI) based on lists of publications submitted by the ERCs, based in turn on such lists contained in their annual reports to NSF. Each database identified as many "source" publications (i.e., papers published by ERC researchers in ISI-covered journals) as possible, along with all of the publications cited by the source publications (i.e., the contents of the reference lists of the source papers), and the "citing" publications that had referenced the ERC source papers subsequent to their publication. In addition to the bibliographic citation and the citing and cited papers, each publication in the databases carried with it the ISI entries of all of the authors, as well as all of the unique addresses that appeared with the paper in its journal of publication.

ISI delivers the databases in Microsoft Access with a proprietary interface called Xite©. This was used to examine the source papers to validate publications and identify various types of collaboration, especially university-industry. Institutions cited by the ERC's papers, as well as those citing the ERC source papers, were also identified. Since the databases included as many as 2359 cited and 4788 citing institutions worldwide, it was decided to examine only the patterns involving the top ten (or more if the tenth institution was tied with others in its number of citations) of each type of institution for each ERC for their institutional focus.

The source papers were characterized by types of collaborations occurring, primarily with industry members and non-members. The list of cited organizations was used to characterize the ERC's tendency to cite its own university's papers. A high ratio of self-citations to the number of the next most cited institutions may be indicative of either its heavy reliance on its own research (no one else to cite in its cutting edge field), or a relatively closed attitude concerning research done elsewhere (the "not invented here" factor). The list of the top ten citing organizations was similarly characterized. This list also included information on the number of international and industrial firms. In addition, the percentage turnover between the two lists was calculated as a possible indicator of the dynamics of development in the ERC's research field.[8] A heavy turnover suggests a dynamic field and wide impact of the ERC; more moderate, a more stable institutional focus for the field.

The data do not seem to lend themselves to many broad or general conclusions. Each ERC is sufficiently unique that any pattern that seems to apply to half of them does not apply to the other half. Several general observations can be made, however.

- Self-citation is the dominant pattern among both the cited and citing papers: the ERC universities are far more likely to cite papers from their own institution than any other institution.

- In all cases, the source papers were dominated by the host university – although MIT was dominant in the multi-university ERC headquartered at Arizona. The collaborative institutions that accounted for other institutional

[8] Turnover from list A to list B is the proportion of new entries in list B that were not on list A.

attributions, whether with industry or other universities, accounted for relatively few of the source papers. The collaboration taking place appears to be among departments within the host university, a major goal of the ERC program.

- MIT appeared in every list of the top ten cited institutions and all but three of the lists of citing insitutions – no other university, this ERC universe or not, appeared in more than four. In all cases MIT stood higher in the rank on the citing than the cited side (i.e., MIT was making more use of others' work than was being made of its own by others).

Beyond this, patterns were hard to discern. Some ERCs collaborated with outsiders extensively, some much less. Some had a substantial number of foreign collaborators, others few. Collaboration with industry ranged from 5 percent to 40 percent of all source papers, while collaboration with member firms ranged from 3 percent to 26 percent. Nearly all of two ERC's industrial collaborations were with members, but only a quarter of the papers from the ERC with the 40 percent industrial collaboration rate were with members. Some were more cited by foreign organizations than U.S. ones, others by U.S. institutions, with a range in between. The turnover between lists of the top ten cited and the top ten citing institutions ranged from 50 to 80 percent, with five in the range of 70 percent, indicating that the ERCs are influencing research in other institutions more than they are influenced by those on whose research they draw, and suggesting that they are having an influence on the dynamics of their research field, stimulating research elsewhere. Some citing and cited lists had a number of industrial firms, others none at all, and some changed in the proportion of industrial organizations between cited and citing, while others did not.

Overall, the only generalization that emerges from this study of ERC publication and citation patterns appears to be that these eight centers are sufficiently different that their publication practices vary widely. Whether more rigorous input from the ERCs would – or would not – produce more evident patterns cannot be judged at this point.

PART 3: COMPARATIVE ANALYSIS OF RESULTS FROM THE 1994/5 AND 2001/2 MEMBER SURVEYS

Reasons for Participating in an ERC

The relative importance to member firms of alternative reasons for deciding to participate in a center did not change drastically for the second cohort of ERCs compared to members of the first cohort. In both cases, access to new ideas and know-how were by far the most important and the ability to license ERC inventions and software least important. However, as Table S-7 shows, a much wider range of benefits was identified as "very or extremely important" by a majority or near majority of member firms in the second cohort, possibly suggesting that industry generally is becoming more aware of the myriad benefits that can result from participation in university-based industrial research consortia.

Table S-7: Importance of Alternative Reasons for Deciding to Participate in Center, 1994/5 and 2001/2

	Percent Responding							
	Not at All or Somewhat Important		Quite Important		Very Important or Extremely Important		Mean Rating*	
Reason for Participating	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2
Access to new ideas and know-how	7.2	6.1	10.9	14.7	80.2	77.6	4.1	4.1
Technological/research focus at ERC matched our interests	8.6	6.8	16.7	23.1	73.0	67.5	4.0	3.9
Access to ERC technology		19.0		22.4		55.2		3.5
Access to specific ERC faculty	17.6	20.7	23.7	21.6	56.1	55.2	3.5	3.4
Opportunity for joint projects	32.1	22.4	24.9	27.6	39.1	48.3	3.1	3.3
Opportunity for cross-disciplinary research	43.5	24.8	24.5	26.5	27.4	46.2	2.7	3.3
Prior connections/ relationships with individuals at the ERC	43.5	23.3	19.8	20.7	32.7	52.6	2.7	3.3
Opportunity to interact with other companies affiliated with the ERC	46.7	26.1	22.6	29.6	27.5	42.6	2.7	3.2
Access to ERC students as prospective new hires	43.7	38.8	25.3	25.0	27.6	33.6	2.8	2.9
Ability to leverage our research investment with money from other ERC sponsors	44.0	41.9	20.1	19.7	30.8	35.9	2.7	2.9
The ERC's engineered system goals		26.5		31.6		33.4		2.9
The ERC's integration of research and education		38.8		24.1		35.3		2.9
Access to equipment, facilities, and/or testbeds at the ERC**	44.9	46.1	23.5	16.2	28.7	34.2	2.8	2.7
Ability to license inventions and/or software development by the ERC	62.4	53.5	19.4	19.0	14.5	25.9	2.2	2.6

Source: SRI International, ERC Survey 1994/5 and 2001/2.
*Items were rated on a 5-point scale, with 1=not at all important, 2=somewhat important 3=quite important (moderately important in 1994-5 scale), 4=very important, 5=extremely important. The midpoint is 3.0.
**The wording of this benefit did not include testbeds in the 1994/5 survey.

Notes: Percentages do not add to 100 horizontally in each of the two surveys due to a small number of respondents who reported "don't know/don't remember."
Missing data indicate that this item was not a choice in the 1994/5 survey.

Benefits Experienced from Participation

When data on the benefits actually realized by center member firms from the two cohorts are compared, the relative ranking of benefits is quite consistent across time. Generally speaking, in both surveys member firms tend to obtain the benefits they expect, with approximately the same degree of relative importance (value) associated with each specific benefit. But the more even distribution of anticipated benefits shown in the previous table is not repeated (at least not as clearly) by the pattern of benefits realized (Table S-8).[9] Although the distribution of benefits reported by representatives of member companies in the second cohort is more even that of the first cohort, the mean ratings do not reveal a similar pattern. This means that, while the *proportion* of member firms reporting specific benefits is more evenly distributed in the 2001/2 survey responses, the distribution of the *values* associated with specific benefits is less even than in the 1994/5 survey.

One important difference between the benefits reported by the two cohorts is the much larger percentage of firms in the 2001/2 survey reporting that they improved a product or process, and developed a new product or process. It is also notable that the proportion of member firms reporting every specific benefit increased, in most cases significantly, suggesting that the second cohort center members are either more aware of the full range of benefits they receive, or actually do receive a wider range of benefits than members of first cohort ERCs.

[9] Because 2001/2 survey instrument was designed to obtain data on the benefits associated with specific center activities and resources, it was not possible to obtain data on the distribution of value ratings for each benefit.

Table S-8: Benefits Experienced from Participation in an ERC, 1994/5 and 2001/2

	Companies Reporting Benefit (percent)		Mean Rating**	
Type of Benefit	**1994/5**	**2001/2**	**1994/5**	**2001/2**
Hired an ERC student or graduate	39.9	41.0	3.4	3.4
We obtained access to new ideas or know-how.*	**84.0**	**91.2**	2.9	2.9
Our R&D agenda was influenced.	**54.1**	**67.0**	2.8	2.7
We improved a product(s) or process(es).	**42.5**	**58.2**	2.9	2.7
We developed a new product(s) or process(es).	**23.6**	**42.9**	2.9	2.7
We had more interaction than in the past with other ERC firms.	50.1	50.5	2.7	2.6
We were able to provide our customers/suppliers with improved technical information.	**44.1**	**56.0**	2.9	2.5
We made unexpected operational changes (e.g., equipment or project additions or cancellations).		18.7		2.4
We patented or copyrighted technology or software we developed as a result of interacting with the ERC.	**8.4**	**14.3**	2.8	2.3
We licensed technology or software developed by the ERC.	11.8	15.4	2.8	2.2

Source: SRI International, ERC Survey 1994/5 and 2001/2.
*Wording in 1994/5 survey was "Obtained access to new ideas, know-how, or technologies through ERC interaction."
**Items were rated on a 4-point scale, with 1=little or none, 2=some, 3=moderate amount, 4=a great deal. The midpoint was 2.5
Notes: Missing data indicate that this item was not a choice in the 1994/5 survey.
Entries in bold face indicate that the differences are statistically significant, $p < 0.05$.
Mean ratings could not be compared statistically because they were obtained in different ways, and standard deviation data were not available for the 1994/5 data.

ERC Student/Graduate Performance

Center member firms hired ERC students or graduates in similar proportions: among survey respondents who knew whether their company unit had hired students or graduates, 30 percent of the 1994/5 member firms surveyed reported hiring center students or graduates as regular employees, and 41 percent of the firms surveyed in 2001/2 reported hiring ERC students or graduates as either regular or summer employees. The earlier survey did not include summer hires, so it is likely that the proportion of member firms hiring ERC students or graduates on a permanent basis has not change significantly. In both surveys, ERC students are rated as "somewhat better or much better" than comparable non-center hires by more than a majority of center representatives on all of the ten dimensions of employee performance. Table S-9 shows the detailed results of the comparative analysis of student performance.

Table S-9: Comparison of Performance of Center Students/Graduates with Comparable Non-Center Hires 1994/5 and 2001/2

	ERC Students/Graduates Are: (percent)							
	Much Worse or Somewhat Worse		About the Same		Somewhat Better or Much Better		Mean Rating**	
Performance Dimension	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2
Breadth of technical knowledge.	0.0	0.0	19.8	14.9	74.3	83.0	4.2	4.3
Ability to work in interdisciplinary teams.	0.0	0.0	23.8	12.8	64.3	83.0	4.0	4.3
Depth of technical knowledge.	0.0	0.0	14.9	18.8	80.2	79.2	4.2	4.2
Overall preparedness for working in industry.	0.0	2.1	14.9	8.5	80.2	87.2	3.8	4.2
Ability to apply knowledge from different disciplines and use technologies in an integrated fashion to solve problems.	1.0	0.0	17.8	17.4	72.3	78.3	4.1	4.1
Contribution to the firm's technical work.	0.0	2.2	17.8	15.2	77.3	80.4	4.2	4.0
Ability to apply engineered systems perspective.*	0.0	0.0	25.7	23.4	63.3	72.3	4.0	3.9
Ability to use knowledge to develop technology.	0.0	0.0	23.8	19.6	66.3	73.9	3.9	3.8
Ability to solve problems within constraints of time, money, and human resources.	1.0	0.0	28.7	29.8	59.4	66.0	4.0	3.7
Firm-funded training required before they became a net contributor to the firm's work.	1.0	0.0	35.1	26.7	52.6	64.4	4.1	3.5

Source: SRI International, ERC Survey 1994/5 and 2001/2.
*Wording in 1994/5 survey was "Familiarity with engineering systems approach."
**Items were rated on a 5-point scale, with 1=much worse, 2=somewhat worse, 3=about the same, 4=somewhat better, 5=much better. The midpoint was 3.0

Comparison of Reasons for Participation and Results

The earlier study compared the results experienced by member firms with their original reasons for participating, and not surprisingly found a close association between expectations and realized benefits. The wording of the expectations and benefits realized survey questions used in each study were somewhat different, and the design of the second study did not permit frequency counts for the degree of benefit received, some limited comparisons can be made. The results for the second study are fully consistent with those of the first: the frequency profile of member firms reporting of the benefits received shows that the ranking of benefits received matches the ranking of original reasons for participating (Table S-10). These results should be considered suggestive only, however, because of the small number of responses in the second survey to several of the specific benefit choices.

Table S-10: Comparison of Reasons for Participating and Results (percent responding)

Original Reason for Participating	A. Originally Very/ Extremely Important		B. Percent of A that Experienced the Result/ Outcome		Moderate Amount		Great Deal	
	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2
Access to new ideas and know-how	80.2	78.9	90.3	73.3	42.9		26.6	
Access to ERC equipment, facilities and/or testbeds	28.7	34.8	72.2	75.0	34.3		41.8	
Access to ERC students as prospective new hires	27.6	33.9	65.6	76.3	15.5	24.1	72.4	41.4
Opportunity to interact with other companies affiliated with the ERC	27.5	43.4	81.9	57.1	40.3		40.3	
Ability to license inventions and/or software developed by the ERC	14.5	26.3	34.0	26.7	41.2		35.3	

Source: SRI International, ERC Survey, 1994/5 and 2001/2.
Note: Empty cells indicate that comparable data were not available from the 2001/2 survey.

Barriers to Realizing Benefits of Membership

As noted earlier in this summary report, the 2001/2 survey showed that most member firms do not consider there to be "significant" or "extremely significant" barriers to realizing the benefits of ERC participation. Topping the list in importance was "other company matters" rather than any barrier associated with ERC activities themselves. As Table S-11 shows, this was also the case in the earlier survey. Indeed, both the overall ratings of specific barriers and the distribution of responses to individual barriers are remarkably similar across both studies.

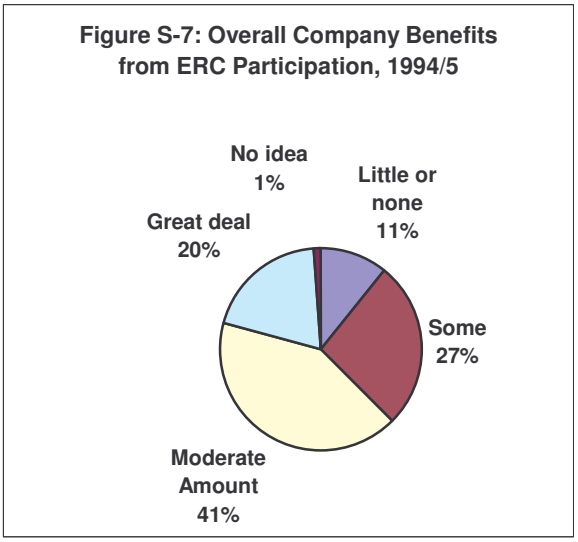
Table S-11: Significance of Barriers to Realizing Benefits of Participation in Centers, 1994/5 and 2001/2

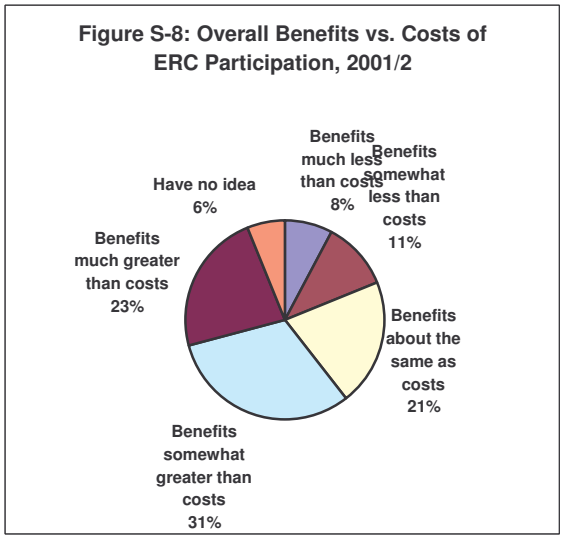
	Percent Responding									
	Not at All Significant		Somewhat significant		Quite significant		Extremely Significant		Mean Rating*	
Type of Barrier	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2
Other company matters preempt increased involvement with the ERC	31.5	17.1	21.4	28.2	23.7	24.8	21.1	19.7	2.4	2.3
Different conceptions of appropriate time between project initiation and completion	31.0	23.1	28.7	34.2	21.9	23.9	13.9	13.7	2.2	2.2
Intellectual property issues	27.6	23.1	34.4	40.2	21.6	18.8	12.2	12.0	2.2	2.1
Lack of awareness about the ERC within my company	33.3	32.5	30.4	33.3	24.9	25.6	9.6	5.1	2.1	2.0
Differences between the ERC and my company in values, mission, or priorities (e.g., academic vs. corporate values)	28.9	44.8	27.1	22.4	28.9	19.8	12.3	11.2	2.3	1.9
Internal company “politics” or requirements	52.6	49.6	22.3	23.5	13.3	14.8	8.4	8.7	1.8	1.8
Poor communication between the ERC and us	55.7	47.0	23.0	21.4	14.7	19.7	4.6	5.1	1.7	1.7

Source: SRI International, ERC Survey 1994/5 and 2001/2.
*Items were rated on a 4-point scale, with 1=not at all significant, 2=somewhat significant, 3=quite significant, 4=extremely significant. The midpoint was 2.5. In the 1994/5 study, the scale items were 1=not a barrier, 2=minor barrier, 3=moderate barrier, 4=major barrier.

Effects of ERC Participation on Overall Member Benefits and Firm Competitiveness

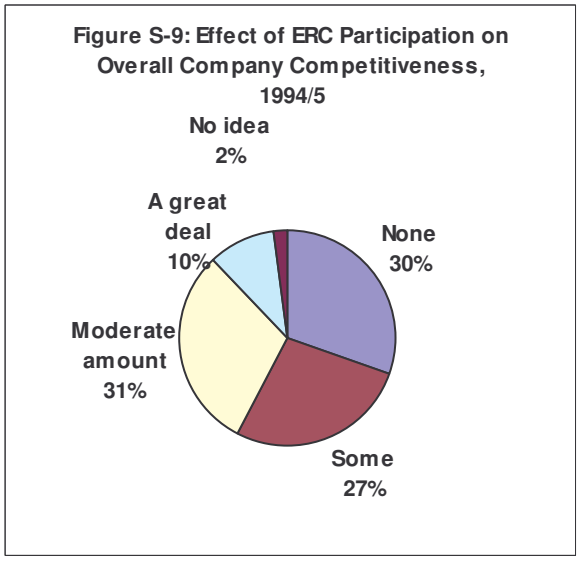
In the 1994/5 survey, member representatives were asked to assess the overall benefits to their firm of ERC participation, whereas in the 2001/2 survey they were asked to assess the overall benefits vs costs of participation. Though not directly comparable, it is useful nonetheless to show both set of results in Figures S-7 and S-8. In both cases, a majority of respondents reported that overall company benefits were positive, and just 11 percent in the 1994/5 survey reported little or no benefits, while 19 percent in the more recent survey reported that benefits of participation were less than the costs.

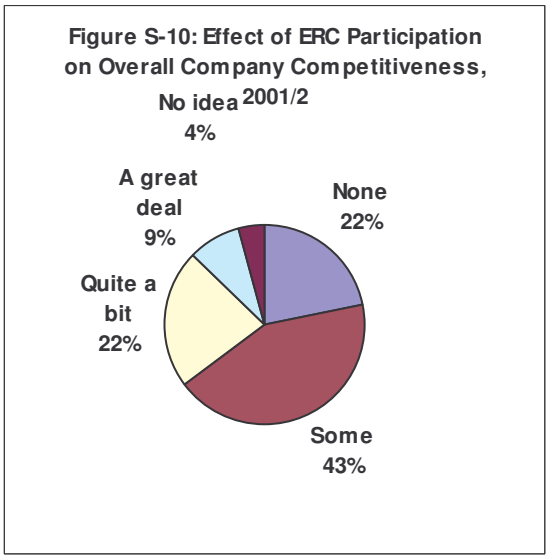




Source: SRI International, ERC Survey 1994/5 and 2001/2.

Representatives of ERC members from both cohorts reported positive effects on their companies' overall competitiveness, with 68 percent in the first cohort and 74 percent in the second cohort reporting at least some increase in competitiveness (Figures S-9 and S-10).





Source: SRI International, ERC Survey 1994/5 and 2001/2.

Factors Influencing Overall Benefit Assessments

Although the two studies used different question formats to inquire about the magnitude of overall benefits realized by ERC member firms, it was still possible to conduct limited comparisons of the influence of two factors on overall benefits: years of company involvement in the ERC, and the technological area of the ERC. Analysis of the data showed that, in both studies, the longer a company had been a member of the ERC, the higher the assessment of overall benefits (Tables S-12 and S-13). However, in neither study was the technological field of the ERC significantly related to overall benefits assessments (Tables S-14 and S-15).

Table S-12: Overall Benefit/Cost Assessment of ERC Participation, by Years of Company Involvement, 2001/2

	Percent Responding			
Years of Company Involvement	Benefits Much Less or Somewhat Less than Costs	Benefits About the Same as Costs	Benefits Somewhat Greater or Much Greater than Costs	Mean Rating*
1 year or less	12.5	62.5	25.0	2.1
2 to 4 years	22.2	24.4	53.3	2.3
5 or more years	19.3	14.0	66.7	2.5

Source: SRI International
Differences in the table are statistically significant, p< .05.
* 3 point scale, midpoint is 2

Table S-13: Overall Benefits to the Company from ERC Participation, by Years of Company Involvement, 1994/5

	Percent Responding				
Years of Company Involvement	Little or None	Some	Moderate Amount	Great Deal	Mean Rating*
1 year or less	25.8	22.6	29.0	22.6	2.5
2 to 4 years	11.9	31.8	41.1	15.2	2.6
5 to 7 years	2.8	25.5	50.0	21.7	2.9
8 to 10 years	8.3	8.3	47.2	36.1	3.1

Source: SRI International
Differences in the table are statistically significant at p < .05.
* 4 point scale, midpoint is 2.5.

Table S-14: Overall Benefit/Cost Assessment of ERC Participation, by Technological Area of Associated ERC, 2001/2

	Percent Responding			
Years of Company Involvement	Benefits Much Less or Somewhat Less than Costs	Benefits About the Same as Costs	Benefits Somewhat Greater or Much Greater than Costs	Mean Rating*
Microelectronics	18.5	14.8	66.7	2.5
Design	21.4	25.0	53.6	2.3
Bioengineering	18.5	22.2	59.3	2.4

Source: SRI International
Differences in the table are not statistically significant.
* 3 point scale, midpoint is 2

Table S-15: Overall Benefits to the Company from ERC Participation, by Technological Area of Associated ERC, 1994/5

	Percent Responding				
ERC Technological Area	Little or None	Some	Moderate Amount	Great Deal	Mean Rating
Biotechnology/bioengineering	8.8	32.4	33.8	25.0	2.8
Design and manufacturing	8.3	28.9	41.3	21.5	2.8
Energy and resource recovery	19.1	21.4	47.6	11.9	2.5
Materials processing	12.9	25.8	45.2	16.1	2.6
Electronics/telecommunications	8.9	21.4	50.0	19.6	2.8

Source: SRI International
Differences in the table are not statistically significant.
* 4 point scale, midpoint is 2.5.

Factors Contributing to ERC-Derived Benefits

In both the 1994/5 and 2001/2 surveys, member representatives were asked to rate nearly comparable lists of factors in terms of their relative contribution to the realization of benefits for the firm. As we saw earlier in this report, data from the more recent survey showed that a wide range of factors contributed to member benefits, some associated with the ERC, some with the member firm, and some with their interaction. A comparison of these results with those obtained in the earlier survey shows a similar pattern (Table S-16). Nearly all the factors listed show an increase in the proportion of representatives who considered the factors to be very important or extremely important to the realization of benefits, with the increases somewhat greater for those factors rated less highly in the earlier survey. This further supports the observation that a very wide range of influences are regarded as important to the realization of ERC-derived benefits for members, and, if anything, the range has widened over time.

Table S-16: Factors Contributing to ERC-Derived Benefits, 1994/5 and 2001/2

	Percent Responding							
	Not at All or Somewhat Important		Quite Important		Very Important or Extremely Important		Mean Rating*	
Factor	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2	1994/5	2001/2
Continuous existence of a strong ERC "champion" in the company unit	35.3	22.1	18.1	25.0	43.1	52.9	3.3	3.5
Management support of the ERC within our company	34.8	25.7	25.0	25.7	38.1	48.6	3.2	3.4
The closeness between the ERC's specific technical focus and ours	23.4	21.1	16.9	31.2	58.3	47.7	3.6	3.4
Responsiveness of ERC faculty/researchers to our needs	26.7	24.3	21.4	24.3	49.2	51.4	3.4	3.3
The ERC's efforts to communicate and stay in contact with sponsors	25.7	25.2	24.8	27.0	48.1	47.8	3.4	3.3
The ERC's emphasis on cross-disciplinary research	40.4	27.8	22.2	30.6	35.1	41.7	3.0	3.2
Receptivity of company technical staff to ERC ideas and/or results	31.9	30.6	24.6	33.3	41.7	36.1	3.2	3.1
Our ability to influence the ERC's research agenda	48.4	36.5	23.9	30.8	25.1	32.7	2.7	2.9
The ERC's engineered systems goals**	50.8	43.1	19.8	23.5	24.5	33.3	2.6	2.8
Integration of research and education		46.1		24.5		29.4		2.8
The commercialization potential of ERC research	55.4	43.3	19.0	26.0	21.9	30.8	2.6	2.8
Our ability to establish proprietary rights	64.1	51.6	11.7	17.2	20.5	31.2	2.5	2.7

Source: SRI International, ERC Survey 1994/5 and 2001/2.

*Items were rated on a 5-point scale, with 1=not at all important, 2=somewhat important 3=quite important (moderately important in 1994-5 scale), 4=very important, 5=extremely important. The midpoint is 3.0.

**The wording of this factor was "The ERC's engineered systems approach to education" in the 1994/5 survey.

Notes: Some percentages do not add to 100 due to a small number of respondents who reported "don't know/don't remember."

Missing data indicate that this item was not a choice in the 1994/5 survey.

PART 4: CONCLUSIONS AND OBSERVATIONS

Member Use of Center Activities and Resources

Member firm use of center activities and resources was not dominated by any one category; usage was spread broadly across the five center activities and resources identified for analysis in this study. However, a greater proportion of member representatives (53 percent) reported using technical advice/consulting services from center faculty compared with the proportion reporting use of the results of both types of center research, use of center facilities/equipment/testbeds, and hiring of center students or graduates (about 40 percent for each of these categories). The frequency with which member representatives reported that their units realized specific benefits ranged widely. Ninety percent reported gaining access to ideas and know-how; 60 percent reported improving or developing new products and processes; 15 percent reported licensing center-produced technology or software. The 40 percent of representatives of firms that hired center students or graduates rated that benefit more highly than was the case for any other benefits studied. These patterns of the realization of specific benefits combined in complex ways to yield, for more than half the firms, a positive overall rating of the ratio of benefits to costs of center membership, and prediction of membership renewal for 2003.

Explaining Impacts on Member Firms

Among the four types of impact considered for use in our analysis, the single *behavioral* indicator of the overall value to center members of their membership is the decision to renew it. That decision is a complex function of numerous factors, many of which are outside the influence of individual ERCs or of the provisions of the ERC Program. One indication of this complexity is the amount of variation in the two impact indicators selected for analysis accounted for by the factors included in this study. Our analysis of the impact on member firms of member and center structural characteristics, patterns of use of center activities and resources (including center student and graduate hiring), and the levels and types of benefits realized "explained" no more than 30 percent of the variation in net benefit ratings and the likelihood of membership renewal in 2003. Depending on the particular analytical model and impact indicator used, typically even less variation than that was accounted for.

Member representatives' assessments of the likelihood that their firm will renew its membership in 2003 were positively and strongly related both to their assessments of whether center membership had increased the firm's competitiveness, and to their assessments of the overall benefits vs. costs of membership. Of the several indicators of impact of membership on firms considered for inclusion in the analysis, increased competitiveness appeared at face value to be the broadest, most subjective, and least directly related to center activities. Member representatives' expectations of the decision to renew is probably the most accurate impact indicator, but it is a function of many factors internal to firms that bear only indirectly on the specific benefits derived from use of center activities and resources. Estimates of the overall relationship between the benefits and costs of membership, despite their qualitative character, have the virtue of being directly related to the impact of center membership on matters of economic and/or technological significance to the firm, as reported by firms' representatives. Clearly, multiple indicators of impact are useful and capture different dimensions of the value of

center membership and involvement, but variations within each indicator add complexity to interpretations of both relationships and results.

Focusing first on the central question of what factors affect impacts on member firms, the answer is relatively robust. Firms whose research agenda was influenced by participation in an ERC were most likely to have a positive benefit/cost rating and most likely to expect continued membership in the center in 2003. Product or process improvements were associated with high benefit/cost ratings as well as greater likelihood of renewal for 2003. Many other influences were at work here, and our findings can only hint at what some of these might be. Somewhat less robust results were obtained when patterns of member use of different center activities and resources, including center student and graduate hiring, were examined for their effect on impact indicators. Obtaining technical advice/consulting services from center faculty, using the results of fundamental research and enabling technology research, and hiring students and graduates were all predictive of higher benefit/cost ratings, but only obtaining technical advice/consulting services was also predictive of the intention to renew in 2003.

Assessments by member representatives of the factors that contribute to the realization of benefits by their firms complement the results of the statistical analyses referred to immediately above. They suggest that a very wide range of diverse factors work together in complex ways to generate benefits for the firm, with characteristics of both ERC and the firm involved, as well as the nature of their interaction. Over time, the number of factors that are considered to contribute in important ways to the realization of benefits appears to have increased. Existence of a strong ERC champion in the firm, management support of the ERC, and the close match between ERC and member firm research foci all matter a great deal, as do the ERC's responsiveness to member needs and efforts to communicate and stay in contact.

ERC Interactions with Small Businesses

SRI's interviews revealed as much about the differences among the eight ERCs as their similarities. Many interactions with ERC-based start-ups and small, non-member firms are heavily influenced by factors over which center managers have little or no control. These include state laws, university policies, university culture, the resources available to the university Technology Licensing Office, tensions inherent in the long-term research focus of centers and the short-term needs of start-ups, the center's technical focus, and the dynamism of the industry served by the center. Yet it is clear that the second generation ERCs are interacting with small firms in a variety of ways that mutually benefit the centers and their host universities, the small firms involved, and the center's full members. To ensure that the substantial benefits of this synergy are preserved, the flexibility of centers to achieve the delicate balance among fostering start-ups, working with non-member small businesses, and preserving the long-term, strategic research essential to the continued health of ERCs must be maintained.

Implications for New Centers

The basic patterns of benefits realized from participation in ERCs and their impacts on industry do not appear to have changed dramatically. Access to ideas, know-how, and the ability to hire center students and graduates continue to top the list of most frequently experienced

benefits, while licensing ERC software and technology continues to be least important to member firms. A significantly higher proportion of member firms from the more recent study reported receiving a number of important benefits, notably product and process improvements and new products or processes. Maintenance of frequent and close communications with member firms is important to the retention of members, as is responsiveness of ERC researchers to member needs. There are also some new findings that have no counterparts in the previous study; these have to do with member firm use of different ERC activities and resources, and the breakdown of benefits resulting from each category of use. Highly favorable assessments by member representatives of the net benefits of participation in ERCs continue, as does the match between expectations of benefits from membership and the benefits actually experienced. And finally, barriers to the realization of benefits by member firms are not serious, and they continue to relate mostly to firm policies and environments, not ERC activities.

The importance of research universities for regional economic growth has become widely recognized over the past two decades, and new government programs at all levels reflect this change. Successful, innovative, research-based businesses are accepted as one of the keys to sustainable regional growth, and university-based start-ups are an important ingredient in the recipe. Industrial liaison officers of the second cohort of ERCs are well aware of this and act knowledgeably and aggressively to help create, develop, and nurture center relationships with small, research-based firms in their regions. They also work closely with university technology licensing offices to foster the creation and growth of start-up forms based in ERC research. While probably more a matter of degree than of kind, this emphasis represents a significant change in ERC-industry relationships since the late 1980s and early 1990s.

Our findings do not suggest that fundamental changes have occurred in ERC-industry relationships, changes that might point to the need for revisions in ERC Program policies or practices. If anything, our results show the need for Program flexibility to continue, allowing Directors, ILOs, and other members of center management teams to adjust to different conditions, e.g., changes over time and variations in policies among ERC host institutions and their environments.

In the next cohort of ERCs, relationships with small businesses, especially start-ups, will continue to grow in importance. ILOs will need to manage a delicate balancing act, one that enables centers to help foster internal start-ups, nurture them, and work effectively with non-member small firms in the region, while at the same time attending to the recruitment and retention of fee-paying members and encouraging lower-level participants to become full members. Here, flexibility in member fee and benefit structures and in the membership agreement are especially critical. ILOs will need to share experiences and best practices among themselves to the greatest extent possible. “Private” sessions at the annual ERC Directors’ meetings, planned and run by ILOs, could prove to be an effective forum for productive exchanges.