

SRI International

• October 2000

OUTCOMES AND IMPACTS OF THE STATE/INDUSTRY- UNIVERSITY COOPERATIVE RESEARCH CENTERS (S/IUCRC) PROGRAM

FINAL REPORT

Report by:

David Roessner

Submitted By:

Science and Technology Policy Program

Prepared for:

The National Science Foundation
Engineering Education and Centers Division

ACKNOWLEDGEMENTS

SRI would like thank a consultant to this study, Professor Irwin Feller, for his contributions to this report, particularly for contributing extensively to Chapter II and reviewing the entire draft document; Catherine Ailes, for her support, careful reviews, and constructive suggestions throughout the course of the project; Roland Bardon, for managing the surveys, reviewing the S/IUCRC data base and annual reports, and for numerous other analytical tasks; Julia Song, for her excellent programming work with the survey data; Lyra Vega, for her careful attention to formatting and production; Katy Vickland, for assistance with the OMB clearance process, instrument design, and pretesting the instruments; Denis Gray for advice and assistance with several aspects of the study; and Joan Ruskus, for advice on OMB clearance, instrument design, and data analysis.

SRI also wishes to thank many staff members at the S/IUCRCs and I/UCRCs surveyed for their cooperation and assistance, especially the Director and staff of the Nonwovens Cooperative Research Center at North Carolina State University; the center representatives for their time and care in responding to the survey; and the State Representatives of seven S/IUCRCs for their time and candor in telephone interviews.

Finally, SRI wishes to thank the NSF staff who supported and advised the project, especially Linda Parker, Lynn Preston, Alex Schwarzkopf, Win Aung, and Marshall Lih.

The conclusions and interpretations presented in this report are those of the author and do not necessarily represent the views of the National Science Foundation or the federal government.

CONTENTS

Acknowledgements	i
Contents	ii
Executive Summary	vi
I. Introduction to the Evaluation	1
A. Brief Overview of the S/IUCRC Program and the Context for the Evaluation.....	1
B. Design of the Evaluation.....	5
II. The Context of the S/IUCRC Program	10
A. State Economic Development Strategies	10
B. A Short History of State S&T Programs.....	11
C. State Economic Development and S&T Strategies	14
D. Federal State Partnership Involving S&T	16
E. Origins of the NSF S/IUCRC Program.....	18
F. State Organizational and Political Context of the S/IUCRCs.....	21
G. References.....	25
III. Firm-Level Outcomes From Center Activities	27
A. Introduction.....	27
B. Profile of Member Firm Participation in Center Activities	27
C. Profile of Results of Member Participation in Center Activities on Firm Behavior	28
D. Center Member Hiring of Students or Graduates	30
IV. Program Impacts	33
A. Value to Member Firms of Specific Outcomes From Center Activities	33
B. Estimates of Overall Program Benefits and Costs.....	34
C. Regional Economic Development Impact: Firm Location	36
D. Regional Economic Impact Data From S/IUCRC Annual Reports.....	38
E. Detailed Analysis of Program Impacts Due to Member Firm Location	41
V. Factors Expected to Influence Program Outcomes and Impacts	47
A. Program Goals, Requirements, and Guidelines	47
B. Descriptive Data on Member Firms and Representatives.....	49
VI. Explaining Outcomes and Impacts	51
A. Member Firm Participation in Center Activities	51
B. Outcomes From Member Firm Participation in Center Activities.....	54
C. Member Firm Representatives' Valuation of Outcomes	56

D. Member Firm Assessments of Benefits and Costs	56
E. Regional Economic Impact of Centers	58
F. Multivariate Analysis.....	59
VII. Conclusions and Observations.....	61
A. Objectives and Design of the Evaluation.....	61
B. Expectations, Results, and Explanations	62
C. The S/IUCRC Program in the State Context	67
D. Conclusions and Observations.....	69

Appendices

- A. Methodological detail
- B. Survey Instrument: S/IUCRC member firm representatives
- C. Survey Instrument: I/UCRC member firm representatives

TABLES AND FIGURES

Table I-1	A Comparison of Goals, Activities, Requirements, Operating Conditions, and Practices of the S/IUCRC and I/UCRC Programs.....	3
Table I-2	Formal Requirements of the S/IUCRC and I/UCRC Programs.....	4
Table I-3	List of S/IUCRCs Included in the Evaluation.....	6
Table I-4	I/UCRCs Included in the Evaluation	7
Table III-1	Results Obtained from Member Participation in Center Activities, by Outcome Category, S/IUCRC (per cent responding).....	30
Table III-2	Results Obtained from Member Participation in Center Activities, by Outcome Category, I/UCRC (per cent responding Within each type of activity).....	30
Table III-3	Number of Center Students or Graduates Hired as Regular Employees by Representatives' Company Units: S/IUCRC.....	31
Table III-4	Number of Center Students or Graduates Hired as Regular Employees by Representatives' Company Units: I/UCRC.....	31
Table III-5	Comparison by Firms of Performance of I/UCRC Center Hires is Comparable non-Center Hires Employed at Member Firms	32
Table IV-1	Degree of Member Benefits Derived from Outcomes of Center Participation: S/IUCRC	33
Table IV-2	Degree of Member Benefits Derived from Outcomes of Center Participation: I/UCRC.....	34
Table IV-3	Estimates of Financial Benefits from Center Membership, S/IUCRC	35
Table IV-4	Program Support Expenditures Reported by Representatives of Center Members, S/IUCRC and I/UCRC.....	36
Table IV-5	Proportion of In-state and Out-of-state Members, S/IUCRC and I/UCRC.....	37
Table IV-6	Comparison of In-state and Out-of-state Member Participation in Center Activities, by Outcome Category: S/IUCRC.....	43
Table IV-7	Comparison of In-state and Out-of-state Member Participation in Center Activities, by Outcome Category: I/UCRC.....	43
Table IV-8	Comparison of In-state and Out-of-state Member Degree of Benefits Derived, by Center Activity and Outcome Category: S/IUCRC....	44
Table IV-9	Comparison of In-State and Out-of-state Member Degree of Benefits Derived, by Center Activity and Outcome Category: I/UCRC	45
Table IV-10	Member Hiring of Center Students/Graduates by Location, S/IUCRC and I/UCRC.....	46
Table V-1	Number of Years Firms have been Center Members by Type of Center	50

Table V-2	Number of Years as Member Firm Representative to Center by Type of Center.....	50
Table VI-1	Member Firm Participation in Center Activity by Type of Center and Firm Size.....	52
Table VI-2	Member Firm Participation in Center Activities by Type of Center and Length of Center Membership	53
Table VI-3	Member Firm Participation in Center Activities by Length of Time as Center Representative, S/IUCRC and I/UCRC.....	53
Table VI-4	Member Firm Participation in Center Activities by Mean Annual Expenditures for Support and Type of Center	54
Table VI-5	Results Obtained from Member Participation in Any Center Activity by Outcome Category and Type of Center	55
Table VI-6	Member Firm Participation in Center Activities by Type of Center and Length of Center Membership	55
Table VI-7	Member Firm Assessment of Benefit/cost Ratio by Type of Center and Firm Size.....	57
Table VI-8	Member Firm Estimates of Total Dollar Savings by Type of Center and Firm Size.....	58
Table VI-9	Response Rates to Survey Items Seeking Quantitative Benefit Estimates by Type of Center	60
Figure III-1	Member Participation in Center Activities	28
Figure IV-1	Assessment of Benefits vs. Costs, S/IUCRC and I/UCRC.....	35
Figure IV-2	Assessment of Benefits vs. Costs, In-State vs. Out-of-State Members, S/IUCRC and I/UCRC.....	38
Figure IV-3	Member Participation in Center Activities by Geographic Location, S/IUCRC and I/UCRC	42

Outcomes and Impacts of the State/Industry-University Cooperative Research Centers (S/IUCRC) Program

EXECUTIVE SUMMARY

A. Project Background

The NSF State/Industry University Cooperative Research Centers Program, initiated with six centers in 1991 and four more in 1992, drew upon the Foundation's favorable experience with other programs intended to promote industry-university cooperation in research to design a related program that would incorporate the interests of state governments. In particular, the S/IUCRC Program called for a "new partnership" between the federal government and the states to promote industry-university cooperation, but in a way that would bring explicit benefits to states as well as the nation. Indeed, the Program was the outcome of an understanding reached in 1990 between NSF and the National Governors' Association. S/IUCRCs were to achieve their objectives through programs of fundamental "core" research, industry-sponsored "non-core" projects that could be proprietary, specific technology transfer efforts involving both types of research, and the explicit involvement of small and medium-sized firms.

NSF supported the present study first to answer the kinds of questions posed by most program evaluations: to what extent has the Program accomplished its goals? What lessons can be learned that might be used to improve the Program's performance? In addition, NSF wished to identify lessons that could inform the agency's planning for future NSF-state partnerships. The existence of the NSF Industry/University Cooperative Research (I/UCRC) Program, on which the S/IUCRC was modeled, offered an unusual opportunity to employ comparative analysis. Thus, in addition to outcome and impact data collected about the S/IUCRC Program itself, equivalent data were collected about the I/UCRC Program and used for comparative purposes. A comparative analysis of the two Programs enabled conclusions to be drawn about the independent effects—the "value added"—of the unique features of the S/IUCRC Program. These included explicit technology transfer activities associated with center research, the "non-core" projects sponsored by one or more industrial members that could involve proprietary work, a requirement for states to match NSF financial support, and the possibility of granting exclusive licenses to center members supporting non-core projects.

Most of the outcome and impact data developed for this study were generated from two surveys conducted by SRI: one of the official representatives of all organizations that were formal members of the nine S/IUCRCs initiated in 1991 and 1992 and still receiving NSF funding in 1998, and a second, similar survey of the official representatives of all organizations that are formal members of seventeen I/UCRCs that have existed for a similar period as the S/IUCRCs. The surveys were supplemented by an historical analysis of the origins and state context of the S/IUCRC Program, telephone interviews with State Representatives to S/IUCRCs, and careful review of S/IUCRC annual reports.

B. Selected Results

Center Activities. The profile of participation by member firms¹ in center activities is roughly similar for both types of centers, and is consistent with the profiles of member firm participation in other university-industry cooperative research centers. One difference that stands out is the significantly larger proportion of I/UCRC member firms that participates in sponsored research (61 per cent) relative to the proportion of S/IUCRC member firms that participates in non-core research (43 per cent). This is particularly surprising given that non-core research in S/IUCRCs was designed to be attractive to member firms as a source of solutions to problems, cost savings, and commercially applicable ideas and technology. None of the other potential explanations (given the data available in this study)—the location of member firms, the size of the firm, the length of the firm’s membership in the center—accounts for this difference. This puzzling result indicates that there may be substantial differences between S/IUCRC non-core research and I/UCRC sponsored research, differences that result in greater incentives to I/UCRC member firms.

Outcomes and Impacts on Member Firms. The pattern of participation in center activities by S/IUCRC member firms yields a wide range of specific results for them. By far the most frequently reported result was “obtained access to new ideas or know-how,” a result deriving primarily from technical advice to members, core research, and training provided by center faculty (between 90 and 95 per cent of those participating in these activities). Following this was product or process improvement, a result reported by representatives of between 60 and 70 per cent of the member firms that participated in core research, access to center facilities, or receiving technical advice. Only a small proportion—19 per cent or fewer—of representatives of members participating in S/IUCRC activities reported that their firm received the following specific results:

- Licensing technology or software developed by the center;
- Patenting or copyrighting technology and/or software developed as a result of interacting with the center;
- Making unexpected operational changes;
- All other direct results.

There is a significant difference between the S/IUCRC and I/UCRC Programs in the extent to which participation in center activities of any kind results in more tangible outcomes related to intellectual property: new product/process development and licensing technology or software developed by the center. For each center activity, S/IUCRC member representatives report these relatively tangible results more frequently than do their I/UCRC counterparts. The higher frequency of results related to intellectual property outcomes reported by representatives of S/IUCRC member firms was not associated primarily with non-core research activities, where effects of the difference in intellectual property provisions of the two Programs should be most evident. Introduction of other factors such as member firm location, firm size, and length of

¹ Both public and private sector organizations could join centers, but the term “firm” will be used to denote both.

center membership failed to account for the pattern of results observed. Although it seems reasonable to expect that the difference in intellectual property provisions plays some role here, the nature of the research actually undertaken and the actual practices regarding intellectual property protection among all centers, regardless of program, probably better explain this difference in results between the two Programs.

Representatives of member firms of both types of centers value center activities and the specific results that derive from participating in those activities roughly equivalently. As measured by these representatives' qualitative assessments of the benefits of center membership compared with the costs, a slightly larger proportion of S/IUCRC member representatives estimated that the benefits their firms derive exceeded the costs (62 per cent vs. 50 per cent), but this difference is not statistically significant. A large majority—about three-quarters--of representatives to both types of centers consider the benefits of membership to at least equal the costs.

When member representative reports of specific results associated with their firms' participation are analyzed by geographic location, it is clear that in-state location is a major influence on the type and number of specific results realized. Regarding member participation in center activities, a significantly larger proportion of in-state members of S/IUCRCs participates in non-core research than out-of-state members (60 per cent vs. 26 per cent), suggesting that S/IUCRCs are more responsive to in-state members, as the Program's economic development goal anticipates. (Fifty per cent of S/IUCRC member firms are located in the same state as the centers in which they participate, vs. 41 per cent of I/UCRC members.) Representatives of in-state members of S/IUCRCs report a much wider range of beneficial outcomes than do out-of-state representatives. Further, these in-state member firms' participation in non-core research was clearly the activity most likely to yield beneficial results relative to out-of-state members; and their participation in this activity resulted in a higher frequency of reports of access to new ideas, improved products or processes, improved technical information for customers or suppliers, and influence on R&D agendas.

Economic Impacts. With respect to member representatives' qualitative assessments of the benefits and costs they associated with center membership, the differences between the two Programs are striking. In the case of the S/IUCRC Program, representatives of in-state members consider center membership to provide far greater benefits than costs than do representatives of out-of-state members (76 per cent vs. 47 per cent), whereas the reverse is true for I/UCRC member firms, although the difference is not as dramatic (46 per cent vs. 52 per cent). If only the extreme categories are considered, differences in impact by region (at least by this measure) are even more pronounced. Nearly 40 per cent of the in-state S/IUCRC member representatives, compared with 17 per cent of the out-of-state member representatives, regard membership benefits to be much greater than the costs, while for the I/UCRC Program, 25 per cent of the out-of-state member representatives vs. 18 per cent of the in-state representatives consider membership benefits to be much greater than costs.

Regarding member firm participation in specific center activities by region, a considerably greater proportion of in-state S/IUCRC members participates in non-core research than out-of-state members (96 vs. 64 per cent), whereas both in-state and out-of-state members

of I/UCRCs participate in sponsored research in about the same proportion (87 vs. 93 per cent). A general pattern of more positive results for in-state members of S/IUCRCs is repeated and reinforced at the level of specific types of outcomes. Representatives of in-state members report a much wider range of types of beneficial outcomes than do out-of-state representatives, but the opposite is largely true for reports from representatives of I/UCRCs.

C. Conclusions and Observations

Based on the analyses conducted in this study, the S/IUCRC Program has been a modest success in the intermediate term as measured against its goals and objectives and compared with the outcomes and impacts of the I/UCRC Program. Centers in the S/IUCRC Program attracted considerably more in-state firms than out-of-state firms and a much greater proportion of small firms than did the I/UCRCs examined in this study. Participation rates in center activities were similar for both Programs, but the frequency and range of beneficial results related to more tangible research outcomes were greater for members of S/IUCRCs than members of I/UCRCs. Some of the S/IUCRC Program's outcomes and impacts can be attributed to its unique features, some to the more general nature of university-industry cooperative research activities, and some to the characteristics specific to member firms in S/IUCRCs. Others remain unexplained, at least by the data available in this study. For example, the low participation rates of S/IUCRC member firms in non-core research, relative to the participation rates of I/UCRC members in sponsored research, its assumed counterpart, are puzzling and call for further investigation. Outcomes related to intellectual property occurred more frequently for S/IUCRC member firms than for I/UCRC member firms, but could not be clearly identified with the intellectual property provisions attached to S/IUCRC non-core research that are unique to that Program.

The difficulties that State Representatives associated with justifying matching funds for S/IUCRCs suggest ways in which future NSF partnerships with states that involve university-industry collaborative research programs might be designed. First, from the states' perspective, the leverage that the S/IUCRC matching requirement provides is not high relative to other opportunities. It is seen as one-to-one: one state dollar leverages one federal dollar independent of the match provided collectively by member firms. Second, the typical S/IUCRC budget is not large, about \$1 million. States regard this as too small to generate many jobs or result in significant economic impact relative to other university-industry alternatives such as Engineering Research Centers or Science and Technology Centers. Third, small businesses are hard to attract to S/IUCRCs because they are viewed as needing a broad range of support, especially business assistance, which is difficult or impossible to provide within the requirements of the S/IUCRC Program. Finally, a state appears to be better able to incorporate an S/IUCRC into its own priorities and agendas if the center can be folded into an established state program intended to foster university-industry cooperation.

The argument for an NSF-state partnership that targets industry-university cooperation is as valid now as it was when the National Governors Association and NSF first discussed such a program in the late 1980s. The design of a future program, however, must account for the lack of integration in many states between economic development plans and programs with S&T plans and programs, and for variations in the nature of state agencies responsible for support of

universities. Given the experience of the S/IUCRC Program, it would seem prudent for a future program whose goal is to strengthen state S&T infrastructures rather than promote regional economic development, with university-industry cooperative research as the means. The form that such cooperative research programs might take would vary considerably, depending on state priorities and needs, and on existing state commitments to such cooperative arrangements.

In future partnerships with states, should NSF, in collaboration with representatives of states, design programs around ends or means? The S/IUCRC Program was designed around means: industry-university research collaboration was the vehicle for implementing the partnership, and the assumption was that the success of the I/UCRC model made it a suitable guide, with some modification, for a state partnership program. It proved more difficult than expected to modify the I/UCRC model, intended as it was to increase the national competitiveness of industrial firms, in a way that would achieve regional economic development through industry-university cooperative research. The difficulties were of two types. First, the model itself probably was an inappropriate means to achieve the goal of regional economic development. Second, wide variations across states in the organizational and political relationships between science and technology-related programs and strategies on the one hand, and economic development programs and strategies on the other, were incompatible with the inflexible requirement for annual state matching being linked to an economic development goal.

To sum up, the S/IUCRC Program was a valuable experiment in NSF-state partnerships. The Program succeeded in at least two ways. It accomplished, to a modest degree, its goal of promoting state economic development. And it demonstrated that explicit requirements such as state matching, explicit attention to technology transfer, industry-oriented intellectual property provisions, and encouragement of small and medium-sized firms as center members, can contribute to the achievement of this goal, even if applied to a program model that may not have been ideally suited to the context. The findings and conclusions from this study suggest that NSF has the ability to develop future partnerships with the states that will lead to benefits valued highly by both partners.

I. INTRODUCTION TO THE EVALUATION

A. Brief Overview Of The S/IUCRC Program And The Context For The Evaluation

In 1990 the NSF Directorate for Engineering established the State/Industry University Cooperative Research Centers (S/IUCRC) Program to complement and extend the Foundation's existing and well-regarded program of industry-university cooperative research centers. While sharing many of the basic goals and structural arrangements of other center programs, especially the Industry/University Cooperative Research Centers (I/UCRC) Program dating from the early 1970s, the S/IUCRC Program sought the involvement of states in which the new centers would be established and explicitly intended that regional economic development would be one of the Program's significant impacts. (Details of the S/IUCRC Program's origins and institutional and political setting are presented in Chapter II of this report.)

In 1997 the Foundation's Division of Engineering Education and Centers (EEC) initiated an external study of selected outcomes and impacts of the S/IUCRC Program. The objectives of the evaluation were to produce information about:

- The extent to which the Program has accomplished its goals;
- Lessons learned for continuous improvement of program performance; and
- Lessons learned that can inform future planning for subsequent NSF-state partnerships.

The EEC Division wished to identify the results attributable to features of the S/IUCRC Program that distinguished it from the I/UCRC Program model on which its design was based. Although the two Programs share certain objectives, requirements, and structural characteristics, there are a number of significant differences that derive from the S/IUCRC Program's technology transfer activities and expectations of regional economic development impacts.

Both the S/IUCRC and I/UCRC Programs seek to foster university-based research relevant to industry needs by supporting a program of generic and fundamental research that is cost-shared with industrial firms and other organizations that choose to join a center. Member organizations pay an annual membership fee to their center, for which they share in the setting of the center's research agenda via representation on an Industrial Advisory Board (IAB); receive results of the generic and fundamental research supported by NSF and the pooled membership fees; obtain access to center facilities and to faculty and staff knowledge, expertise, and advice; interact with students working on center projects; and have the opportunity to receive training from center faculty and staff. Member organizations may elect to hire center faculty and staff as consultants and enter into contractual agreements with centers for the conduct of proprietary research. In both Programs, host universities are expected to share in the costs of supporting the center.

As suggested above, the S/IUCRC Program has a number of unique features, relative to the I/UCRC Program, related to its origins as a program of partnership with states. The most important of these features were intended to promote industrially-relevant research with more

immediate potential for payoffs to industry. The mechanisms for accomplishing this included explicit technology transfer activities, a program of “non-core” projects sponsored by one or more industrial members that could involve proprietary work, and the possibility of granting exclusive licenses to members supporting non-core projects.² A key element of the S/IUCRC Program, originating with the involvement of the National Governor’s Association (NGA) in the Program’s design, was the requirement that NSF annual support must be matched by state governments.³ Finally, the S/IUCRC Program requires its centers to “work closely with industry (including small businesses) to facilitate diffusion of center research results and technology innovation with a view to impacting economic development.” Table I-1 summarizes the goals, requirements, operating conditions, and practices of the two Programs in a comparative format, and Table I-2 summarizes their formal requirements.

² Members of some I/UCRCs may obtain an exclusive license to center intellectual property under certain conditions, but the default situation is royalty-free, nonexclusive rights or options.

³ The origins of the S/IUCRC Program will be described in Chapter II.

**Table I-1.
A Comparison of the Goals, Activities, Requirements, Operating Conditions, and Practices of the S/UCRC and I/UCRC Programs**

	S/UCRC Program	I/UCRC Program
GOAL	Advance state economic development	Strengthen cooperative research relationships between universities and industry
ACTIVITIES	<p>Provide support for a "core" research program of industrially-relevant generic and fundamental research.</p> <p>Engage in experimentation of technical feasibility to promote technology advancements, technology implementation services, and "non-core" sponsored projects with more immediate potential.</p> <p>Work closely with industry (including small and medium-sized businesses) to facilitate diffusion of center research results and technology to impact states' economic development through the center's "core" technology transfer program.</p>	<p>Provide support for a research program of industrially-relevant generic and fundamental research.</p> <p>Sponsored research (optional)</p>
FORM OF AWARD	Cooperative agreement	Grant
LENGTH OF AWARD	Initial award of 4 years, with possible renewal for an additional 4 years.	5 year award; centers may apply for a second period of up to 5 years
MEMBERSHIP	Members may be industrial firms or other organizations such as federal laboratories.	Members may be industrial firms or other organizations such as federal laboratories.
NSF SUPPORT	\$150K, \$225K, or \$300K annually during award period.	\$100 K annually for first 5 years, \$50K annually for the second 5 years.
OTHER SUPPORT	<p>NSF annual support must be matched by the state government and by the center membership fees.</p> <p>Host universities provide cost sharing through in-kind support (not required).</p>	<p>Centers must obtain at least \$300K annually in cash membership fees from a minimum of six center members.</p> <p>University cost sharing required.</p>
TREATMENT OF INTELLECTUAL PROPERTY	Core research and technology transfer programs provide non-exclusive, royalty-free licenses or center patents to member companies. Exclusive licenses are permitted for non-core, sponsored projects.	<p>Participating university holds patents on NSF-supported inventions, with participating firms generally receiving royalty-free, nonexclusive rights or options.</p> <p>Some centers have by-laws in which non-exclusivity is the default but might allow for non-exclusive royalty-free rights for all members; limited but royalty-bearing licenses for a member that shares in filing costs; exclusive license if only one member is interested; or exclusive license for a non-member if no members are interested.</p>
OTHER REQUIREMENTS		Uniform membership agreements

SOURCE: <http://www.eng.nsf.gov/eec/0-intro.htm>; <http://www.nsf.gov/pubs/1998/nsf97164/nsf97164.htm>; D.O. Gray and S. G. Walters, *Managing the Industry/University Cooperative Research Center: A Guide for Directors and Other Stakeholders*. Columbus, OH: Battelle Press, 1998; NSF/EEC staff.

**Table I-2
Formal Requirements of the S/IUCRC and I/UCRC Programs**

Feature	Program	
	S/IUCRC	I/UCRC
Fundamental shared, core research	Required	Required
Directed projects sponsored by one or a few firms for its interest	Required	Not required (or desired by NSF)
Scope of impact	State	National
Emphasis on industry input to project selection with evaluator/center analyst	Required	Required
Industrial support	Required	Required
State support	Required	Not required
Core technology transfer activities	Required	Not required

SOURCE: NSF/EEC staff

A significant feature of the context for an evaluation of the S/IUCRC Program was that, as of 1997, NSF decided not to hold competitions for additional S/IUCRCs. Existing centers will continue until the end of their award period, subject to meeting annual continuation criteria. Thus there was no concern among the parties-at-interest that the results of the evaluation would affect the Program's future funding. Instead, the evaluation's results would be used to improve the effectiveness and efficiency of the existing Program and, potentially, other similar programs, and to gain insights that could be used to help design and implement future NSF programs involving the states.

The I/UCRC Program is the oldest continuing NSF program intended to foster industry-university cooperation in research based on university-based groups of industrial firms.⁴ Its origins rest in an experimental program of university-based research centers working with groups of firms that began in the early 1970s; on the basis of the success of these experiments, a formal program was begun in 1980. As of 1999, there were 48 active I/UCRCs with 684 member organizations. NSF provides \$100,000 annually for the first five years for new centers, and \$50,000 annually for the second five years, with the bulk of their funding coming from other sources. In particular, the total effective budget of the I/UCRCs for 1998-99 was \$72.2 million, with NSF providing 6 per cent, industry 34 per cent, states 5 per cent, other federal agencies 26 per cent, universities 8 per cent, and the remaining portion from other NSF programs and non-federal sources. The mean I/UCRC center budget was \$1.5 million for 1998-99; a typical center has 14 members whose primary members contributed an average of \$42,194.⁵

Initially, ten S/IUCRCs were funded in two cohorts: 1991 and 1992. An additional three centers were funded in 1996, and nine are currently funded from the first two cohorts. NSF provides \$300,000 in support annually to these centers, with states required to match this support

⁴ Throughout this report, the term "firm" will be used to refer to members of S/IUCRCs and I/UCRCs, but it is important to note that a significant minority of center members in both Programs, estimated to be in the range of 25 to 35 per cent, are public agencies and non-profit organizations.

⁵ The study includes the nine centers that were established in 1991 and 1992 and were funded at the commencement of the SRI study in 1997.

in cash. In addition, membership fees provided by member firms must equal a total of \$300,000. There are currently more than 280 member organizations associated with the twelve existing centers.⁶

B. Design Of The Evaluation

The existence of the I/UCRC Program offered an unusual opportunity for a comparison-group evaluation design, and the NSF Task Order called for this approach. The specifics of the comparative design used by SRI are based on the fact that centers under the two Programs engage in a number of similar activities:

- Programs of fundamental and generic research, consisting of research funded in part from the pooled membership fees of center members. These programs of research are decided upon jointly by center researchers and member representatives to each center, and results are available to all members. In the S/IUCRC Program, this category of activity is referred to as “core” research. In the I/UCRC Program it is referred to as fundamental research.
- Sponsored or project research, consisting of research supported by one or more center members to address problems or issues specific to the sponsoring members. Sometimes this research is proprietary and supported by only one member; sometimes it is supported by two or more members and the results shared. This category of research is expected to be shorter term, narrower in scope, and of greater relevance to specific member problems than fundamental or core research. In the S/IUCRC program, this category of research is referred to as “non-core” research, and is called out as a separate functional activity for NSF reporting purposes. There is no formal, functional equivalent in the I/UCRC Program, but the I/UCRCs engage in sponsored research, which may be proprietary, with support from one or more members. This is similar to the S/IUCRC non-core research activity.
- Use of research facilities available at the center, for which a fee may be charged by the center.
- Provision by the center of technical advice and consulting services to member firms, for which a fee may be charged.
- Provision of training to member firm staff, usually for a fee.

This similarity of programmatic activities facilitates comparison of the two Programs and offers the opportunity for a detailed look at the relative participation rates of members in these activities, as well as the outcomes and impacts associated with each category of activity. Comparisons can be made both within and across Programs. Although it is likely that the activities undertaken by each Program under the categories described immediately above (e.g., fundamental research and “core” research) are not strictly identical in scope and focus *across* the two Programs, it is also likely (based on SRI’s reading of center annual reports and discussions

⁶ The study includes the nine centers that were established in 1991 and 1992 and were funded at the commencement of the SRI study—1997.

with center staff) that there are equally large variations in what actually constitutes “fundamental” versus “sponsored” research *within* the I/UCRC Program and core versus non-core research within the S/IUCRC Program.

SRI’s primary research strategy consisted of conducting two surveys: one of the official representatives of all members (i.e., those organizations that were recognized as formal, fee-paying members to centers as of 1998) of the nine existing S/IUCRCs that were initiated in 1991 and 1992 and still receiving NSF funding in 1998, and a second, similar survey of the official representatives of all firms that are formal members of seventeen I/UCRCs that have existed for at least a similar period as the S/IUCRCs. The surveys were supplemented, in the case of the S/IUCRC analysis, by telephone interviews with state economic development officials and state science and technology policy officials and careful review of S/IUCRC annual reports. Table I-3 lists the nine S/IUCRCs whose member representatives were surveyed; Table I-4 lists the 17 I/UCRCs that were included in the evaluation. These latter centers existed as of 1991 and were still substantially the same in 1998, when the SRI survey design was implemented.⁷

Table I-3
List of S/IUCRCs Included in the Evaluation

Center	Host Institution
Capsule Pipeline Research Center	University of Missouri
Computer-Aided Life Cycle Engineering Center for Electronic Packaging (CALCE)	University of Maryland
Electronic Imaging Systems	University of Rochester
Integrated Electronics Engineering Center	State University of New York at Binghamton
Intelligent Information Retrieval	University of Massachusetts
Low-Cost, High-Speed Polymer Composite Processing	Michigan State University
Molecular and Microstructure of Composites (CMMC)	Case Western Reserve University
Nonwovens Cooperative Research Center	North Carolina State University
Rock Mechanics Research Center	University of Oklahoma

⁷ The list of active I/UCRCs is continually changing as new centers are formed and existing ones are terminated or, more frequently, are refocused by partnering with one or more additional universities. A final list of 19 I/UCRCs that SRI sought to include in the survey was checked by the I/UCRC Program Director for accuracy and continuity over the period of interest in the evaluation. Two of these 19 centers did not agree to provide SRI with membership lists and were excluded from the study. Table I-4 contains only the centers whose member representatives were surveyed.

**Table I-4
I/UCRCs Included in the Evaluation**

Center	Host Institution
Advanced Communications	Villanova University
Advanced Computing and Communication	North Carolina State University
Advanced Electronic Materials, Devices and Systems	Texas A&M University
Aseptic Processing and Packaging Studies	North Carolina State University
Biological Surface Science	SUNY at Buffalo
Building Performance and Diagnostics	Carnegie Mellon University
Coatings Research	Eastern Michigan University
Dielectrics	Pennsylvania State University
Engineering Tribology	Northwestern University/ Georgia Institute of Technology
Hazardous and Toxic Waste Management	New Jersey Institute of Technology
Integrated Pest Management	North Carolina State University
The Logistics Institute/ Materials Handling Research Center	Georgia Institute of Technology
Micro-Engineered Materials	University of New Mexico
Non-Destructive Evaluation	Iowa State University
Polymer Interfaces	Lehigh University
Separations Using Thin Films	University of Colorado
Wireless Information Networks	Rutgers University

SRI's research strategy was based on the premise that the major, direct impacts of both Programs are experienced by the firms that are fee-paying⁸ members of centers. The primary link from center research, technology transfer, technical assistance and other activities to the regional economy is through member firms' cost savings, sales increases, employment changes, capital investments, and other changes that have economic consequences for the regional economy and can be attributed to center membership. The official representatives to centers from member firms were assumed to be in the best position to identify the range of impacts that center membership has produced for them, and to estimate the value of those impacts on their firm's economic performance and competitiveness, and so were the designated respondents to the two surveys. In both the S/IUCRC and I/UCRC Programs, member representatives attend Industrial Advisory Board (IAB) meetings, participate in research project selection, and take research results back to their organizations. They constitute the primary linkage between center researchers and the firm, and thus are in the best position to know whether and how their firm has benefited from membership.

SRI sought to complement the survey data with data on several types of center impacts that are not necessarily manifested in member firms, e.g., benefits from center interactions with nonmember firms; the formation of startup companies from center research; the hiring of center graduates by local, nonmember firms; benefits to nonmember firms and other organizations resulting from the dissemination of center research results; and the attraction of new firms to the region because of the center's existence. Careful review of S/IUCRC annual reports has enabled SRI to identify some of these additional consequences. Interviews with state economic development officials in some cases yielded qualitative descriptions of additional economic impacts.

⁸ It is possible that some centers permit in-kind payment of fees.

The two surveys of center member representatives were designed using measures of the impact of industry-university research and technology partnerships employed successfully in previous studies. In particular, SRI drew extensively on two studies that used surveys of participating firms: the impact of interaction with Engineering Research Centers (ERC) on member firms⁹ and the impact on firms of collaboration with Iowa State's Center for Advanced Technology Development.¹⁰ The survey instruments for the present study were designed so that analysis of the resulting data could establish relationships among four categories of variables:

- the activities carried out by centers to achieve their objectives;
- the possible outcomes of these activities as understood by member firms;
- estimates of the value to the firm of these outcomes;
- estimates of the value to the local (state) economy generated by member firms, as a result of their membership.¹¹

Previous studies of this type have shown that estimates of the benefits that firms report from such partnerships are conditioned by several additional factors, including the nature and extent of the firm's involvement in center activities, the position within the firm of the person responding to the survey, and characteristics of the firm itself such as firm size and degree of centralization. Thus the survey instruments included items intended to capture such information that was not available from center archival materials.

It is important to note that estimates of benefits and costs of membership were requested for the entire period that the member firm had been a member of the center. SRI's past research on the industry impact of interaction with Engineering Research Centers and the pre-test discussions with member representatives to S/IUCRCs showed that it would be difficult for these representatives to confine their estimates of benefits and costs to a single year (e.g., the most recent).

SRI considered analyzing cost and benefit data aggregated at the individual center level and at the entire Program level, but for several reasons abandoned this effort. First, member representative estimates of economic benefits to responding firms do not represent benefits accruing to all current members, although it could be assumed that non-responding member firms experienced similar costs and benefits to those whose representatives responded. Second, membership rosters in individual centers are constantly changing, so that current estimates of economic benefits do not represent past member benefits. Third, member representative reports of benefits are for different periods of firm membership, although it would be possible to calculate the average annual benefits over the membership period. Fourth, individual center costs can be specified as a total over the center's period of existence and an average annual cost calculated. But member benefits estimated by responding representatives are not necessarily for

⁹ Catherine P. Ailes, J. David Roessner, and Irwin Feller. *The Impact on Industry of Interaction with Engineering Research Centers*. Arlington, VA: SRI International, January 1997. Final Report prepared for the National Science Foundation, Engineering Education and Centers Division. <http://www.sri.com/policy/stp/erc/>

¹⁰ David Roessner, Barry Bozeman, Philip Shapira, and Yong Lee. *Evaluation of Iowa State University's Center for Advanced Technology Development (CATD)*. Atlanta, GA: School of Public Policy, Georgia Institute of Technology, June 1996.

¹¹ Note that it is important to distinguish between the economic impacts on, and regional economic impacts generated by, member firms within a center's local economy and those outside the region.

the same period the center has been in existence. For all these reasons, SRI did not attempt to estimate the benefit/cost ratio for each *Program* by aggregating estimates of member firm benefits and dividing them by total or annual Program costs. In principle, it would be possible given the data sought in the two SRI surveys to develop quantitative estimates of the ratio of benefits to costs *as estimated by center member representatives—i.e. member-level assessments*. As will be seen in later chapters of this report, however, the low response rates to all questions seeking quantitative estimates of member benefits raised serious doubts about the accuracy or representativeness of such estimates. This also precluded any meaningful calculation of *Program-level* benefit/cost ratios for each of the S/IUCRC and I/UCRC Programs using estimates of member benefits and center cost data, whether aggregated across all years or on an annual basis.

The two surveys of center member representatives were conducted during the summer of 1999. This period was chosen to avoid conflicting with the annual surveys of I/UCRC member representatives and participating faculty researchers undertaken by center evaluators as required by NSF. Response rates to the two surveys played a major role in determining what kinds of analytic techniques could be applied to the results. In the case of the S/IUCRC survey, SRI received 72 total responses from 130 valid member addresses, for a response rate of 55.4 per cent. For the I/UCRC survey, SRI received 156 total responses from 239 valid member addresses, a response rate of 65.3 per cent.¹² In each survey, respondents were the most recent representatives of the member firms to a specific center. Their responses were to cover their operational unit's involvement in the center, not just their individual involvement.¹³ Representatives' responses covered the entire period during which their firms were involved with a center, not just their own tenure. Center Directors provided SRI with the names and addresses of these representatives as well as the most current listing of member firms.

¹² Non-respondents to the initial survey mailing received a second mailing with a request to respond. An additional follow-up by telephone and/or e-mail was carried out for remaining non-respondents. Because of the similarity between the basic objectives of the two Programs and the conditions under which firms choose to join centers in each Program, there is no reason to conclude that non-response biases, to the extent that they exist, differ substantially across responses to the two surveys.

¹³ The representative's operational unit was defined in the survey instrument as the division, center, department, section or other organizational entity that is the primary direct beneficiary of the firm's participation in the S/IUCRC or I/UCRC. SRI's previous experience with surveys of ERC member firm representatives showed that, in large firms especially, representatives could accurately describe only the results *for their unit* of the firm's involvement in center activities.

II. THE CONTEXT OF THE STATE/INDUSTRY UNIVERSITY COOPERATIVE RESEARCH CENTER PROGRAM¹⁴

A. State Economic Development Strategies

Promotion of economic development is an historic activity of America's state governments. The specific strategies employed have varied according to the historic stage of the nation's and each state's economy, prevailing distributions of responsibilities and initiatives between the federal government and the states, political theories concerning the appropriate role for public sector involvement in the economy, and economic theories concerning the "levers" or critical factors in economic growth (Nelson, 1993). Subsidies and bounties to construct "strategic" industries such as ironworks date to the colonial period; subsidies to canal and railroad companies were common in the immediate pre- and post-bellum periods; tax concessions and subventions to construct industrial parks spread across the states in the 1950s; venture capital funds, incubators, research parks, and centers of advanced technologies have become staples of state economic development policies and programs since the 1980s.

Resurgence of interest in federal-state partnerships involving science and technology (S&T), of which creation of the S/IUCRC Program in 1990 was an example, was one consequence of increased activism by state governments in the 1980s to restructure economies hard hit by reductions in core industrial bases. A characteristic of this activism was a shift in economic development policies towards "demand-side" strategies that emphasized the creation of new firms and jobs in rapidly expanding industries, away from long-dominant "supply-side" strategies that sought to recruit existing firms through subventions that lowered the cost to the firm of operating in the state relative to other states ("smokestack chasing") (Eisinger, 1984).

Demand-side strategies embodied four related tenets:

- 1) New ("sunrise") firms and industries (and thus jobs) were needed to replace declining traditional manufacturing sectors;

¹⁴ A early draft of this chapter was prepared by Irwin Feller, Director, Institute for Policy Research and Evaluation, and Professor of Economics, The Pennsylvania State University. The chapter is intended to provide information about the S/IUCRC Program's origins and its place within the larger context of federal and state programs designed to strengthen state S&T infrastructures, promote regional economic development through research, development, and technology transfer, and foster industry-university collaboration in research, that is sufficient to place the conclusions of this evaluation in proper context (i.e., prevent substantial misinterpretation of the results). Such information is also intended to provide insight into the present evaluation's results that will enable some lessons to be drawn concerning subsequent NSF-state partnerships. The chapter does not, however, offer a detailed history of NSF efforts to work with state and local governments, nor does it describe and assess in detail the S/IUCRC Program's origins, both of which are beyond the scope of this study. Information and analyses of these matters may be found, among other sources, in Irwin Feller, *An Assessment of the Intergovernmental Science and Technology System and its State Government Component*, Report to the National Science Foundation, Grant No. RII-8506018, January 1990; Jay Kayne, *A New Paradigm for Collaborative Science and Engineering Research*, Washington, DC: National Governors Association, Report 06504, July 1996; W.Henry Lambright and Albert H. Teich, "Science, Technology, and State Economic Development," *Policy Studies Journal* **18** (Fall 1989): 135-147. These sources were drawn upon extensively in the final sections of this chapter.

- 2) Technological innovation was a prime mover in the spawning of new firms and jobs;
- 3) Universities were key sources of technological innovation; and
- 4) Universities needed direction, incentives, new organizational structures, policies and cultural norms, and a degree of prodding to target more effectively their research and technology transfer activities toward research topics and end users that would enhance the economic competitiveness of their home state.

Thus strengthening of state S&T infrastructures and promotion of university-based research, technology development and transfer, and the creation and support of new, entrepreneurial firms emerged as key elements in demand-side strategies for economic development.

B. A Short History Of State S&T Programs

Given the problem diagnosis of stagnant state economies and recognition of the potential for technology-based economic growth engendered in part by university research, state governments in the early 1980s took upon themselves the roles, variously, of entrepreneur and of catalyst in forging new forms of (government)-university-industry partnerships. Accordingly, in the 1980s, several northeastern and mid-western (“rustbelt”) states—New York, Ohio, Pennsylvania, Michigan, Illinois, Massachusetts—established or expanded science and technology programs designed to stimulate economic development and technology transfer. Universities were assigned key roles in most of these programs. The generic policy approach and set of interventions quickly spread to other states (Babbit, 1984); by 1991, at least 45 states had S&T agencies to stimulate technological innovation. (Minnesota Department of Trade and Economic Development, 1988; Atkinson, 1991).¹⁵ State S&T programs, numbering more than 250 by the end of the 1980s, included a diverse array of techniques: technology development centers, technology transfer programs, incubators, and venture capital funds. The visibility of state initiatives in this period was brightened by its stark contrast to the perceived inaction of the federal government, stalemated by ideological and partisan disagreements about the political rectitude or economic efficiency of government efforts to pick industrial or technological winners (Lambright, Teich, and O’Gorman, 1992).¹⁶ In this shifting arena of intergovernmental activity, Ohio’s Edison Centers Program, Pennsylvania’s Ben Franklin Partnership Program, and New York’s Centers for Advanced Technology Program became national symbols of the new economic role of the states (Fosler, 1984; Atkinson, 1991).

State S&T programs diffused widely in the late 1980s; as they did so the total level of expenditures rose. Early estimates (Minnesota Department of Trade and Development, 1988; Burton, 1989; Phelps and Brockman, 1992) ranged widely, from about \$143,000 to \$1.0 billion. This range reflected differences among estimates in definitions of state science and technology

¹⁵ States reported a total of 390 discrete technology-based development initiatives as of 1994 (*Partnerships*, 1995, p. 9).

¹⁶ “A key but largely unstated part of the new model (of economic development) was the initial absence of federal involvement. In the 1980s states themselves recognized the problems, saw the potential of cooperative technology to help solve those problems, and acted on their own” *Partnerships*, p. 7.

expenditures, coverage of programs, time periods, and databases (*Partnerships*, p. 38). Estimates from the State Science and Technology Institute (SSTI) place state expenditures for “cooperative technology” programs at \$306 million in 1992, \$315.5 million in 1993, \$396 million in 1994, and \$405 million in 1995 (State Science and Technology Institute, 1996).¹⁷ Nationally, the portfolio of generic pre-competitive research, applied research, product development/commercialization research, and manufacturing modernization activities found in state science and technology programs has varied both across states and within states over time. (For descriptions of state science and technology programs, see Feller, 1993; *Partnerships*, 1995.) Several states have more than one S&T program; thus, as illustrated by Ohio’s applied research programs, university-based programs directed at basic research, technology transfer and

¹⁷ SSTI defines cooperative technology programs as “public–private initiatives involving government and industry and often universities—that sponsor the development and use of technology and improved practices to measurably benefit specific companies. The primary goal is economic growth” (*Partnerships*, 1995, p. 1). Specific activities include:

Technology Development:

- Research and applications for new or enhanced industrial products/processes
- University-industry technology centers
- Government-industry consortia
- University-industry research partnerships
- Equipment and facility access programs

Industrial Problem Solving:

- Identifying and resolving company-level industrial needs through technology and best-practice applications
- Technology extension/deployment
- Federal technology applications programs
- Implementation grants

Technology Financing:

- Public capital or help in gaining access to private capital
- Company financing
- Project financing
- State-sponsored federal outreach

Start-up Assistance:

- Aid to new small technology-based businesses
- Incubators
- Federal start-up assistance
- Research parks

Teaming:

- Help in forming strategic partnerships and alliances
- Industrial networks
- Interactive databases

product development may be found in a single state. Other states (e.g., Connecticut and Pennsylvania), however, have concentrated their cooperative technology efforts on a single strategy that emphasizes product development.

Variation also exists both across states and within states over time in the emphasis accorded to launching “sunrise” industries through new knowledge-based product- and process-innovations and directed at improving the competitive position of existing state industries through technological innovation. Yet another source of variation is the organizational arrangement for administering and operating state science and technology and manufacturing modernization programs (Lambright, 1991; *Partnerships*, 1995). Some programs are operated by state departments of commerce or economic development; others by state science and engineering foundations; yet others by quasi-independent agencies. As highlighted in some studies (e.g., Lambright and Teich, 1989), and noted below, these variations in organizational arrangements can affect the political and financial visibility and stability of state S&T programs.

The funding of state government S&T programs has fluctuated; debate exists about whether these patterns reflect “cyclical” fluctuations in state expenditures and an expected leveling off of previously rapidly increasing rates of funding increases, or a harbinger of political and policy disenchantment (Blumenstyr, 1992). The surge in state interest in S&T programs in the 1980s was followed by a period of budgetary retrenchment and withdrawal in the early 1990s, which has been more recently followed by a period of general consolidation in several states and occasional new or intensified commitments by selected states. Lambright, Teich, and O’Gorman (1992) characterized these initiatives as having had an “initial burst of youthful energy.” in the 1980s. By the early 1990s, these programs were seen as having “to struggle along with other state political institutions for survival. They must engage in political battles and fight to hold on to whatever policy niche state S&T programs have carved out for themselves.” Relatedly, Eisinger has pointed to “signs of withdrawal ‘by state governments’ from the economic development dedication forged in the 1980s” (1995, p. 148). State science and technology partnerships, in particular, were reported to be in a “defensive position,” fending off budget cuts, termination of seed development funds for universities, and a general, disenchanting recognition on the part of state government officials “that the time from university research to product development, and from commercialization to job generation, is both too long and too uncertain to justify the price of science and technology partnerships” (Eisinger, 1995, p. 148). In a contrary manner, the State Science and Technology Institute’s 1996 estimate of state funding for cooperative technology programs points to an increase from \$369 million in FY 1994 to \$405 million in FY 1995, or about 10 percent, with 34 states reporting increases in cooperative technology budgets between FY1992-1995 (State Science & Technology Institute, 1996). SSTI has presented these data as pointing to a robustness to state interest in cooperative technology programs.

Currently, several trends in state government support of S&T programs may be identified, although not all observers might agree on their direction, sustainability or effectiveness. First, there appears to be a general lessening of state emphasis on university-industry technology development centers. Second, to the extent that these centers have survived state budgetary and performance review cycles and/or changes in administration, increased pressure has been placed on them to focus on shorter-term, more applied research projects and to

become more involved in “active” technology transfer. Third, university-industry R&D centers appear to be directing their efforts more to the technological needs of existing firms and less to the launching of spin-off firms from academic research. Fourth, many states are emphasizing a rebuilding of their university research infrastructures. Finally, state S&T strategies have shifted towards increased emphasis on technical assistance programs that focus on the needs of small- and medium-sized firms rather than on technological innovation. These manufacturing modernization programs tend to offer an array of technical and managerial assistance (Shapira, 1990; National Research Council, 1993), for the most part drawing on off-the-shelf technologies. The heightened emphasis on technical assistance/manufacturing modernization programs has been spurred both by state initiatives in establishing or expanding existing industrial modernization programs, for example, and, more significantly, by a series of federal initiatives—the Omnibus Trade and Competitiveness Act, the Technology Reinvestment Project, and the establishment of NIST’s Manufacturing Extension Partnership Program—that over the course of a decade transformed manufacturing extension from a limited number of state operations into a national system of programs, jointly funded by the federal government, state governments, and user fees. One consequence of this shift in emphasis has been to reduce the roles of (research) universities as vehicles of state economic development priorities. Although a number of universities do operate or administer manufacturing programs, in several states (or regions in a state) operation of the center is in the hands of a not-for-profit organization, a community college, or a hybrid state agency.

C. State Economic Development And S&T Strategies: Comparison And Contrast

State economic development strategies are undergoing many changes. The changes reflect changing national and state economic conditions, lessons gleaned (correctly or incorrectly) from operational experiences about the successes or failures of existing programs, emergence of new theories, paradigms or fads in state economic development, and changing state government priorities accorded to economic development relative to other state needs and objectives. Other than detailed examination of each state’s economic and political setting, few sources exist to capture readily the type and magnitude of the factors that are shaping state economic development and science and technology strategies; even scantier are documented findings that relate past economic development strategies to economic outcomes. As a first approximation to placing the S/IUCRC Program within the context of state strategies, a review was conducted of a set of accessible state economic development and state science and technology plans. This review was augmented by findings from the recent study conducted by the State Science and Technology Institute for the Economic Development Administration of the U.S. Department of Commerce (SSTI, 1997).

Obvious limitations exist to the use of economic development or science and technology policy (or plans) as measures of state thinking and priorities. Plans on whatever subject are expressions of intent, not actions. Plans can constitute symbolic politics, used to form coalitions of interests and to demonstrate the commitment of an organization to particular politically salient goals, not necessarily a blueprint for action. Moreover, as reflected in the state economic development and science and technology plans reviewed below, most are the products of gubernatorial or agency initiatives. They do not necessarily reflect the thoughts, much less the

support, of state legislatures. A final caveat to conflating plans with outcomes is the standard reminder of the gap between the cup and the lip: issuance of a plan is not tantamount to implementation. To anticipate the discussion below, the evidence on implementation of the strategies called for in state plans is limited, but it is evident that recent plans have been shelved in several states.¹⁸

The SSTI study reviews state economic development and S&T strategic plans developed between 1991 and 1995. Twenty-nine states reported adopting economic development strategies between 1991 and 1995, 13 states adopted dedicated science and technology strategic plans, and 7 of these 13 states prepared both a general economic development strategy and a science and technology strategic plan (SSTI, 1997, p. 41). Within states, these plans were frequently undertaken by different groups or agencies, and often contain quite different emphases.

The SSTI report also distills a set of “best-practice” precepts about the contents and processes by which such plans are to be prepared. Science and technology strategic plans are seen as allowing a “state to assess its existing technical resources, determine whether they can be leveraged better to generate economic activity, and identify needs that must be addressed to support a technology-intensive and technology-driven economy” (p. 3). The planning process also can be used “to enlarge the base of support for the state’s science and technology initiatives by involving businesses and communities which may not have been aware of the potential benefits of the state’s technology investments” (pp. 3-4).

The report outlines in general form the strategies found in the 13 state science and technology plans, as follows: improving or capitalizing on the state’s research base, building the technical skills of the existing and future workforce, creating a climate supportive of entrepreneurs and technology-based businesses, accelerating the commercialization and deployment of technology, and investing in technology infrastructure (pp. 45-46). Few details are offered, however, about any single state’s plans, reasons for changes in state science and technology strategies over time, integration and consistency of economic development and science and technology plans in those states that produced both sets of documents, or steps taken to implement recommendations contained within the plans. Thus little information is provided about the importance attached to state university-industry cooperative research programs.

Independent review of a limited number of states coupled with distillation of the trends noted above point to replacement of the “entrepreneurial” state government of the 1980s in several states that were the hallmarks of activist government roles, such as New York, Pennsylvania, Michigan, Massachusetts, and Virginia, by a “minimalist” political philosophy, which seeks to reduce the “burden of government on the private sector” through a combination of reduced taxes, privatization of formerly public services, and deregulation. These views are most evident in those state economic development plans where lower taxes and deregulation

¹⁸ “Determining the extent to which the recommendations in strategies developed several years ago have been implemented is difficult because many states established no mechanism for tracking implementation, and staff turnover has resulted in little institutional memory (I)n three of the states that adopted strategies in 1991 and 1993 (Iowa, Maryland, and Montana), changes in administrations and the state’s science and technology leadership made it difficult to determine how effectively the strategy was implemented, if at all. While the strategies may have influenced the state’s investment in science and technology, those most involved in developing and implementing the strategy are no longer with state government” (SSTI, 1997, p. 54).

appear far more prominently as linchpins to gubernatorial strategies than do investments in public sector programs to stimulate new industries through technological innovation. This shift reflects strong beliefs in the efficacy of market forces to promote economic growth. It also reflects a disenchantment with the modest effects reported for many state economic development initiatives.¹⁹

What emerges from a review of these state plans and from the history of S&T strategies in the state context is, among other things, a structural and political contrast between state economic development and state S&T strategies. Structurally, state S&T agencies and advisory units have tended to originate in, and remain attached to, the governor's office, while economic development units reside within well-established agencies in the state bureaucracy, usually a Department of Industry and Trade or its equivalent. Politically, S&T agencies and the programs they operate are often, although not always, at the mercy of the administration in office. A change in governors usually means a change in direction for state S&T policy. Economic development programs, in contrast, have long histories, are well-ensconced in state budgets, and enjoy support from the legislature. In theory, incorporation of S&T-based development into ongoing state economic development strategies and organizations should have reflected the apparent eagerness with which states embraced demand-side development theory, with its acknowledgement of the central role of research and technological innovation. In practice, only a few states have accommodated S&T quickly, smoothly, or relatively permanently into the structure and politics of economic development.

D. Federal-State Partnerships Involving Science And Technology

Questions of the optimal allocation of funding, administrative, and managerial responsibilities for public sector research and development programs that have both national and state government impacts are longstanding in the U.S. political system. Relatively stable arrangements for shared funding, administration, and management for research and development have evolved in agriculture and transportation, as evidenced by relationships between the U.S. Department of Agriculture's Agricultural Research Service and the State Agricultural Experiment Station systems, and between the Federal Highway Administration and state departments of transportation. Similar arrangements, however, are far less developed in several other public sector areas. In particular, an expressed concern of state governments at least since the 1970s has been that many areas of "domestic technology" have been "federalized," with the federal government determining research priorities and choice of performer, often to the exclusion of any substantive involvement by state governments. As expressed in 1972, in *Power to the States*, an important statement of the "new federalism" political tenor of the time, "The multi-billion dollar federal research and development effort has virtually left state governments out of the picture in the development of public technology priorities and applications" (*Power to the States*, 1972, pp. 1-2).

¹⁹ "Most evaluations conclude that state and local business financing to stimulate economic development outside big cities does not achieve the explicit goals; the programs have little influence on either the level or the distribution of economic growth. Studies show that programs without specific geographic targets are used disproportionately by business in growing areas of a state but have no measurable effects on the growth of the state economy" (Dewar, 1998, p. 68).

Similar sentiments on the need for greater parity in intergovernmental science relationships are contained in documents and statements expressing the position of state governments and their representatives in the economic growth and science policy debates of the 1980s and 1990s. (Blanchard, 1991; Jones, 1991). These perspectives have found their most recent expression in the Carnegie Commission on Science, Technology, and Government's report, *Science, Technology, and the States in America's Third Century* (1992). The report notes, for example, that "For two generations the balance in the realm of science and technology has been heavily weighted toward the federal government. This balance was appropriate to the task that dominated the national agenda, namely responding to the challenge of the Cold War. However, with the end of the Cold War, the demands of national security have lost their primacy. Today's challenges—better schools, more efficient and accessible health care, refurbished public infrastructure, a clearer environment, and firms that are more competitive in world markets—require the striking of a new balance. While the balance will vary depending on the issue at hand, it will generally involve the states more deeply and intensely than at any point in the past half century" (Carnegie Commission, p. 16).

A key analytical issue in the design of federal and state S&T programs is the spatial appropriability of various forms of knowledge generated by R&D. In most mainstream economic models of the R&D process, pre-competitive generic research is considered spatially "footloose"; that is, it is potentially available to and useful to all industrial sponsors of a university-based center independent of the place (state) in which the university is located (Malecki, 1991). Thus, while both analytical treatments and empirical evidence attest to the generic importance of strong research universities as sources of regional economic growth, both for their direct contributions (e.g., the launching of new firms) and their indirect contributions to forming part of a strong regional technology infrastructure that attracts and nurtures knowledge-intensive manufacturing and service industries (Tassey, 1991), the footloose character of pre-competitive generic research generated by a university center provides little assurance (to state officials) that the economic benefits associated with transforming this knowledge into new products and processes will be captured by firms within the state in which the university is located. This analytical scenario leads to the projection that state governments will exhibit limited interest in supporting this type of university-based center, and that federal government support is necessary if university-industry partnerships directed at pre-competitive research are to be sustained.

Where states presumably have a greater stake in the knowledge generated by university-based centers is in those fields and types of research that: a) contribute to the competitiveness of firms (industries) already situated in the state (for other locational reasons); b) serve as the basis for establishing "first-mover" advantages to newly created firms in the state to commercialize newly developed products and processes; c) are specific to the production needs of specific firms within the state; and d) are readily shielded via intellectual property rights from rapid imitation by firms in other states.²⁰ This paradigm of the assignment of federal and state government roles

²⁰ The stylized character of this model should be emphasized. Allowing for political factors that constrain the use of the term "basic" or "exploratory" research in discourse within state capitol chambers, selected states, e.g., Texas, New York, have seen it in their interest to support "fundamental" research in their cooperative technology development programs; these states also have benefitted as a result of this strategy (Ebert, Fields, and Wingaarder, 1991; Feller and Anderson, 1994).

in supporting domestic technology permeates the above-cited Carnegie Commission report, *Science, Technology, and the States in America's Third Century*: "A partnership to spur U.S. economic competitiveness might be based on a division of roles in which the federal government supported research near the basic end of the spectrum, while the states and industry supported applied research and development of more direct interest to industry."²¹

The S/IUCRC Program, in effect, embodies this analytical framework of the distribution of roles: it seeks to provide states with an opportunity to leverage a "national" investment by the federal government (and industrial sponsors of the S/IUCRCs) in pre-competitive generic research towards applied R&D of more direct relevance and appropriability by firms in the state to the economic benefit of their state. In the context of these efforts to redefine federal-state government relationships in the support of domestically oriented research and development, the S/IUCRC Program represents an (implicit) test of propositions concerning the optimal intergovernmental distribution of funding responsibilities and program direction. On the one hand, the S/IUCRC Program, like NSF's I/UCRC Program and indeed several other NSF, other federal agency, and state funded university-industry-government center programs, seeks to bridge the putative gap between pre-competitive generic research and product and process development by forging collaborative linkages between universities and firms. On the other hand, these programs are also focused on development of specific products/processes of ready application by firms within single states.

E. Origins Of The NSF S/IUCRC Program

The decade of the 1960s represented a new era in federal-state-local government relationships, as evidenced most obviously in the explosion of federal categorical grants to state and local governments from \$4.9 billion in 1958 to \$23.9 billion in 1970. This period might be viewed as a re-awakening of political awareness among federal agencies and the Congress of the federal nature of the U.S. system of government. As federal agencies worked to establish intergovernmental programs suited to their missions, science and technology also became a focus for attention in the intergovernmental arena. This was the era of technology transfer from federal R&D agencies to units of state and local government; of technology utilization programs; of knowledge utilization efforts by R&D-intensive federal agencies; of the creation of large-scale information dissemination systems based in research and intended in part for use by state and local governments. The phrase "public technology" came into widespread use.

The National Science Foundation was arguably in a unique position to respond to this new intergovernmental focus. With no emphasis on specific areas of research or technology, it could consider strategies for building the capacity of state and local governments to recognize, adapt, and apply the fruits of federally-funded research, from whatever source, to public problems. In 1967, Frank Hersman proposed that NSF create "a program to strengthen the scientific and technology capability of, and resources at, the state and local levels of government" (quoted in Feller, 1990, p. 41). Regardless of NSF's motivations (which remain

²¹ The difficulties of converting this principle into operation also are noted in the report: "It should be recognized, though, that the research and development process does not conform to such neat distinctions . . . State technology programs, too, blur traditional distinctions between R&D stages" (p. 45).

unclear; see Feller, 1990) for launching the Intergovernmental Science and Public Technology Program, the Program and its offspring expended over \$40 million during FY 1967-82; the program was terminated in 1982. The history of the rise and fall of NSF's Intergovernmental Program (IP)²² is complex and interesting, but of particular relevance to this report are the lessons learned, which Feller (1990) compiled and analyzed from a number of separate reports as well as from his own examination of the program.

During the 1970s, under the aegis of its Intergovernmental Program, NSF supported a wide range of programs directly with jurisdictions of state and local governments, as well as with the national associations that represented them, primarily the National Governors Association, (NGA), the National Conference of State Legislators (NCSL), and the International City Management Association (ICMA). Reviews of the IP conducted after its termination noted that NSF occupied a preeminent position among federal agencies in providing support to state and local jurisdictions, a position explained in part because NSF was not associated with specific areas of technological application but instead could be viewed as "neutral" or "cross-cutting" (Feller, 1990: 15-16). As the IP evolved, however, its initial focus on technology transfer and capacity-building in areas related to science and technology gave way to broader efforts best described as policy management assistance. What little involvement there was initially by NSF's traditional constituency, universities and colleges, soon disappeared, and the IP became increasingly viewed, at least within NSF, as beholden to state and local governments and their associations. NSF experienced "increasing discomfort at being cast in a role that carried with it financial responsibilities for activities (and organizations) that were viewed as beyond its mission" (Feller, 1990: pp.12-13). The Reagan administration's dismantling of the intergovernmental system provided an opportunity for NSF to divest itself of a program that management had concluded was outside the agency's mission. Feller concludes that

"...unless the endeavor is encapsulated in a larger, organizationally compatible objective, these [intergovernmental, capacity-building] programs are not compatible with NSF's mission and will be rejected (pp. 19-20) . . . "such a program is viable only to the extent that it either relates to NSF's core missions of promoting research or education or to some overarching political mandate or perceived opportunity" (p. 239).

At the very time that the IP was engendering tension within NSF, the late 1970s, NSF embarked on a new program that was intended to be responsive to congressional pressures to broaden the Foundation's geographic distribution of research funds and foster improvements in state S&T infrastructures. The Experimental Program to Stimulate Competitiveness in Research (EPSCoR), begun in 1978, initially provided five states with five-year grants aimed at strengthening the ability of these states' research universities to compete for federal funds. The program was a great success, at least in the eyes of Congress, and in FY 1985 the program was expanded to include 17 "have-not" states. Unlike the IP, EPSCoR provided grants to NSF's traditional constituents, universities and colleges, and selected the winners using the peer review

²² The program began in FY 1969 as the Office of Intergovernmental Programs. In FY 1972 it was called the Office of Intergovernmental Science and Research Utilization, part of the Division of Intergovernmental Science and Public Technology. In FY 1979 it became the Intergovernmental Program. The organizational location of the program underwent even more changes during its lifetime.

process. Furthermore, the intended result of these awards was research output, thus placing them well within the NSF mission (Lambright, Teich, and O’Gorman, 1992; Feller, 1990).

By the late 1980s, the political context for renewed federal involvement with states had changed again in a more positive direction, but now, following the period of state activism in S&T described earlier in this chapter, federal interest was less in some form of capacity-building and more toward forming partnerships with states in their role as innovators, as “laboratories of democracy.” In 1986, NSF began to rebuild connections with states via the “NSF/States Initiatives: A Pilot Program to Enhance Communication between NSF and the States.” This program of workshops and small studies, conducted out of the Office of Legislative and Public Affairs, was channeled primarily through the NGA in cooperation with other organizations and state governments (Feller, 1990: 245).

In 1989 the NGA’s Science and Technology Council of the States and NSF established a working group to explore an expanded role for states in NSF engineering research programs (Kayne, 1996). This working group’s activity led to creation of the State/Industry University Cooperative Research Center Program, based on the model of university-industry cooperative research centers established by the NSF I/UCRC Program. The features that distinguished the S/IUCRC Program from the I/UCRC Program were described in the previous chapter, but in terms of this chapter’s focus, the key features that affect each S/IUCRC’s political and organizational environment are the goal of state economic development, the requirement (initiated by the NGA) that states share support for the centers equally with NSF and the private sector,²³ the flexibility to use the pooled state and industry funds for activities other than core research, such as technology transfer, and the appointment of a State Representative to coordinate each center’s activity with the state’s economic development programs and policies.

Establishment of the S/IUCRC Program in 1990 thus reflected the convergence of trends in state economic development strategies with changing patterns of federal government-state government relationships in science and technology policy. Although the S/IUCRC Program was envisioned as a cooperative state-NSF undertaking, little is known about who speaks for state government in matters pertaining to science and technology. Most state science and technology initiatives have originated with governors or their representatives, yet state policy making, as with that of the federal government, is a complex amalgam of executive, legislative agency and stakeholder interaction. As observed by Flentje, “The pluralistic nature of state political systems creates a turbulent and unpredictable policy environment for state policy makers and particularly the governor” (1982, p. 20). The result of this amorphous and diffuse structure is that policy making “often results in policies with ‘vague, contradictory and fluctuating purposes’”. Some programs are adopted with no stated goals; other have ambiguous statements of goals; others have multiple goals, some of which overlap; and still others have immediate rather than long-term goals. In this system in which policy is continually subject to challenge and to the influence of bureaucratic forces, state government functions without comprehensive direction and without a conceptual framework of purposes to be served by state actions” (p. 20)

²³ The S/IUCRC Program requires that state matching funds be “new” money rather than reprogrammed university funds.

F. State Organizational And Political Contexts Of The S/IUCRCs

Generically, the S/IUCRC Program is one of the large number of university-industry-government programs that seek to foster the development and transfer of commercially-relevant science and technology from American campuses to the market place. According to Cohen, Florida, and Goe, (1994), an estimated 1056 industry-university research centers were in operation in 1990, with an estimated annual expenditure of \$4.1 billion. Most of the centers were established after 1980, reflecting the prevailing and pervasive belief in the efficacy of bilateral and multilateral university–industry–government R&D partnerships.

The subject of state government commitments to S/IUCRCs arises both out of attention to program design—whether the program is functioning as projected—and program evaluations. In the absence of any independent evaluations of the S/IUCRC Program as a whole, or of individual centers, a gap may exist between state science and technology offices and the standing of S/IUCRCs on discussions between NSF and its representatives. For the latter, at the time of the Program’s creation it constituted a symbol of new intergovernmental partnerships, whereas for state governments it was only one of a set of state policy tools.

The requirements upon state governments in the S/IUCRC Program raise several questions about the role of S/IUCRCs within the larger framework of state economic development and science and technology development strategies, programs, and activities. Implicitly associated with the state stake in the operations of S/IUCRCs is an increased state role in the direction and monitoring of center activities. Also, the formal requirement for state matching funding suggests that S/IUCRCs were expected by the states to be more systematically integrated into the science and technology and economic development plans of state governments than, say, IUCRCs, or for that matter, any of the larger number of university-industry R&D cooperative programs to which a state may be providing financial support. This matching requirement mirrors similar provisions of several other recent federal initiatives to support state research and technology endeavors, broadly defined. For example, NSF’s EPSCoR and NIST’s Manufacturing Extension Partnership Program require matching funds either directly from the state, or indirectly, as universities seeking to secure program awards turn to their states for financial aid.

From a broader perspective, these federal-state programs may be viewed as complements to one another; they essentially complete a linked chain of support for strengthened academic research, targeted research at engineering problems of joint interest to universities and firms, and efforts to assist small and medium-sized firms modernize their operations through accelerated adoption of existing and new practices. To the extent that they require state matching funds, these programs inevitably compete with one another. They compete most obviously in claims upon the governor and legislature for state funds. To the extent to which they are each administered or overseen by a single state agency, they may vie for attention and support by a cabinet-level secretary. To the extent that administration and oversight is distributed among one or more agencies or independent bodies, as noted above, competition may exist between state entities.²⁴

²⁴ They do so within their host universities, as institutions in many cases are called upon to contribute part of the required matching funds, or to make good on shortfalls on expected revenues from state appropriations or user fees.

A joint NSF/NGA Roundtable in 1996 reviewed the NSF-state partnership strategy in terms of the experience with two programs: the S/IUCRC Program and the Small Business Innovation Research (SBIR) Program (Kayne, 1996). One of the issues discussed at the roundtable was the ability of states to sustain the commitment to annual matching funds for their S/IUCRCs. The report on the roundtable observes that the commitment is easier to maintain in states where the state economic development agency or S&T agency are already linked to the university system, as in New York's Centers for Advanced Technology. In other states, however, where universities are regarded as the province of a higher education department or Board of Regents, tension exists when a line item for supporting an S/IUCRC appears in the budget of an economic development or S&T agency, and the intended relationship between university-based research and state economic development is imperiled (Kayne, 1996: 8).

Competition also can exist among the organizations that perform the research and dissemination services provided through these programs or by the groups that potentially benefit from them. Programs that emphasize pre-competitive generic research and are intended to support R&D-intensive firms or to serve as the magnet for attracting new firms to the state may apportion funds primarily to research-intensive universities; programs that emphasize applied research and product development may prefer state colleges as service delivery providers; programs that emphasize technical assistance and training may opt for community colleges. No fixed formula exists to apportion these roles or funds among different types of higher education institutions, but the fact of multiple performers inevitably produces competition.

Aggravating the political intensity of this competition is that even though the state programs serve complementary ends (i.e., are intended to promote S&T-based economic development) and are funded by different federal agencies, from the perspectives of state officials they all have one common theme: they represent additional funds to universities. They thus can quickly run up against predetermined ceilings on the amount of funds that the state wants to allocate to these institutions. Differences among state programs may even take on partisan dimensions, as when one party has been responsible for initiating one program, while another party has been the leader in fostering another. (Pennsylvania, in which Governor Thornburgh, a Republican, received national visibility for establishing the Ben Franklin Partnership Program and Governor Robert Casey, a Democrat, and his successor, launched the Industrial Resource Centers program offers such an example.)

A major challenge for S/IUCRCs, which sets them apart from I/UCRCs, thus is obtaining the required state matching funds. As suggested by external review committee reports (National Science Foundation, 1994), this can be a formidable requirement, especially after the initial endowment that accompanies launching of a center. Changing priorities within state governors' offices or legislatures, as well as changes in governors or legislative sponsors, constrain the ability of centers to obtain multi-year commitments to sustain ongoing research programs. Lacking this stability, industrial sponsors may withdraw; also withdrawing may be faculty, who find being able to fund their research programs, which in cases may involve making up-front commitments to graduate students, too uncertain. If the commitments are made and state funding does not come through, centers and/or cooperating departments or colleges and faculty may find themselves the residual payees.

Based on this overview, one would expect the sources of the state matching funds required annually by the S/IUCRC Program to differ across states, and perhaps even to change over time within states. One would also expect the demands for justification of matching funds to differ in intensity and the criteria used to provide justification to vary as well. Finally, the place of S/IUCRCs in larger state strategies for promoting economic development would also be expected to vary considerably. All of these factors will affect any future NSF plans for programs that involve partnerships with, and financial commitments from, the states. Therefore, to enrich the chapter's general discussion with specific information about the state contexts of the nine S/IUCRCs studied for this evaluation, SRI conducted telephone interviews with seven of the nine State Representatives to the nine S/IUCRCs studied.²⁵ Interviews lasted approximately 20-30 minutes and covered the following questions:

- What has been the history of the organizations and procedures involved in requesting, justifying, and approving the annual matching requirement for the S/IUCRC?
- What have been the kinds of data and information used to support or justify the request for matching funds?
- What is the place of the S/IUCRC and of other university-industry partnerships in the state's broader efforts to encourage economic development?

The remainder of the chapter summarizes the results of these interviews.

Generally, the history of the State Representative's organizational home and identity is stable over the period since the S/IUCRCs studied were initiated. Some changes resulting from periodic reorganizations of state economic development and science and technology support organizations have occurred, but these do not appear to have disturbed greatly the responsibilities or identities of the State Representatives to the S/IUCRCs. In four of the centers, State Representatives work out of a science-and-technology-specific organization such as the New York State Office of Science, Technology, and Academic Research (formerly the New York State S&T Foundation) or the Oklahoma Center for Advanced Science and Technology. These organizations are responsible for strengthening the state's science and technology infrastructure, with the ultimate goal of promoting state economic development. Three of the Representatives work in public or quasi-public agencies with broad economic development responsibilities, such as the Ohio Department of Development and the Michigan Economic Development Corporation.

With one exception, S/IUCRC matching funds were initially approved as part of larger agency budget requests to the legislature and, once approved, experienced relatively routine annual renewal procedures that did not require major new efforts for justification. This is not to say that changes have not occurred, or that difficulties do not occur as part of the annual budget process. State Representatives mentioned a number of problems they faced in both initial and subsequent matching fund justification:

- The one-to-one match of NSF and state funds is not seen as attractive relative to other programs requiring state match;

- University-based research is sometimes not considered to be of interest to small firms, yet small firms are a specific target of many state economic development efforts;
- The model on which the S/IUCRC is based, involving groups of firms pooling membership fees to support precompetitive, generic research, sometimes is not regarded as the optimum model for providing the resources firms need to generate regional economic development impacts;
- Matching funds for an S/IUCRC are harder to justify when international companies are members.

Typically, the approval process for matching funds involves preparation and justification for a larger budget request from the host university, the state science and technology organization, or the state economic development organization to the legislature. About half the states for which SRI obtained information had a formal process for obtaining matching funds for proposals requiring them, while for the other half it was *ad hoc*. The basis for justification varied but not systematically by the type of organization either making the justification or approving the match. In nearly every case the justification was not specific to the S/IUCRC's technical field or programmatic objectives, but instead involved more general justifications related to strengthening the state's S&T infrastructure. This is elaborated in the following paragraph.

The State Representatives in the states represented in SRI's interviews reported that industry-university linkages and collaboration are an important and growing element in their state's overall economic development strategy, although in at least two states this was not necessarily part of a formal science and technology strategy. Most State Representatives reported that their states have accepted a general belief that it is worthwhile to fund research at universities; that doing so strengthens the state's technical capabilities relative to competing states, helps academic programs and benefits students, and helps bring in federal research money. However, within this general belief, the specific characteristics of S/IUCRCs do not necessarily make a good match. For example, as noted earlier, the amount of direct federal leverage is seen by some as relatively weak: one-to-one. The average center budget of about \$1 million is not regarded as particularly likely to generate many jobs or significant economic activity relative to other types of university-industry programs such as the Engineering Research Centers Program or the Science and Technology Centers Program. Small businesses are harder to attract to university-based groups of firms because their needs are often broader than research—e.g., business assistance. And finally, several representatives noted the mismatch between the legislative or gubernatorial term and the expected time for payoff in jobs or new products from industry-university collaboration.

G. References

- Atkinson, R. (1991). "States Take the Lead: Explaining Reformation of State Technology Policies." *Economic Development Quarterly* 5: 33–44.
- Babbit, Bruce (1984). "Grassroots Industrial Policy." *Issues in Science and Technology*, Fall.
- Blanchard, James Governor (1991). "A Governor's View of Science and Technology." In Margaret Meredith, Stephen Nelson, and Albert Teich (eds.), *Science and Technology Policy Yearbook–1991*. Washington, DC: American Association for the Advancement of Science. Pp 217–220.
- Blumenstyr, Goldie (1992). "States Reevaluate Industrial Collaboration Built Around Research Grants to Universities." *The Chronicle of Higher Education* 8(25).
- Burton, Laurence (1989). "Indicators for State Science and Technology Programs." *Policy Studies Journal* 18: 164–175.
- Carnegie Commission on Science, Technology, and State Government (1992). *Science, Technology, and the States in America's Third Century*. New York.
- Coburn, C. (Ed.) (1995). *Partnerships*. Columbus, OH: Battelle.
- Coburn, C. and D. Brown (1997). "A State–Federal Partnership in Support of Science and Technology." *Economic Development Quarterly* 11: 296–309.
- Council of State Governments (1972). *Power to the States: Mobilizing Public Technology*. Lexington, KY.
- Cozzens, S. and J. Melkers (1997). "Use and Usefulness of Performance Measurement in State Science and Technology Programs." *Policy Studies Journal* 25: 427–435.
- Ebert, J., C. Fields, and J. Wyngaarder (1991). Evaluation of the Advanced Research Program and Advanced Technology Programs." A report to the Texas Higher Education Coordinating Board.
- Eisinger, P. (1988). *The Rise of the Entrepreneurial State*. Madison, WI: University of Wisconsin Press.
- Eisinger, P. (1990). "State Economic Development in the 1990s: Politics and Policy Learning." *Economic Development Quarterly* 9: 146–158.
- Feller, I. (1990). *An Assessment of the Intergovernmental Science and Technology System and its State Government Component*. Report to the National Science Foundation, Grant No. RII-8506018.
- Feller, I. (1993). "The Effectiveness of State/Investments in Science and Technology." In S. R. Johnson and S. A. Martin (eds.), *Industrial Policy for Agriculture in the Global Economy* (Ames, IA: Iowa State University Press), 129–148.
- Feller, I. (1994). "The University as an Instrument of State and Regional Economic Development—The Rhetoric and Reality of the U.S. Experience." Paper prepared for the conference on "University Goals, Institutional Mechanisms, and the Industrial Transferability of Research."
- Feller, I. and G. Anderson (1994). "A Benefit-Cost Approach to the Evaluation of State Technology Development Programs." *Economic Development Quarterly*.
- Flentje, H. E. (1982). "Knowledge and Gubernatorial Policy Making: Policy and Management Context." In Lynn Muchmore (ed.), *Gubernatorial Policy Making Through Science Advice*. Washington, DC: National Governors' Association.
- Fosler, Scott (1998). *The New Economic Role of the States*. New York: Oxford University Press.

- Jones, Graham (1991). "State Science and Technology Initiatives in a Time of Fiscal Crisis." In *Science and Technology Policy Yearbook-1991*. Washington, DC: American Association for the Advancement of Science. Pp. 225-231.
- Kayne, Jay (1996). *A New Paradigm for Collaborative Science and Engineering Research*. Washington, DC: National Governors Association.
- Lambright, W. H. (1991). "Science, Technology and the States: From the 1980s to the 1990s." In *Science and Technology Policy Yearbook-1991*. Washington, DC: American Association for the Advancement of Science. Pp. 223-240.
- Lambright, W. H. and A. Teich (1989). "Science, Technology, and State Economic Development." *Policy Studies Journal* 18: 134-147.
- Lambright, W. H., A. Teich, and M. O'Gorman (1992). "The Turbulent Condition of State S&T Programs in the 1990s." In W. Henry Lambright and Dianne Rahm (eds.), *Technology and U.S. Competitiveness*. New York: Greenwood Press. Pp. 70-82.
- Malecki, E. (1991). *Technology and Economic Development*. New York: John Wiley and Sons.
- Minnesota Department of Trade and Economic Development (1988). *State Technology Programs in the United States*. Report by the Office of Science and Technology Policy.
- National Research Council (1993). *Learning to Change*. Washington, DC.
- National Science Foundation (1994). "Industry/University Cooperative Research Centers Program." Report of Renewal Criteria Committee (Wormley Report).
- Nelson, A. (1993). "Theories of Regional Development." In Richard Bingham and Robert Meier (eds.), *Theories of Local Economic Development*. Newbury Park, CA: Sage Publications). Pp. 27-57.
- Phelps, P. and P. Brockman (1992). "Science and Technology Programs in the States." Alexandria, VA: Advanced Development Distribution, Inc.
- Shapira, P. (1990). "Modern Times: Learning from State Initiatives in Industrial Extension and Technology Transfer." *Economic Development Quarterly* 4: 186-202.
- State Science and Technology Institute (1996). *State Funding for Cooperative Technology Programs*. Columbus, OH: State Science and Technology Institute.
- State Science and Technology Institute (1997). *Science and Technology Strategic Planning*. Columbus, OH: State Science and Technology Institute. Report to the Economic Development Administration.
- Tassey, G. (1991). "The Functions of a Technology Infrastructure in a Competitive Environment." *Research Policy* 20: 345-361.

III. FIRM-LEVEL OUTCOMES FROM CENTER ACTIVITIES

A. Introduction

This chapter presents data on center member representative responses to two basic features of the interactions their firms have had with their respective centers: the type of center activities in which member firms have been participating in and the type of results (outcomes) associated with each activity. The activities are:

- Core research/fundamental research;
- Non-core/sponsored research;
- Use of center facilities;
- Technical advice and consulting with center staff;
- Training provided by center staff.

The list of outcomes or results for center member firms from participating in these activities was developed from previous SRI research that sought similar information from industry members of NSF Engineering Research Centers, pretests of the survey instrument with representatives of S/IUCRC member firms, and discussions with NSF staff. The categories of results for which SRI sought data from representatives of center members are as follows (the text is drawn directly from the relevant survey item):

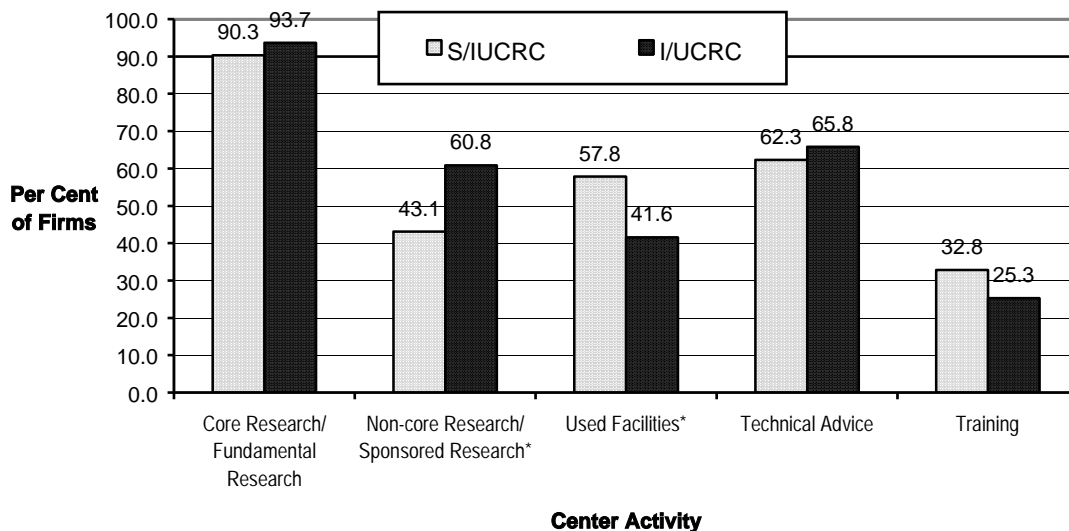
- ◆ *We obtained access to new ideas or know-how;*
- ◆ *We had more interaction than in the past with other Center firms;*
- ◆ *We improved a product(s) or process(es);*
- ◆ *We were able to provide our customers/suppliers with improved technical information;*
- ◆ *Our R&D agenda was influenced;*
- ◆ *We developed a new product or process;*
- ◆ *We licensed technology or software developed by the Center;*
- ◆ *We patented/copyrighted technology/software we developed as a result of interacting with the Center;*
- ◆ *We made unexpected operational changes;*
- ◆ *Other direct results.*

B. Profile Of Member Firm Participation In Center Activities

For both the S/IUCRC and I/UCRC Programs, nearly all center members participate in core research or fundamental research, which is not surprising since these activities are supported directly with membership fees. Less than a third of center members obtain training from the center staff, while other activities vary from 42 per cent participation rates (I/UCRC members taking advantage of access to facilities) to 66 per cent (I/UCRC members receiving technical advice). One surprising result is the significantly larger percentage of I/UCRC members participating in sponsored research relative to S/IUCRC members, since in the case of the

S/IUCRC program this activity was specifically designed to stimulate firm-relevant research projects. The complete results are presented in Figure III-1.

Figure III-1
Member Participation in Center Activities, S/IUCRC and I/UCRC



NOTE: A single asterisk (*) indicates that the difference between participation rates for the two types of centers is significant at the .05 level.

C. Profile Of Results Of Member Participation In Center Activities On Firm Behavior

Tables III-1 and III-2 show two aspects of member firm participation in center activities: first, the number of members who participate in each of the five types of activities SRI asked about (presented graphically in Figure III-1); and second, the proportion of those participating in each activity that report one or more types of results attributable to their participation. The data will be considered first on an overall basis, then activity-by-activity.

The major differences between results reported by member representatives of the two Programs are most distinctly revealed by considering the results obtained from member firm participation in *any* center activity (right-hand columns of Table III-1 and III-2). For the S/IUCRC Program, following access to new ideas or know-how, second in frequency was product or process improvement (73 per cent), then a cluster of results not as directly related to tangible outcomes (more interaction with other firms, improved technical information to customers/suppliers, influence on the firm's R&D agenda). More than half the representatives (54 per cent) reported that their firm developed a new product or process from participating in at least one center activity. Twenty per cent of the representatives reported that their firm licensed a technology or software that was a direct result of involvement with the center. These latter

results contrast significantly with the results for I/UCRCs: 40 per cent of the representatives reported that their firms had developed a new product or process, and just 7 per cent reported licenses resulting from center involvement.

Access to new ideas was the most common result reported for any of the activities taken individually, for both the S/IUCRC and I/UCRC Programs, followed by improved product or process resulting from using center facilities for the S/IUCRC Program. Product or process improvement was second in frequency for both Programs, but in the case of S/IUCRCs this resulted from use of facilities and obtaining technical advice, and for I/UCRC members it resulted from obtaining technical advice only. There is a significant difference between the two programs in the extent to which participation in center activities of various kinds results in more tangible impacts such as new product/process development, patenting or copyrighting technology or software, and licensing technology or software developed by the center. For three of the five activities, core research, use of facilities, and receiving technical advice, S/IUCRC member representatives consistently reported a significantly greater number of “hard” technology-related results (that is, results related in some way to protectable intellectual property) than did their I/UCRC counterparts.²⁶ This suggests that the former Program’s more explicit emphasis on commercial outcomes and technology transfer appears to have been successful. As will be shown later in this report, one important reason for this may be the considerably greater proportion of center members that are geographically proximate to the center—in particular, located in the center’s state. Another possible influence may be the S/IUCRC Program’s encouragement of intellectual property protection relative to the I/UCRC Program’s more open policy, although it is puzzling that this difference does not show up prominently for non-core research vs. sponsored research, where intellectual property guidelines differ formally between the two Programs.

²⁶ It is revealing to group results received by member firms into two categories: results associated with protectable intellectual property, either by the member firm or the center’s university, and results unrelated to intellectual property protection. In the former category are: “We developed a new product or process;” “We licensed technology or software developed by the Center;” “We patented/copyrighted technology/software we developed as a result of interacting with the Center.”

**Table III-1
Results Obtained from Member Participation in Center Activities, by Outcome Category, S/UCRC**

Result received by firm	Per cent responding					
	Core Research N=72	Non-core Research N=36	Use of Facilities N=37	Technical Advice N=43	Training N=22	Any activity N=69
We obtained access to new ideas or know-how	89.6	80.6	69.4	95.1	90.9	97.1
We had more interaction than in the past with other Center firms	65.0	38.2	40.5	41.0	50.0	68.3
We improved a product(s) or process(es)	60.9	52.8	69.4*	66.7	59.1	73.1
We were able to provide our customers/suppliers with improved technical information	55.4	45.7	62.2	53.8	50.0	63.6
Our R&D agenda was influenced	50.0	50.0	45.9	55.5	33.3	64.2
We developed a new product or process	41.5	47.1	41.7	50.0*	22.7	54.4*
We licensed technology or software developed by the Center	19.4**	11.4	5.4	9.8	4.8	20.3**
We patented/copyrighted technology/software we developed as a result of interacting with the Center	12.5	9.1	2.7	7.7	4.8	14.7
We made unexpected operational changes	11.9	11.4	14.3	20.0	9.5	20.6
Other direct results	8.3	8.3	5.0	2.2	9.8	12.5

**Table III-2
Results Obtained from Member Participation in Center Activities, by Outcome Category, I/UCRC**

Result received by firm	Per cent responding					
	Fundamental Research N=150	Sponsored Research N=102	Use of Facilities N=60	Technical Advice N=96	Training N=37	Any Activity N=152
We obtained access to new ideas or know-how	94.7	86.4	82.8	92.8	81.6	97.4
We had more interaction than in the past with other Center firms	59.1	46.8	29.6	29.7	39.5	60.7
We improved a product(s) or process(es)	53.1	55.6	49.1*	67.4	54.1	63.5
We were able to provide our customers/suppliers with improved technical information	56.6	52.0	49.1	61.7	57.1	68.5
Our R&D agenda was influenced	63.0	60.0	46.4	53.8	38.9	72.2
We developed a new product or process	30.8	36.5	25.0	28.4*	21.1	40.1*
We licensed technology or software developed by the Center	4.8**	8.4	3.6	5.4	8.3	7.4**
We patented/copyrighted technology/software we developed as a result of interacting with the Center	6.9	6.3	1.8	7.6	5.6	9.5
We made unexpected operational changes	12.2	10.5	10.7	20.9	11.1	18.7
Other direct results	8.2	0.0	3.1	3.0	4.2	11.4

NOTE: A chi-square test of significance was performed on the data in Tables III-1 and III-2. A double asterisk (**) indicates a difference in the frequency of participation in center activities between the two types of centers that is significantly different from the expected value at the .01 level; a single asterisk (*) indicates a difference that is significant at the .05 level.

D. Center Member Hiring Of Students Or Graduates

Most center member firms have not hired graduates of, or students who were associated with, centers. Previous work suggests that this is not because firms do not wish to hire center students, but because such students are in great demand or because member firms have not been

in a position to hire new staff. One indication that one or both of these explanations still apply is the consistent report that center students perform better than comparable hires. Nearly twice as many I/UCRC member firms as S/IUCRC firms (33 per cent vs 17 per cent) hired center students or graduates and, among firms that had hired graduates or students from either Program, most had hired one or two. The distribution of number of hires is roughly similar for both Programs, so there is no evidence that, in the case of the S/IUCRC Program, member firms on average hired a larger number of center students than did I/UCRC member firms (Tables III-3 and III-4).

Table III-3
Number of Center Students or Graduates Hired as Regular Employees by Center
Representatives' Company Units: S/IUCRC

Number of Hires	Per Cent of Company Units	Number of Company Units
None	82.9	58
One or more	17.2	12
One	7.1	5
Two	4.3	3
Three	0.0	0
Four or more	2.9	2
At least one	2.9	2

Table III-4
Number of Center Students or Graduates Hired as Regular Employees by Center
Representatives' Company Units: I/UCRC

Number of Hires	Per Cent of Company Units	Number of Company Units
None	67.1	100
One or more	32.8	49
One	10.1	15
Two	8.7	13
Three	1.3	2
Four or more	6.7	10
At least one	6.0	9

In addition to providing counts of center students or graduates hired in their company units, the representatives of member firms rated the performance of their firm's center hires compared with the performance of employees in their firm with similar experience and education along a number of dimensions. In the case of the S/IUCRC Program, the number of firms hiring center graduates or students is so small that tabulation of results by category of employee performance is not particularly meaningful; however, in every performance dimension center hires were rated more highly than non-center hires. There are more data available about I/UCRC hires both because of the larger number of I/UCRC respondents and the greater proportion of respondents who hired center graduates or students. The relative performance of center hires for I/UCRC member firms is shown in Table III-5. Note that at least one-fourth of the representatives found the I/UCRC hires "much better" in every performance category. This was

especially the case with respect to depth of technical knowledge, contribution to the firm's technical work, ability to work in teams, and overall preparation for work in industry. On the other hand, a plurality of firm representatives (41.7 per cent) indicated that their I/UCRC hires needed about the same amount of firm-funded training as comparable non-center hires. Similarly, about a third of the representatives assess their I/UCRC employees as about the same as comparable employees in their ability to solve problems.

**Table III-5
Comparison by Firms of Performance of I/UCRC Center Hires with Comparable non-Center Hires
Employed at Member Firms**

Performance dimension	Much worse	I/UCRC Hires Are:				N
		Somewhat worse	About the same	Somewhat better	Much better	
Depth of technical knowledge	0%	0%	14.9%	27.7%	57.4%	47
Breadth of technical knowledge	0	2.1	21.3	44.7	31.9	47
Contribution to firm's technical work	0	2.2	15.2	37	45.7	46
Firm funding for training required	0	0	41.7	33.3	25	36
Ability to apply knowledge	0	0	25.6	37.2	37.2	43
Ability to solve problems	0	0	32.6	32.6	34.9	43
Ability to work in teams	0	0	28.6	28.6	42.9	42
Ability to use knowledge to develop technology	0	0	20.5	45.5	34.1	44
Overall preparedness for working in industry	0	0	15.2	39.1	45.7	46

IV. PROGRAM IMPACTS

A. Value To Member Firms Of Specific Outcomes From Center Activities

Tables IV-1 and IV-2 present the benefit ratings that representatives of member firms from both types of centers associated with specific outcomes that the firms realized, as far as the representatives were aware, from participating in center activities. Because of the large variations in the number of responses for each cell of these tables, it is difficult to identify patterns simply through observation. To aid in interpreting the data, cells in which the number of responses was extremely low (less than 10) are shaded. In addition, the mean value rating for each type of result was calculated. Finally, analyses of variance were conducted on the unshaded portions of Tables IV-1 and IV-2. In each instance, the differences in mean benefit ratings both across center activities and across categories of results were too small to be statistically significant. Looking first *within* Programs, there are no major variations in the mean value ratings reported for all activities, taken together, at least for those types of results for which most firm representatives responded. Looking *across* Programs, the similarity of ratings is apparent, and this was confirmed statistically by performing a chi-square test, which revealed no significant differences in ratings across Programs. Indeed, what is striking about the impact patterns both within and across Programs is their uniformity.

Table IV-1
Degree of Member Benefits Derived from Outcomes of Participating in Centers: S/UCRC

Outcome	Degree of Benefits Derived by those who Obtained Result (Mean Rating)*					Mean Rating for all Activities
	Core Research N = 72	Non-core Research N = 36	Use of Facilities N = 37	Technical Advice N = 43	Training N = 22	
We obtained access to new ideas or know-how	2.9	2.9	3.0	2.9	3.0	2.9
We had more interaction than in the past with other Center firms	3.0	3.0	3.1	3.1	3.0	3.0
We improved a product(s) or process(es)	2.8	2.9	2.9	2.9	2.8	2.9
We were able to provide our customers/suppliers with improved technical information	2.9	3.1	3.1	2.9	2.9	3.0
Our R&D agenda was influenced	2.7	2.9	2.6	2.9	2.7	3.0
We developed a new product or process	2.9	2.9	2.8	2.9	3.0	2.9
We licensed technology or software developed by the Center	3.2	2.3	2.0	3.0	3.0	2.9
We patented/copyrighted technology/software we developed as a result of interacting with the Center	2.1	3.0	3.0	3.0	3.0	2.6
We made unexpected operational changes (e.g., equipment or project additions or cancellations.)	2.6	3.5	2.6	2.7	3.5	2.8
Other direct results	4.0	3.0	4.0	N/A	4.0	3.8

*Items were rated on a 4 point scale, with "little or none" = 1, "some" = 2, "moderate amount" = 3, and "great deal" = 4. The midpoint is 2.5.

Shading indicates that the number of responses is too low for tests of statistical significance.

To determine whether the differences in ratings in the unshaded portions of the table were statistically significant *within* the S/UCRC Program, analyses of variance were performed across activities and across outcomes. They revealed no statistically significant differences at the .05 level.

**Table IV-2
Degree of Member Benefits Derived from Outcomes of Participating in Centers: I/UCRC**

Outcome	Degree of Benefits Derived by those who Obtained Result (Mean Rating)*					Mean Rating for all Activities
	Fundamental Research N=150	Sponsored Research N=102	Use of Facilities N = 60	Technical Advice N = 60	Training N = 37	
We obtained access to new ideas or know-how	2.9	3.0	2.8	3.0	2.9	3.0
We had more interaction than in the past with other Center firms	2.8	2.9	2.7	3.2	3.1	2.9
We improved a product(s) or process(es)	2.9	2.8	2.9	3.0	2.6	2.9
We were able to provide our customers/suppliers with improved technical information	2.9	3.0	3.0	2.9	2.6	2.9
Our R&D agenda was influenced	2.7	2.7	2.5	2.8	2.6	2.7
We developed a new product or process	2.9	2.7	3.1	3.1	2.4	2.9
We licensed technology or software developed by the Center	3.0	2.9	3.0	3.0	2.0	2.9
We patented/copyrighted technology/software we developed as a result of interacting with the Center	2.9	2.8	4.0	3.1	3.0	3.1
We made unexpected operational changes (e.g., equipment or project additions or cancellations.)	2.9	3.1	2.2	2.8	2.8	2.8
Other direct results	3.7	N/A	4.0	3.0	3.5	3.7

*Items were rated on a 4 point scale, with "little or none" = 1, "some" = 2, "moderate amount" = 3, and "great deal" = 4. The midpoint is 2.5.

Shading indicates that the number of responses is too low for tests of significance to be applied.

To determine whether the differences in ratings in the unshaded portions of the table were statistically significant *within* the I/UCRC Program, analyses of variance were performed across activities and across outcomes. They revealed no statistically significant differences at the .05 level.

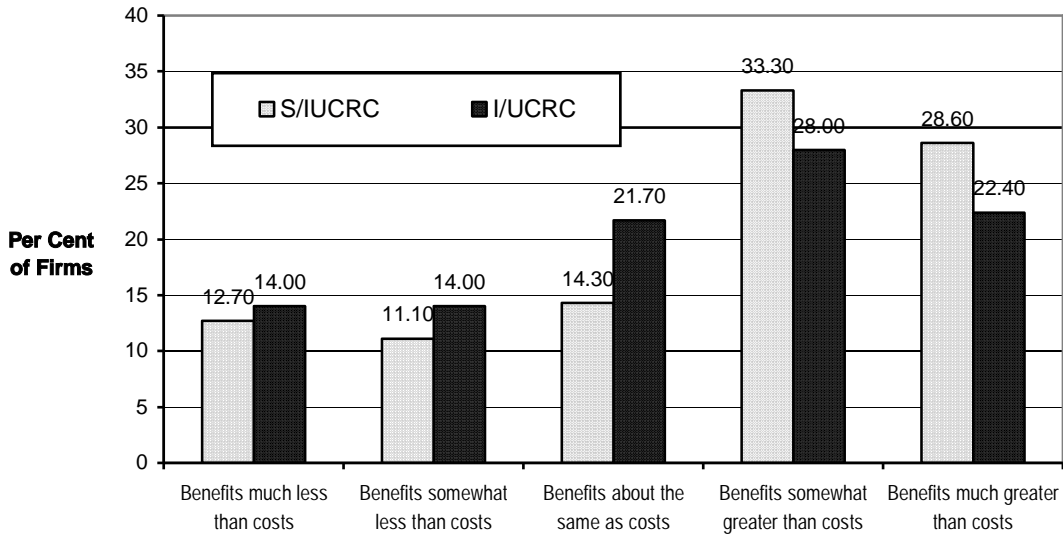
B. Estimates Of Overall Program Benefits And Costs

The value to firms of the benefits of participating in center activities was estimated in several ways. First, representatives of member firms were asked to gauge the value of center membership in the most general way: were the benefits resulting from membership much less than the costs, somewhat less, about the same, somewhat greater, or much greater? Second, representatives were asked to estimate the dollar value of cost savings resulting from hiring center graduates or students; the dollar value of savings achieved other than those from hiring center students or graduates; and the dollar value of any benefits that accrued beyond cost savings. The following chart (Figure IV-1) summarizes the results of the qualitative assessment of benefits relative to costs.

Representatives from member firms to both types of centers regard their firms' participation in center activities worthwhile: over half of the member representatives in both Programs report that the benefits their firms received were either somewhat greater or much greater than the costs (62 per cent of S/IUCRC member representatives, 50 per cent of I/UCRC member representatives). About a quarter of the representatives of members of both Programs felt that the benefits were not worth the costs (24 per cent of S/IUCRC member representatives, 28 per cent of I/UCRC member representatives). A slightly greater proportion of S/IUCRC member representatives relative to I/UCRC member representatives thought that the benefits their firms derived exceeded the costs, but the differences were not statistically significant. If those who estimated that the benefits and costs were about equal are included with those who had more positive assessments, the two Programs are viewed almost identically from the

perspective of this broad benefit/cost framework. (Note: Nearly all member representatives responded to this question: 63 S/IUCRC and 141 I/UCRC member representatives.)

**Figure IV-1
Assessment of Benefits versus Costs, S/IUCRC and I/UCRC**



Slightly less than half of the representatives provided dollar estimates of savings from their firms' memberships (refer to Table IV-3). Therefore, the amounts reported cannot be considered representative. The figures for total financial benefits are the sums of benefit estimates for the three different categories, not responses to a separate question. Because in both programs the distributions of cost savings and financial benefits reported were highly skewed (as is typical for responses to questions of this kind), median values are more meaningful. They show that the typical center representative *among the small proportion responding to this question* does not report that his/her firm experienced significant dollar benefits from being a member. The differences between the two Programs are not statistically significant.

**Table IV-3
Estimates of Financial Benefits from Center Membership, S/IUCRC and I/UCRC**

Type of savings	S/IUCRC (9 Centers)				I/UCRC (17 Centers)			
	Total (\$000)	Mean (\$000)	Median (\$000)	N	Total (\$000)	Mean (\$000)	Median (\$000)	N
Savings in training costs	185	12	0	16	1,987	37	0	54
Savings beyond training cost savings	2,300	92	25	13	19,415	360	0	54
Financial benefits beyond cost savings	13,328	555	60	24	29,920	680	0	44
Total financial benefits	15,813	494	100	32	51,322	790	30	65
Average Benefits per center (\$000)		1,757				3,019		

In contrast to estimates of financial benefits from center memberships, most representatives of center members were willing and able to estimate their firm's total expenditures for membership, including cash, in-kind contributions, fees for use of facilities, training, and technical assistance, and other kinds of support. The S/IUCRC and I/UCRC Programs were nearly identical in the mean and median levels of support, as Table IV-4 shows. (Note that the category of "Total support" is not the sum of the separate categories, but a separate question in the survey instrument.)

**Table IV-4
Program Support Expenditures Reported by Representatives of Center Members, S/IUCRC and I/UCRC**

Type of support	S/IUCRC (9 Centers)				I/UCRC (17 Centers)			
	Total (\$000)	Mean (\$000)	Median (\$000)	N	Total (\$000)	Mean (\$000)	Median (\$000)	N
Cash	13,551	251	50	54	22,038	168	95	130
In-kind	4,001	74	10	54	4,199	32	0	130
Fees for use of facilities	175	3	0	54	169	1.3	0	130
Fees for training	183	3	0	54	321	2.5	0	130
Fees for technical assistance	182	3	0	54	1,256	9.6	0	130
Other	46	0.9	0	54	1,288	9.9	0	129
Total support	19,433	313	100	62	51,727	364	128	140
Average support per center (\$000)		2159				3,043		

C. Regional Economic Development Impact: Firm Location

In contrast to the I/UCRC Program, the S/IUCRC Program was specifically intended to promote economic development within states supporting centers. Since membership in a center was not restricted to in-state organizations and center students could work with, and be hired by, out-of-state firms, however, obviously some center-related benefits accrued to organizations outside each center's state boundaries. An important question to be addressed in this evaluation is, therefore, the relative economic impact of the center on in-state (IS) vs. out-of-state (OOS) organizations. Since data are available from I/UCRC member organizations, a related question is the extent to which economic and other benefits accrued proportionately to IS members of S/IUCRCs versus IS members of I/UCRCs. The zip codes of members of both centers provided the information necessary to address these questions.

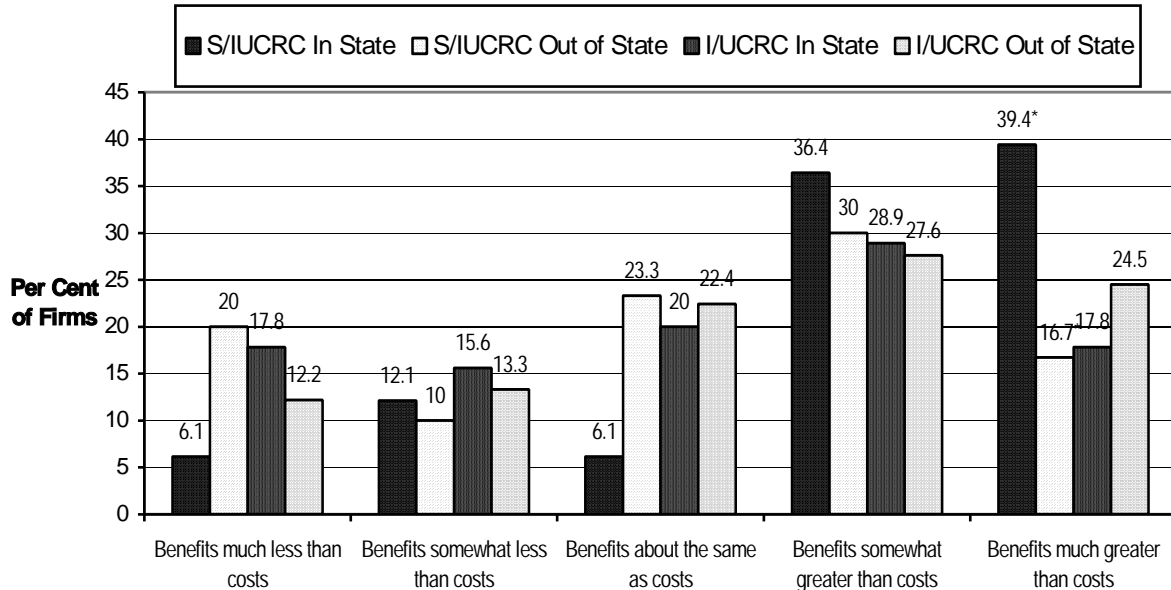
An initial observation is that a substantially greater proportion of S/IUCRC member organizations (more precisely, the units that interact principally with the center) are in-state than is the case for members of I/UCRCs. In particular, slightly more than half (51.4 per cent) of S/IUCRC member organizations are IS, whereas just under thirty per cent (29.5 per cent) of I/UCRC members are IS (see Table IV-5).

Table IV-5
Proportion of In-state and Out-of-State Members,
S/IUCRC and I/UCRC

Location	S/IUCRC		I/UCRC	
	N	%	N	%
In-state	37	51.4	46	29.5
Out-of-state	35	48.6	110	70.5
Total	72	100.0	156	100.0

Figure IV-2 arrays the assessment of benefit-cost ratio for each Program's centers into IS and OOS groups. The difference in the reported benefits versus costs between IS and OOS member firms for each of the two Programs is striking: in the case of the S/IUCRC Program, IS representatives consider centers to provide much higher benefits to costs than do OOS representatives (this difference is statistically significant), whereas the reverse is true for I/UCRCs, although the difference is not nearly as dramatic (and is not statistically significant). For the S/IUCRC Program, 76 per cent of the IS representatives vs. 47 per cent of the OOS representatives consider the benefits of membership to be greater than the costs, while for the I/UCRC Program only 46 per cent of the IS representatives versus 52 per cent of the OOS representatives rate their firm's experience this positively. If only the extreme categories are considered, the differences between the two Programs are even more pronounced: nearly 40 per cent of the IS S/IUCRC representatives, compared with 17 per cent of the OOS representatives, regard membership benefits to be much greater than costs, while in the case of the I/UCRC representatives the reverse is the case—25 per cent of the OOS vs. 18 per cent of the IS representatives consider membership benefits to be much greater than costs. At the other end of the scale, the situation is just reversed. Only 6 percent of the IS representatives to S/IUCRCs, compared with 18 per cent of the IS I/UCRC representatives, regard the benefits to be much less than the costs, while 20 per cent of the OOS S/IUCRC representatives and 12 per cent of the OOS I/UCRC representatives had such a negative response.

Figure IV-2
Assessment of Benefits versus Costs In-State vs. Out-of-State Members,
S/IUCRC and I/UCRC



NOTE: An asterisk (*) indicates a difference that is significant at the .05 level.

D. Regional Economic Impact: Data From S/IUCRC Annual Reports

S/IUCRCs provide NSF with annual reports that include sections on accomplishments, contributions to state and local economic development strategies, lists of collaborations, and lists of patents and licenses with cumulative royalty payments. Potentially, information in these reports could be used as an additional source of data on the regional economic impact of each S/IUCRC. SRI reviewed the most recent annual reports that could be obtained for each of the nine S/IUCRCs studied, as follows:

- Center for Molecular and Microstructure of Composites, Case Western Reserve University & University of Akron: 1997 Annual Report;
- Computer-Aided Life-Cycle Engineering Electronic Packaging Research Center, University of Maryland: 1994-95 Annual Report;
- Center for Low-Cost, High-Speed Polymer Composites Processing, Michigan State University: 1995-96 Annual Report;
- Capsule Pipeline Research Center, University of Missouri at Columbia: 1994-95 Annual Report;
- Nonwovens Cooperative Research Center, North Carolina State University: 1994-95 Annual Report;
- Integrated Electronics Engineering Center, State University of New York at Binghamton: 1997-98 Annual Report;

- Center for Intelligent Information Retrieval, University of Massachusetts at Amherst: 1998-99 Annual Report;
- Rock Mechanics Research Center, University of Oklahoma: 1994-95 Annual Report;
- Center for Electronic Imaging Systems, University of Rochester with Rochester Institute of Technology: 1998-99 Annual Report.

Estimates of the regional economic impact of university-industry research collaboration could be obtained from the following kinds of data, all of which must be attributable to private firms' collaboration with university research generally or to one or more firms' involvement with specific university-based centers such as S/IUCRCs: the amount of new sponsored research obtained by state institutions attributable to university-based centers, new firms attracted to the state as a result of center activities, the number of jobs created or saved as a result of center interaction with member firms located in the state, cost savings to center member firms, increased sales of member firms, and increased capital investment by member firms.²⁷ Other kinds of data such as patents or licenses issued, royalty income to the university, or new business startups resulting from center activities, attributable to S/IUCRC activities, might provide measures of impact that could be compared, for example, with the impact on the state of other kinds of state economic development strategies. Thus SRI sought both types of information in the S/IUCRC annual reports. The remainder of this section describes the nature of data available in each of the annual reports examined and draws conclusions about the feasibility of using such data for estimating regional economic impacts attributable to S/IUCRC activity.

CWRU Center for Molecular and Microstructure of Composites. The report provides qualitative descriptions of the consequences, mostly technical, of the Center's interactions with small businesses. One patent is mentioned and listed in the tabular presentation of patents and licenses. One exclusive license was granted.

University of Maryland CALCE. The report describes the consulting activities of the Center, the partnerships initiated, and lists research projects (as all reports do). Two small companies were created as a result of the Center's activities, and one software product, resulting from core research, was licensed on a non-exclusive basis to all member companies.

²⁷ Examples of studies that have used these kinds of data to generate estimates of regional economic impact include I. Feller and G. Anderson, "A Benefit-cost Approach to the Evaluation of State Technology Development Programs." *Economic Development Quarterly*, **8** (1994): 127-140; D. Roessner, Y. Lee, P. Shapira, and B. Bozeman, *Evaluation of Iowa State University's Center for Advanced Technology Development*. Atlanta, GA: School of Public Policy, Georgia Institute of Technology, 1996. Final Report; Nexus Associates, *Evaluation of the New York Industrial Technology Service*, Cambridge, MA: Nexus Associates, 1994, Prepared for the New York State Science and Technology Foundation; J.D. Riggle, R.R. Stough, and J.J. McElwain, *Virginia's Center for Innovative Technology: Economic Impact and Client Assessment Survey, Fiscal Year 1995*. George Mason University, The Institute of Public Policy, 1995; Shapira, P. and J. Youtie, "Evaluating Industrial Modernization: Methods, Results, and Insights from the Georgia Manufacturing Extension Alliance," *Journal of Technology Transfer*, vol. 23, no. 1 (spring 1998): 17-27; L. Pressman, S.K. Guterman, I. Abrams, D.E. Geist, and L.L. Nelsen, "Pre-Production Investment and Jobs Induced by MIT Exclusive Patent License: A Preliminary Model to Measure the Economic Impact of University Licensing." *Journal of the Association of University Technology Managers*, 1995.

Michigan State Center for Low-Cost, High-Speed Polymer Composites Processing. The report describes interactions between the Center and member companies, lists non-core activities, and describes in some detail projects with the federal Technology Reinvestment Project and the Advanced Technology Program at NIST. One patent resulting from a non-core project is listed.

University of Missouri CPRC. The report consists primarily of descriptions of research projects, most of which are with federal agencies. Four patents are listed, all held by the university. No licenses had been granted.

North Carolina State NCRC. The Center's outreach efforts and collaborations are described.

SUNY Binghamton IEEC. In the "nuggets" section the report describes a faculty spin-off company to exploit software developed under the Center's sponsorship, and reports an estimate of 25-40 jobs created in a member company over a two year period that "could be directly attributed to the company's relationship with the University" (p. 15). The report also describes technical assistance provided to companies and lists two licenses awarded for software developed from core projects.

University of Massachusetts CIIR. The report discusses the fact that some companies have decided to be near the Center. Fifteen licenses for software have been granted, all from core projects, and a cumulative royalty income from these licenses of approximately \$14,000 is listed.

University of Oklahoma RMRC. Collaborations with companies and the nature of linkages are described.

University of Rochester CEIS. The report describes one startup company originating with the Center that has been acquired by Corning. It has 28 employees and "several million dollars." The report notes that the New York State Science & Technology Foundation (now NYSTAR) evaluates all the state's Centers for Advanced Technology (CAT), of which CEIS is part. NYSTAR asks all CATs to estimate corporate gross revenue in New York state attributable to the CAT, the number of jobs created in New York, including graduates, using \$100K/year for the first year and \$75K per year afterward as the basis for estimating economic impact. CEIS reports that 62 jobs have been created in New York since its inception and that several startups have resulted, but that "exact measures of economic impact have not been determined . . ." (p. 7-6). The report also lists five patents granted.

The lack of specific information in these reports and the wide variation in the types and specificity of data across reports mean that, at least at present, center annual reports cannot serve as a reliable source of data on the economic impact of the S/IUCRC Program or of individual centers. There was no consistent relationship between the amount or type of data and the date of the report, so there was no apparent trend toward more detailed reporting, with the possible exception of the Rochester Center. Here, the requirements imposed by the state of New York may lead to the collection and reporting of specific, reliable estimates of economic impact. For this report, however, SRI had to rely on the survey data for information about the S/IUCRC's regional economic impact.

E. Detailed Analysis Of Program Impacts Due To Member Firm Location

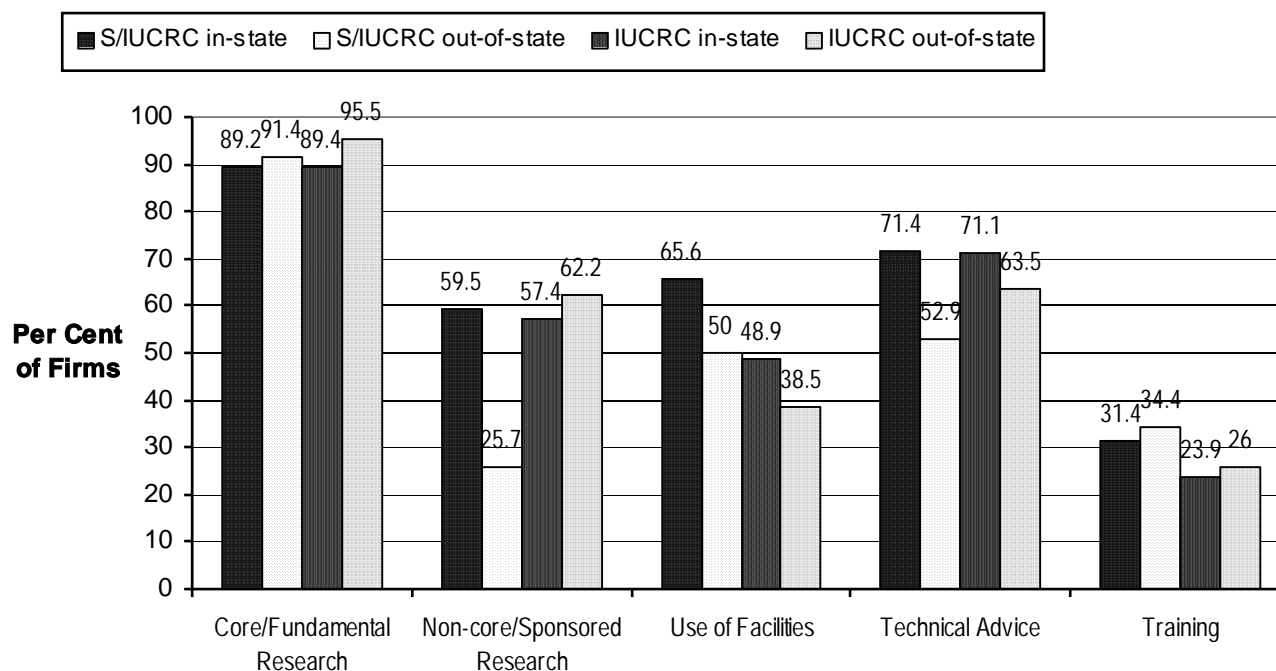
This section examines in finer detail the pattern of benefits reported by representatives of member firms. It has already been determined that, in the case of the S/IUCRC Program, in-state representatives report substantially greater benefit-to-cost ratios than do out-of-state representatives (although a majority of both groups report at least a breakeven experience). There is no such substantial difference in benefit-cost comparisons provided by representatives of IUCRC member firms, however; although out-of-state representatives report slightly higher ratios than do in-state representatives.

To what extent do in-state center member firms participate in center activities compared with out-of-state members, and how do patterns of participation vary across the two NSF Programs? The analysis in Chapter III showed that nearly all member firms of both Programs participated in core/fundamental research, as an integral aspect of their membership fees. Beyond this, participation rates varied, with typically between 40 per cent and 60 per cent of member firms participating in one or more of non-core/sponsored research, access to facilities, or obtaining technical advice. Only about a quarter of the representatives of member firms of centers in both Programs reported that their firms participated in training offered by centers. The major difference across the two Programs was that two-thirds of the IUCRC member firms participated in sponsored research, while just half of the S/IUCRC member firms participated in non-core research, a required activity of the S/IUCRC Program.

Figure IV-3 shows that a considerably greater proportion of in-state S/IUCRC members participate in non-core research than do out-of-state members (60 per cent vs. 26 per cent; statistically significant at the .01 level), suggesting that S/IUCRCs are more responsive in their research programs to in-state members, as the Program's objectives would predict. (Later results show that in-state members of S/IUCRCs also gain a broader spectrum of benefits from non-core research than do out-of-state members.) However, both in-state and out-of-state IUCRC members participate in sponsored research in about the same (high) proportion as do in-state S/IUCRC members. (Recall, however, that S/IUCRC members as a group participate less frequently in non-core research than IUCRC members participate in sponsored research. See Figure III-1.)²⁸ Out-of-state members of IUCRCs participate in sponsored research significantly more frequently than do out-of-state members of S/IUCRCs—62 per cent vs. 26 per cent. The remaining differences in participation rates both within and across Programs are not statistically significant.

²⁸ Recall, also, that the nature of S/IUCRC non-core research may be different from IUCRC sponsored research. For example, it is possible that S/IUCRC representatives are more directly involved in their center's research.

Figure IV-3: Member Participation in Center Activities by Geographic Location, S/IUCRC and I/UCRC



NOTE: An asterisk (*) indicates a difference that is significant at the 0.5 level.

Tables IV-6 and IV-7 show the effect of geographic location on member firm participation in center activities for the two Programs, as their participation relates to specific outcomes. The cell entries are the result of crosstabulations of outcome categories with type of center activity, classified by in-state and out-of-state firm location. Chi-square tests of significance were performed on the data. Some quite striking and consistent patterns emerge when the outcomes of member participation in center activities are broken out by the member firm's geographic location. First, it is apparent that in the case of the S/IUCRC Program, in-state member representatives report a much wider range of types of beneficial outcomes than do out-of-state representatives. The opposite is largely true for the I/UCRC Program: it is out-of-state member representatives who are more likely to report a wide range of beneficial results. For in-state members of the S/IUCRC Program, non-core research was clearly the activity most likely to yield beneficial results (relative to out-of-state members). For these in-state member firms, participation in non-core research resulted in a relatively higher frequency of reports by representatives to centers of access to new ideas, improved products or processes, improved technical information for customers or suppliers, and influence on their firm's R&D agenda. Core research and technical advice were the paths for in-state member firms to product or process development (again, relative to out-of-state member firms).

For out-of-state members of the I/UCRC Program a quite different pattern of beneficial outcomes is reported. No single center activity stands out as the path to a wide range of beneficial results, although as a contrast to the S/IUCRC situation, it was out-of-state representatives who more frequently mentioned that their firm's R&D agenda was influenced and developed a new product or process. In-state member firms experienced a wider range of results than out-of-state members only when they participated in training, probably because their geographic proximity made training more feasible.

Table IV-6
Comparison of In-State and Out-of-state Member Participation in
Center Activities, by Outcome Category: S/IUCRC

Outcome	Core Research	Non-core Research	Use of Facilities	Technical Advice	Training
We obtained access to new ideas or know-how	0	IS>	0	*	*
We had more interaction than in the past with other Center firms	0	0	0	0	*
We improved a product(s) or process(es)	0	IS>	0	0	*
We were able to provide our customers/suppliers with improved technical information	0	IS>	0	0	*
Our R&D agenda was influenced	IS>	IS>	IS>	0	*
We developed a new product or process	IS>	0	0	IS>	*
We licensed technology or software developed by the Center	*	*	*	*	*
We patented/copyrighted technology/software we developed as a result of interacting with the Center	*	*	*	*	*
We made unexpected operational changes	*	*	*	*	*
Other direct results	*	*	*	*	*

IS> means that in-state mean frequency of responses was significantly higher than out-of-state frequency, $p \leq 0.1$

OOS> means that out-of-state mean frequency of responses was significantly higher than in-state frequency, $p \leq 0.1$

0 means that there was no substantial difference between mean in-state and out-of-state frequencies.

*means that 50 per cent of the cells had expected counts of less than five, making the chi-square test unreliable

Table IV-7
Comparison of In-State and Out-of-State Member Participation in
Center Activities, by Outcome Category: I/UCRC

Outcome	Fundamental Research	Sponsored Research	Use of Facilities	Technical Advice	Training
We obtained access to new ideas or know-how	0	0	0	*	*
We had more interaction than in the past with other Center firms	0	0	0	0	IS>
We improved a product(s) or process(es)	OOS>	0	0	0	0
We were able to provide our customers/suppliers with improved technical information	0	0	IS>	OOS>	IS>
Our R&D agenda was influenced	0	OOS>	OOS>	0	0
We developed a new product or process	0	OOS>	0	0	0
We licensed technology or software developed by the Center	*	*	*	*	*
We patented/copyrighted technology/software we developed as a result of interacting with the Center	0	*	*	*	*
We made unexpected operational changes	0	*	*	*	*
Other direct results	*	*	*	*	*

IS> means that in-state mean frequency of responses was significantly higher than out-of-state frequency, $p \leq 0.1$

OOS> means that out-of-state mean frequency of responses were significantly higher than in-state frequency, $p \leq 0.1$

0 means that there was no substantial difference between mean in-state and out-of-state frequencies.

*means that 50 per cent of the cells had expected counts of less than five, making the chi-square test unreliable

How do member representative valuations of benefits vary by type of outcome or result, and by center activity? Representatives of member firms rated the value of each outcome on an ordinal scale, so it is possible to analyze the pattern of valued results reported earlier in this chapter by geographic location—IS vs. OOS. Because response rates to these benefit questions varied widely, and because some types of results such as licensing technology were infrequent, most categories contained too few cases to permit statistical analysis. The following two tables therefore present patterns of impact by geographic location for both the S/IUCRC and I/UCRC Programs, with results reported only when there were sufficient data for a t-test to be used to determine if the difference in mean values reported by in-state and out-of-state members was statistically significant.

Basically the data indicate that there were no clear patterns in representatives' valuations of benefits derived from each result their firms obtained that distinguished in-state from out-of-state members of either Program. Especially in the case of the S/IUCRC Program, the small number of responses eliminated many categories from the analysis, notably those outcomes associated with intellectual property protection, which were especially highly valued (Table IV-9).

Table IV-8
Comparison of In-State and Out-of-State Member Degree of Benefits Derived,
by Center Activity and Outcome Category: S/IUCRC

Outcome	Core Research	Non-core Research	Use of Facilities	Technical Advice	Training
We obtained access to new ideas or know-how	0	0	0	0	0
We had more interaction than in the past with other Center firms	0	*	*	*	*
We improved a product(s) or process(es)	0	*	0	0	*
We were able to provide our customers/suppliers with improved technical information	IS>	*	0	0	*
Our R&D agenda was influenced	0	*	*	0	*
We developed a new product or process	0	*	*	*	*
We licensed technology or software developed by the Center	*	*	*	*	*
We patented/copyrighted technology/software we developed as a result of interacting with the Center	*	*	*	*	*
We made unexpected operational changes	*	*	*	*	*
Other direct results	*	*	*	*	*

IS> means that in-state mean valuations were significantly higher than out-of-state valuations, $p \leq 0.1$

OOS> means that out-of-state mean valuations were significantly higher than in-state valuations, $p \leq 0.1$

0 means that there was no substantial difference between mean in-state and out-of-state valuations

*means that 50 per cent of the cells had expected counts of less than five, making the chi-square test unreliable

**Table IV-9
Comparison of In-State and Out-of-State Member Degree of Benefits Derived, by Center Activity and Outcome Category: I/UCRC**

Outcome	Fundamental Research	Sponsored Research	Use of Facilities	Technical Advice	Training
We obtained access to new ideas or know-how	0	0	0	0	0
We had more interaction than in the past with other Center firms	0	0	*	0	*
We improved a product(s) or process(es)	0	0	IS>	0	0
We were able to provide our customers/suppliers with improved technical information	0	0	0	0	0
Our R&D agenda was influenced	0	0	0	0	*
We developed a new product or process	IS>	IS>	*	0	*
We licensed technology or software developed by the Center	*	*	*	*	*
We patented/copyrighted technology/software we developed as a result of interacting with the Center	*	*	*	*	*
We made unexpected operational changes	*	*	*	*	*
Other direct results	*	*	*	*	*

IS> means that in-state mean valuations were significantly higher than out-of-state valuations, $p \leq 0.1$

OOS> means that out-of-state mean valuations were significantly higher than in-state valuations, $p \leq 0.1$

0 means that there was no substantial difference between mean in-state and out-of-state valuations

*means that 50 per cent of the cells had expected counts of less than five, making the chi-square test unreliable

In the previous chapter, analysis of center member representatives' reports of their firm's hiring²⁹ showed that most member firms do not hire center students or graduates, that just under 20 per cent of S/IUCRC member firms had hired center students/graduates, and that about a third of I/UCRC member firms had done so. In centers from both Programs, more than half of the firms that hired center students hired just one or two, so that there is no reason to believe that firms associated with a center in one Program tended, on average, to hire more students/graduates than was the case with firms associated with centers in the other. A breakdown of firms by location (Table IV-10) shows that, among firms that did hire center students/graduates, in-state members of S/IUCRCs were more likely than in-state I/UCRC members to hire them. Although the numbers are small, half the S/IUCRC member firms that hired students or graduates were located in the same state as the center, compared with 41 per cent of the I/UCRC firms.

The results are therefore mixed regarding the question of the regional economic impact of S/IUCRCs as measured by student/graduate hires. On the one hand, S/IUCRC member firms

²⁹ Recall that member representatives were estimating the results of center membership for their unit only, not for the entire firm.

were less likely to hire center students/graduates than were I/UCRC members (17 per cent vs. 33 per cent); on the other hand, among the member firms of both Programs that did hire students/graduates, a greater proportion of S/IUCRC member firms was located in the same state as the center (50 per cent vs. 41 per cent).

Table IV-10
Member Hiring of Center Students/Graduates by Location, S/IUCRC and I/UCRC

Firm location	S/IUCRC			I/UCRC		
	Total	Yes, hired center student(s)	No	Total	Yes, hired center student(s)	No
In state	35	6	29	46	20	26
Out of state	35	6	29	105	29	76
Total	70	12	58	151	49	102

V. FACTORS EXPECTED TO INFLUENCE PROGRAM OUTCOMES AND IMPACTS

There are at least three broad categories of factors that can influence the outcomes and impacts of the S/IUCRC and I/UCRC Programs:

- Each Program's goals, objectives, formal requirements, and informal guidelines and practices;
- Features of individual centers such as leadership style and quality, levels of financial support and staffing, characteristics of the academic setting, number of center members, and size profile of member firms;
- Characteristics of center member firms and their representatives, such as firm size, firm location (proximity to center), length of time as a center member, and length of time as member representative to a center.

The design of this evaluation focuses on only some of these factors, namely the characteristics of the S/IUCRC Program, especially those that distinguish it from the I/UCRC Program, and information about center member firms and their representatives. This chapter first discusses the characteristics of each Program in terms of their potential influence on key outcomes and impacts of interest:

- Center member firm participation in center activities;
- Results experienced by member firms from their participation in center activities;
- Level of benefit that member representatives associate with specific results;
- Member representatives' assessment of the benefits and costs of their firm's involvement with a center; and
- The regional impact of center activities as measured by the location of member firms.

This discussion is followed by descriptive data on member firm location, firm size, average number of members per center, the length of time member firm representatives have served in that capacity, and the annual expenditures of member firms in support of a center. The discussion and descriptive material anticipate Chapter VI's effort to explain the outcomes and impacts measured in this study.

A. Program Goals, Requirements, And Guidelines

Chapter I presented, in tabular form, the formal requirements, goals, activities, and other features of the S/IUCRC and I/UCRC Programs (Tables I-1 and I-2). Considering first the formal requirements, both Programs require centers to support fundamental, core research funded in part by the pooled membership fees of member firms, and require a minimum level of industrial support. Thus member firms, by paying their membership fees, participate at some

minimal level in their center's core research in the case of the S/IUCRC Program and in fundamental research in the case of the I/UCRC Program. Participation in all other center activities is discretionary, so participation rates of member firms would be expected to be influenced primarily by the kinds of results expected or obtained from participating in different activities and the value that member firms associate with those results. For example, use of center facilities for research will be influenced, in part, by whether a given center is characterized by the existence of unique facilities not available easily in other universities or in industry. Consulting and technical advice are resources characteristic of most industry-university research centers and would be expected to be frequently used and highly valued by member firms of centers in both Programs. Non-core research, however, is required of S/IUCRCs, whereas its (assumed) counterpart, sponsored research, is not required of I/UCRCs. It might be expected, then, that member participation in non-core research in S/IUCRCs will occur relatively more often than participation in sponsored research in I/UCRCs, *all else being equal*.

Two formal requirements of the S/IUCRC Program not shared by the I/UCRC program are state financial support and the inclusion of technology transfer activities as part of the core program of research. Both of these requirements reflect the S/IUCRC Program's goal of state economic development, and predict that, relative to I/UCRC member firms, S/IUCRC member firms might be more likely to be located in the same state as the center with which they are involved (as a consequence of the center's recruiting strategies and explicit attention to technology transfer). The proportion of small firms choosing to become members of S/IUCRCs would also be expected to be greater than in the case of I/UCRCs, since other research has suggested that large firms are more likely to join university-based groups of firms than are small firms, for reasons related to the kinds of benefits firms more frequently experience from such involvement (longer term, less tangible benefits such as access to students, ideas, expertise, and know-how rather than shorter term problem solving and new technology).³⁰ In particular, the S/IUCRC Program's differential emphasis on technology transfer and on the involvement of small and medium-sized firms would produce this result. Despite these differences, however, both Programs share the common core of fundamental research, so it would be surprising if the profile of results obtained by member firms of these two types of centers differed markedly from the profile of results recorded in studies of other industry-university cooperative research activities: the most frequently experienced results have longer term and relatively intangible benefits for the involved firms; students are highly valued; specific, tangible results such as new products and processes, licensed technology or software, and patentable technology are relatively infrequent outcomes (but highly valued when they do occur).

Differences in Program goals, guidelines, and practices are also likely to affect participation rates in different center activities as well as selected outcomes and impacts. Many of these differences reinforce the expectations just described. For example, the S/IUCRC Program's goal of advancing state economic development should influence these centers' member recruitment and student/graduate placement strategies, favoring in-state firms. Similarly, this Program's explicit mandate to include small and medium-sized businesses at part

³⁰ David Roessner and H. Roberts Coward, *An Analytical Synthesis of Empirical Research on U.S. University-Industry and Federal Laboratory-Industry Research Cooperation*, Arlington, VA: SRI International, January 2000. Final report to the Research on Science and Technology Program, National Science Foundation.

of the technology transfer requirement should increase the proportion of small and medium-sized firms relative to the membership profile of I/UCRCs. Finally, the different ways in which the two types of centers treat intellectual property should affect member firm participation in different center activities as well as the results obtained from participation (and, possibly, the value associated with those results). The S/IUCRC Program, like the I/UCRC Program, provides for non-exclusive, royalty-free licenses or center patents to member companies. But unlike the I/UCRC Program, it permits exclusive licenses for non-core, sponsored projects. This difference should provide incentives for S/IUCRC member firms to participate in the (mandated) program of non-core research, and should lead to a higher frequency of results for member firms that involve intellectual property: e.g., new product or process development, licensing technology of software from the center, or generating a patent or copyright within the firm attributable to knowledge or technology resulting from involvement with a center.

B. Descriptive Data On Member Firms And Representatives

The previous chapter described the proximity of member firms to their centers for each Program in terms of their in-state or out-of-state location. For the S/IUCRC Program, slightly over half the members were in-state (IS), while less than a third—30 per cent—of the I/UCRC members were IS. Geographic location turned out to be a significant factor in accounting for patterns of member firm participation in center activities and of beneficial outcomes from participation.

One of the S/IUCRC Program's objectives, not shared by the I/UCRC Program, is to involve small and medium-sized firms in center activities. For the S/IUCRC Program, the mean percentage of small firms across all nine centers SRI studied is 41.2 (N=72).³¹ A slightly larger proportion of in-state firms is small: 44.9 per cent vs. 35.7 per cent out-of-state. For the I/UCRC Program, the mean percentage of small firms across the 17 centers included in the study is 11.0 (N=158). As with the S/IUCRC Program, a somewhat larger proportion of in-state firms is small: 14.1 per cent vs. 9.6 per cent of out-of-state firms. The S/IUCRCs clearly have attracted a much higher proportion of small firms, suggesting that this important Program objective (not shared with the I/UCRC Program) has been achieved—at least relative to the comparison Program.

To some degree the number of center members is a measure of a center's viability, or at least its attractiveness to firms in industries related to the center's research foci that are willing to provide membership fees. Thus there may be a relationship between the average number of firms in the center to which a firm belongs and that firm representative's reporting of outcomes and benefits from participation. However, such relationships are complicated by the fact that, in both Programs, membership fees vary across centers and by firm size. This of course affects the number and types of firms that become involved in centers.

³¹ Only six of the 72 firms (8 per cent) were medium-sized, and four of these 6 were members of the S/IUCRC at North Carolina State University. Given the small number of medium-sized firms among S/IUCRCs studied, the skewed distribution among centers, and the lack of data on the number of medium-sized firms that are members of I/UCRCs, the analyses of firm size that follow focus on small firms only.

According to information supplied by directors of the nine S/IUCRCs included in the study, the mean number of firms per center was 14.8 and the range was 2 to 31 (N=133 firms, 9 centers); however, among the 72 firms whose representatives responded to the SRI survey, the mean number of firms per center was 18.2 and the range was 1 to 15 (N=72 firms, 9 centers). According to information SRI obtained from the NSF I/UCRC data base, the mean number of firms among the 17 I/UCRCs chosen for this study was 15.1 and the range was 7 to 23 (N=227 firms, 17 centers); the mean number of firms per center among the 156 firms whose representatives responded was 11.6 and the range was 5 to 25 (N=156, 17 centers).

Although the I/UCRC Program has existed considerably longer than the S/IUCRC Program, the length of time that the member firms included in this study have participated in centers is similar for both Programs, according to the firms' representatives. This result is in part due to SRI's selection of I/UCRCs for inclusion in the study, which ensured that these centers had existed at least as long as the nine S/IUCRCs in the study. For both types of centers, about a third of the firms have been members for more than six years, and between 40 and 44 per cent have been members for three years or less. S/IUCRC member firms exhibit a slightly "older" profile of membership than do I/UCRC members, but the differences are not statistically significant (Table V-1).

Table V-1
Number of Years Firms have Been Center Members by Type of Center

Years	S/IUCRC		I/UCRC	
	N	%	N	%
1	7	10	20	13.0
2	10	14.3	30	19.5
3	11	15.7	18	11.7
4	8	11.4	15	9.7
5	9	12.9	14	9.1
6	1	1.4	5	3.2
More than 6	24	34.3	52	33.8
No response	2	-	4	-
Total	70	100.0	154	100.0

As Table V-2 shows, S/IUCRC member representatives to their respective centers have been serving in this capacity longer than have their counterparts in I/UCRC member firms, although again the differences are not large. Fifty-seven per cent of the representatives to S/IUCRCs have served for three years or more, in contrast to the 43.2 per cent of I/UCRC representatives that have served this long.

Table V-2
Number of Years as Member Firm Representative to Center by Type of Center

Years	S/IUCRC		I/UCRC	
	N	%	N	%
1	15	21.4	41	26.5
2	15	21.4	48	31.0
3	15	21.4	20	12.9
4	7	10.0	16	10.3
5	6	8.6	8	5.2
6	0	0	2	1.3
More than 6	12	17.1	20	12.9
No response	2	-	3	-
Total	70	99.9	155	100.0

VI. EXPLAINING OUTCOMES AND IMPACTS

This chapter pulls together data and analyses from previous chapters and seeks to explain, in light of the factors discussed in Chapter V, first the patterns of outcomes observed in the two programs; second, the patterns of impacts; and finally, what accounts for the different experiences center member firms have had as indicated by their representatives' assessments of whether, overall, the benefits of membership were greater than, less than, or about the same as the costs.

A. Member Firm Participation In Center Activities

The results and analyses presented in Chapter III showed that nearly all members of the S/IUCRCs and IUCRCs included in this study participated in core/fundamental research—an obvious result of the nature of the pooled resource basis of the generic/fundamental research elements of both Programs. Two-fifths of the members of the S/IUCRCs and three-fifths of the members of the IUCRCs participated in non-core/sponsored research; three fifths of S/IUCRC members and two-fifths of IUCRC members used center facilities; just over 60 per cent obtained technical advice, and about a quarter obtained training. Compared with the expectations outlined in the previous chapter, most of these results are unsurprising; they can be explained by both Programs' requirements and the fact that, aside from the different features associated with non-core research in the S/IUCRC Program vs. sponsored research in the IUCRC Program, the other activities are characteristic of many university-industry cooperative research centers. However, the expected higher rate of member participation in non-core research in the S/IUCRC Program relative to the IUCRC Program did not occur; it is substantially lower. This calls for a more detailed look at the data.

Recall that just over half the member firms in the S/IUCRCs studied and 30 per cent of the IUCRC members are in-state. Analyses presented earlier in the report showed that a considerably greater proportion of in-state members of S/IUCRCs participate in non-core research and obtain technical advice, relative to out-of-state members. Also, non-core research is more likely to yield beneficial results for in-state members than for out-of-state members. In addition, since a greater proportion of members of IUCRCs, most of which are out-of-state, participate in sponsored research, that program's counterpart of non-core research, it seems clear that geographic proximity is a major factor in S/IUCRC member firms' choosing to participate in non-core research. Indeed, the opportunity to participate in non-core research may have been a major factor in local firms' decision to become members of the center. But it is still unclear why a lower proportion of S/IUCRC members participates in non-core research than IUCRC members do in sponsored research.

Small businesses comprise a considerably greater proportion of the membership in the S/IUCRCs than in IUCRCs: the mean proportion of small businesses in the former program is 41 per cent, while in the latter it is 11 per cent (among the centers studied by SRI). In both types of centers, small firms have slightly greater representation among in-state members than out-of-

state, but the differences are not great (45 per cent vs. 36 per cent in the S/IUCRC Program; 14 per cent vs. 10 per cent in the I/UCRC Program). Analysis of firm size by participation in center activities shows that, for both types of centers, there was no significant relationship between the size of firms and the types of activities in which they participated. In general, small firms participate in center activities with the same frequency as do larger firms (Table VI-1). In the I/UCRC Program, slightly fewer small firms obtain training from centers than do larger firms, and slightly more participate in sponsored research than do larger firms. So firm size does not account for the differential participation rates in non-core and sponsored research between the two Programs.

Table VI-1
Member Firm Participation in Center Activity by Type of Center and Firm Size

Type of Center	Per cent participating											
	Total		Core/Fundamental Research		Non-core/Sponsored Research		Use of Facilities		Technical Advice		Training	
	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small
S/IUCRC	72	41.2	65	38.9	31	42.9	37	36.3	43	47.1	22	40.8
I/UCRC	158	11.0	148	10.9	96	12.5	62	12.1	98	11.4	38	8.5

Considering next the effect of length of center membership, there are some indications that, at least for some activities, the longer a firm has been a member of a center, the more likely it is to participate in the full range of activities available (Table VI-2). However, the differences both within and across Programs are not statistically significant. A similar analysis (Table VI-3) of the length of time a member representative has served shows that there are some significant relationships. Within the I/UCRC Program, there is a significant positive relationship between member firms' receipt of technical advice or consulting and the length of time the representative to the center has served in that capacity. Comparing the two Programs, representatives of S/IUCRCs who have served for just one year report that their firms are more likely to use center facilities than are their counterparts of I/UCRCs. Representatives who have served two years as representatives to I/UCRCs, on the other hand, are more likely to report that their firms participate in sponsored research than second-year representatives to S/IUCRCs are to report participation in non-core research. Finally, representatives to I/UCRCs who have served for three or more years are more likely to report that their firms receive technical advice than are similarly-tenured representatives to S/IUCRCs.

**Table VI-2
Member Firm Participation in Center Activities by Type of Center and Length of Center Membership**

S/IUCRC					
Per cent participating					
Years	Core Research	Non-core Research	Use of Facilities	Technical Advice	Training
1 (N=7)	85.7	28.6	60.0	71.4	16.7
2 (N=10)	100.0	20.0	50.0	50.0	20.0
3 (N=11)	100.0	54.5	40.0	45.5	20.0
4 or more (N=42)	90.5	50.0	64.1	68.3	41.5
Total (N=70)	92.9	44.3	57.8	62.3	32.8

I/UCRC					
Per cent participating					
Years	Fundamental Research	Sponsored Research	Use of Facilities	Technical Advice	Training
1 (N=20)	80.0	40.0	26.3	55.0	15.0
2 (N=30)	96.7	56.7	43.3	69.0	13.3
3 (N=18)	94.4	72.2	58.8	88.9	22.2
4 or more (N=86)	97.7	66.3	40.7	62.5	32.5
Total (N=99)	94.8	61.7	41.5	66.0	25.0

**Table VI-3
Member Firm Participation in Center Activities by Length of Time as Center Representative, S/IUCRC and I/UCRC**

S/IUCRC					
Per cent participating					
Years	Core Research	Non-core Research	Use of Facilities	Technical Advice	Training
1 (N=15)	86.7	40.0	66.7*	64.3	23.1
2 (N=15)	100.0	26.7*	53.3	60.0	20.0
3 or more (N=40)	92.5	52.5	56.8	62.5*	41.0
Total (N=70)	92.9	44.3	57.8	62.3	32.8

I/UCRC					
Per cent participating					
Years	Fundamental Research	Sponsored Research	Use of Facilities	Technical Advice**	Training
1 (N=41)	87.8	56.1	33.3*	52.6	23.7
2 (N=48)	97.9	58.3*	41.3	56.5	17.0
3 or more (N=66)	97.0	66.7	46.0	79.7*	32.8
Total (N=155)	94.8	61.3	41.2	65.5	25.5

NOTE: A single asterisk (*) indicates a statistically significant difference at the .05 level. A double asterisk (**) indicates a statistically significant difference at the .01 level. Asterisks associated with individual cell-entries show significant differences between Programs; the asterisk associated with Technical Advice indicates significant differences within the Program.

For I/UCRCs, the mean annual expenditures of member firms in support of their centers are similar across the five categories of program activity SRI asked about (Table VI-4). There were eight S/IUCRC firms who received training from their centers and who provided estimates of their total expenditures, and the mean value of those estimates is substantially higher than the

mean value of estimated costs per year of those who participated in other S/IUCRC center activities. Overall, however, none of these differences is statistically significant, so expenditures of member firms per year has no bearing on their participation in different center activities.

None of these possible explanations accounts for the low rate of participation in non-core research by members of S/IUCRCs, relative to the participation rates of IUCRC members in sponsored research. It may be that this difference is due to the differing character of the research conducted under these two labels in the two Programs, a possibility that cannot be explored further given the data available in this study.

**Table VI-4
Member Firm Participation in Center Activities by Mean Annual Expenditures for Support and Type of Center**

Type of Center	Mean annual expenditures for support (\$000) for participating firms				
	Core/Fundamental Research	Non-core/Sponsored Research	Use of Facilities	Technical Advice	Training
S/IUCRC	67.2	104.0	76.5	68.7	103.6
IUCRC	76.1	99.8	45.2	87.1	57.9

B. Outcomes From Member Firm Participation In Center Activities

Chapter III presented data on the results that member firms obtain from participating in centers. For convenience, the summary outcome patterns are repeated in Table VI-5 below. Aside from the significant differences in results related to intellectual property, the distribution of results by type of center activity (Tables III-1 and III-2) did not reveal any patterns that would easily explain the higher rates of favorable results reported by representatives to S/IUCRCs. The significant differences in reported results between the two Programs appear to be related to “tangible” outcomes associated with intellectual property: new product or process development or improvement and technology or software licensing as a result of involvement with the center. One possible explanation for this was noted earlier in the report in several places: differences in the guidelines for intellectual property protection provided by each type of center to its member firms. However, the higher frequency of results related to intellectual property outcomes was not confined to member firm participation in non-core vs. sponsored research, where the formal requirements of the two Programs differ. Other explanations need to be considered.

Table VI-5
Results Obtained from Member Participation in Any Center Activity by Outcome Category and Type of Center

Result received by firm	Per cent of firms	
	S/IUCRC N=69	I/UCRC N=152
We obtained access to new ideas or know-how	95.7	97.4
We had more interaction than in the past with other Center firms	62.3	56.6
We improved a product(s) or process(es)	71	60.5
We were able to provide our customers/suppliers with improved technical information	60.9	65.8
Our R&D agenda was influenced	62.3	71.1
We developed a new product or process	53.6*	38.8*
We licensed technology or software developed by the Center	20.3**	6.6**
We patented/copyrighted technology/software we developed as a result of interacting with the Center	14.5	8.6
We made unexpected operational changes	20.3	18.4
Other direct results	13	11.8

NOTE: A double asterisk (**) indicates a difference in the frequency of participation in center activities between the two types of centers that is significantly different from the expected value at the .01 level; a single asterisk (*) indicates a difference that is significant at the .05 level.

In-state location probably facilitates the interaction necessary for new product or process development, and in-state location was found to be statistically related to S/IUCRC member representatives reporting new product or process development from core research and receiving technical advice; there were no significant relationships between location and new product or process developments for I/UCRCs (refer to Tables IV-9 and IV-10).

Considering the effect of length of center membership, there are no consistent patterns relating this factor to participation in center activities, since none of the relationships shown in Table VI-6 is statistically significant. So, none of the data or analyses available in this study provides a clear explanation for the profile of results observed among member firms of the two Programs. It is certainly possible that, contrary to the initial assumption of this study, there are substantial differences between the non-core research undertaken in S/IUCRCs and the sponsored research undertaken in I/UCRCs. It may also be the case that formal Program requirements and guidelines are not followed consistently among centers.

Table VI-6
Member Firm Participation in Center Activities by Type of Center and Length of Center Membership

Years	S/IUCRC				
	Per cent participating				
	Core Research	Non-core Research	Use of Facilities	Technical Advice	Training
1 (N=7)	85.7	28.6	60.0	71.4	16.7
2 (N=10)	100.0	20.0	50.0	50.0	20.0
3 (N=11)	100.0	54.5	40.0	45.5	20.0
4 or more (N=42)	90.5	50.0	64.1	68.3	41.5
Total (N=70)	92.9	44.3	57.8	62.3	32.8

IUCRC					
Years	Per cent participating				
	Fundamental Research	Sponsored Research	Use of Facilities	Technical Advice	Training
1 (N=20)	80.0	40.0	26.3	55.0	15.0
2 (N=30)	96.7	56.7	43.3	69.0	13.3
3 (N=18)	94.4	72.2	58.8	88.9	22.2
4 or more (N=86)	97.7	66.3	40.7	62.5	32.5
Total (N=99)	94.8	61.7	41.5	66.0	25.0

C. Member Firm Representatives' Valuation Of Outcomes

The analyses presented in Chapter IV showed that there were no statistically significant variations in the value that representatives of member firms associated with participation in different center activities, or in the value they assigned to specific results they derived from participating. This was the case within and across both the S/IUCRC and I/UCRC Programs.

D. Member Firm Assessments Of Benefits And Costs

As noted in previous chapters of this report, SRI sought in a variety of ways to obtain estimates of the benefits center members experienced from their memberships and the costs they incurred. SRI also asked member firm representatives for an overall assessment, in qualitative terms, of the extent to which benefits exceeded costs, or the reverse. Because such a small number of representatives were willing or able to provide dollar estimates of both benefits and costs, it was not meaningful to compare benefits and costs quantitatively for either Program. However, 63 S/IUCRC member representatives (87.5% of those responding) and 141 I/UCRC member representatives (90% of those responding) did provide qualitative assessments of the benefits of membership compared with the costs. Recall that in the case of both Programs, more than half the representatives of member firms thought the benefits exceeded costs, and about three-fourths thought that they had at least broken even. Beyond this generally favorable assessment of membership shared by both Programs, a slightly greater proportion of S/IUCRC member representatives relative to I/UCRC member representatives reported that the benefits their firms obtained exceeded the costs (62 per cent vs. 51 per cent), but this difference is not statistically significant.

The member firm's geographic location does appear to make a difference, at least in the case of the S/IUCRC Program (refer to Figure IV-2). A significantly larger proportion of representatives of member firms from within the state had very favorable assessments of the benefit/cost ratio associated with membership, and a relatively tiny fraction (6 per cent) had the opposite experience. This result is the more striking because it contrasts with the I/UCRC member representatives' experiences, in which representatives of out-of-state members reported slightly more favorable (but not statistically significant) benefit/cost assessment than did representatives of in-state members. One reason for this may be that, relative to I/UCRC member firms, in-state S/IUCRC member firms participate somewhat more frequently in the full range of center activities, particularly in non-core research and technical advice. Relatedly,

representatives of in-state members of S/IUCRCs reported a wider range of favorable results from their firm’s participation than was the case with representatives of I/UCRC member firms, where representatives of out-of-state members reported a wider range of favorable results (refer to Tables IV-6 and IV-7). Finally, representatives of those firms that contribute annually more to their centers tend to report higher benefit/cost ratios, and this tendency probably also helps explain the differences between center members with differing assessments—in benefit/cost terms—of their membership experience.

There are no significant relationships between the mean proportion of small firms and member representatives’ comparisons of the benefits and costs of center membership in the case of the S/IUCRC Program (Table VI-7). Among the eight firms that were members of S/IUCRCs and that rated their costs to be much greater than the benefits they received, a relatively large proportion were small firms, but the number of firms is so small that this could easily have occurred by chance.

**Table VI-7
Member Firm Assessment of Benefit/cost Ratio by Type of Center and Firm Size**

Type of Center	Per cent responding											
	Total		Ratio of benefits to costs									
	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small
S/IUCRC	63	41.1	8	43.3	7	37.7	9	39.3	21	32.2	18	53.2
I/UCRC	143	11.0	20	9.7	20	10.7	31	10.5	40	12.1	32	12.0

One objective of the S/IUCRC Program was to involve small and medium sized firms as members and, presumably, to provide them with significant benefits as a result of their participation in center activities. Although the benefit to cost ratio data presented above do not show a strong relationship between firm size and assessed benefits versus costs, another measure of benefits is each firm representative’s estimate of the total dollar benefits derived from membership. Although the proportion of member representatives willing and able to provide such estimates is small (only 32 of 72 in the case of the S/IUCRC Program), it is worth presenting these estimates by firm size for both Programs. The results are displayed in Table VI-8. Here, there is no statistically significant relationship between firm size and estimated savings from membership in a center; however, only about half the representatives answered this question.

There was no statistically significant relationship between member representatives’ assessments of membership benefits to costs and the length of time that member firms had been members of centers, or the length of time that representatives had served in that capacity (analyses not shown).

**Table VI-8
Member Firm Estimates of Total Dollar Savings by Type of Center and Firm Size**

Type of Center	Per cent responding									
	Total dollar savings by quantile									
	Total		0		>0 to <100K		≥100K to <360K		≥360K	
N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	N	Mean % small	
S/IUCRC	32	45.2	9	41.9	6	48.9	9	48.9	8	41.1
I/UCRC	65	12.5	26	13.2	14	17.1	10	9.9	15	9.8

E. Regional Economic Impact Of Centers

The economic impact of the S/IUCRC Program was measured in this study in two ways: the results that accrued to in-state vs. out-of-state center members from their participation in center activities, and the hiring of center students and graduates by in-state vs. out-of-state member firms. Because no consistent, reliable data on the dollar value of these impacts could be obtained from S/IUCRC member firms, center annual reports, or S/IUCRC State Representatives, the most meaningful assessment of the economic impact of the Program consists of comparisons of center impact measures with equivalent measures of the impacts of I/UCRCs. The data for these comparisons were presented in Chapter IV, and the results of the analysis will be summarized here.

Recall that, for the S/IUCRC Program, slightly over half the member firms were located in-state, while less than a third (30 per cent) of I/UCRC member firms were in-state. This result alone indicates that features unique to the S/IUCRC Program differentially attract and retain in-state firms as center members. If the economic impact of a center is measured by the results of center involvement that accrue to member firms, then a state hosting an S/IUCRC enjoys greater economic benefits than a state hosting an I/UCRC, *all else being equal* (such as the number, size and growth rate of member firms).

Other results support this conclusion and help explain the greater in-state economic impact of S/IUCRCs. First, representatives of in-state members of S/IUCRCs consider the benefits of membership to be much greater than do representatives of out-of-state members, whereas the opposite is true for I/UCRCs, although the difference is not statistically significant. Second, relative to out-of-state members, a significantly greater proportion of in-state S/IUCRC member firms participates in non-core research, suggesting that this center activity, especially, pays off for in-state members. Geographic proximity likely facilitates the interaction that leads to valued benefits, especially those related to new products and processes and licensed technology.

Third, representatives of in-state members of S/IUCRCs report a wider range of beneficial outcomes from their firms' participation in center activities than do representatives of out-of-state members, while the opposite is the case for I/UCRCs (refer to Tables IV-6 and IV-7). Participation in non-core research provided these in-state member firms with the widest range of beneficial results, relative to out-of-state firms: obtaining access to ideas or know-how,

product or process improvement, increased technical information for suppliers/customers, and influence on the firm's R&D agenda. New product development was also a more frequent outcome for in-state S/IUCRC members; this resulted from participation in core research and obtaining technical advice, not non-core research, so the intellectual property provisions of S/IUCRCs cannot explain this particular pattern of impact. In contrast, no single activity stood out as the path to a similarly wide range of beneficial results for either in-state or out-of-state members of IUCRCs.

Finally, S/IUCRC member firms were less likely to hire center students or graduates than were IUCRC members (17 per cent vs. 33 per cent), but among those firms that did hire them, a greater proportion of S/IUCRC members relative to IUCRC members were located in the same state as the center (50 vs. 41 per cent). The most likely explanation for the first of these results is that a far greater proportion of S/IUCRC members are small firms than is the case for IUCRCs, and these smaller firms may be in a less favorable position to hire new employees. A logical explanation for the second result is that proximity of firms to the center matters for ease of hiring, probably from both the student/graduate's point of view as well as the member firm's.

F. Multivariate Analysis

Ideally it would be desirable to conduct multivariate analyses in an effort to identify those factors that contribute most significantly and independently to variations in the level of benefits and benefit/cost ratios that representatives of center members report. However, limitations in the data, largely the result of low response rates to certain survey questions and the very large number of potentially influential variables, greatly reduced the types of analyses that could be meaningfully interpreted. SRI regressed each of the quantified "impact" variables against the full range of data available describing potential influences on center member experience: in particular, the following impact measures were considered:

- Survey question 13, the ordinal estimate of benefit/cost ratio
- Survey question 14a, estimates of savings resulting from reduced training costs
- Survey question 14b, estimates of cost savings other than from reduced training costs
- Survey question 15, the dollar value of financial benefits beyond cost savings
- Total dollar benefits (the sum of responses to questions 14a, 14b, and 15)
- Calculated benefit/cost ratio, the ratio of total dollar benefits to total costs (survey question 12).

The total number of responses to each of the relevant survey questions and the response rate based on the total sample for each Program are listed in Table VI-1.

Table VI-9
Response Rates to Survey Items Seeking Quantitative Benefit Estimates by Type of Center

Data source	S/IUCRC		I/UCRC	
	N	Response rate (%)	N	Response rate (%)
Question 13	63	48.5	143	59.8
Question 14a	16	12.3	54	22.6
Question 14b	25	19.2	54	22.6
Question 15	24	18.5	44	18.4
Total dollar benefits	32	24.6	65	27.2
Calculated benefit/cost ratio	30	23.1	64	26.8

Clearly the response rates to all but question 13 are sufficiently low to raise serious doubts about the representativeness of the estimates. Nonetheless, when these variables were regressed against the full range of independent variables,³² in nearly every case the models with the best “fit” to the data (explained the largest amounts of variation in the dependent variable) included only questions to which a handful of representatives of member firms had replied (e.g., we licensed technology or software developed by the center), so that the number of cases in the regression typically was five or six, so that no meaningful interpretation could be obtained. For example, using S/IUCRC data, a model with 17 cases explained 99 per cent of the variation in the calculated benefit/cost ratio, but with only one independent variable in the model. The equivalent regression using I/UCRC data included 31 cases, accounted for 35 per cent of the variance in the calculated benefit/cost ratio, yet included only one independent variable in the model. If the requirement of goodness-of-fit is relaxed, the number of cases included increased, but of course the amount of variance accounted for dropped considerably. Any advantages gained in the number of cases by using question 13 as the dependent variable were offset by the questionable interpretation of regression results using an ordinal rather than interval variable as the dependent variable. As a consequence of this situation, the conclusions and interpretations reported in the next chapter rely exclusively on descriptive statistics and crosstabulations of the survey data.

³² In each regression a correlation matrix was first generated and the large number of intercorrelated variables identified. Among the highly intercorrelated groups of variables, the one that had the largest correlation with the dependent variable was entered into the regression.

VII. CONCLUSIONS AND OBSERVATIONS

A. Objectives And Design Of The Evaluation

The NSF State/Industry University Cooperative Research Centers Program, initiated with six centers in 1991 and four more in 1992, drew upon the Foundation's favorable experience with other programs intended to promote industry-university cooperation in research to design a related program that would incorporate the interests of state governments. In particular, the S/IUCRC Program called for a "new partnership" between the federal government and the states to promote industry-university cooperation, but in a way that would bring explicit benefits to states as well as the nation. In addition to promoting university-based, industrially-relevant research, both fundamental and proprietary (a goal common to other NSF centers programs), the S/IUCRC Program was to "facilitate diffusion of center research results and technology innovation with a view to impacting economic development. Technology transfer is considered part of the core program."³³ Thus economic development that can be attributed to an S/IUCRC and is confined to the state hosting the center is clearly one desirable, expected impact of the Program. According to the original NSF Program Announcement (NSF 90-87), the S/IUCRCs were to achieve their objectives through programs of fundamental "core" research, industry-sponsored "non-core" projects that could be proprietary, specific technology transfer efforts involving both types of research, and the explicit involvement of small and medium-sized firms.

NSF supported the present study first to answer the kinds of questions posed by most program evaluations: to what extent has the Program accomplished its goals? What lessons can be learned that might be used to improve the Program's performance? But in addition, NSF wished to identify lessons that could inform the agency's planning for future NSF-state partnerships. The fact that the S/IUCRC Program will not support any additional centers means that this study's emphasis is less on measures of the "cost-effectiveness" of the overall Program (typical of a summative evaluation), and more on how existing and future programs of this type—especially those involving partnerships with states—might be improved in their design and their implementation. Both the design of this study and the kinds of analyses conducted sought to address these questions.

The existence of the NSF Industry/University Cooperative Research Program since the late 1970s and its rich set of existing center-level data offered an unusual opportunity to employ comparative analysis in the present evaluation, and full advantage of this opportunity was taken. Thus, in addition to outcome and impact data collected about the S/IUCRC Program itself, equivalent data were collected about the I/UCRC Program and used for comparative purposes. The two Programs share important similarities in structure and programmatic activities that make comparative analysis feasible: both types of centers consist of groups of university-based industrial firms and other organizations that provide membership fees; and both engage in fundamental research supported by pooled membership fees, project research often funded by a single member, research facilities that could be accessed by members, technical advice and consulting with center researchers available to members, and training for member organizations' personnel. Equally important, the two Programs differ in ways that highlight the distinctive

³³ <http://www.eng.nsf.gov/eec/0-intro.htm>

goals, objectives, and requirements of the S/IUCRC Program. Thus a comparative analysis of the two Programs enables conclusions to be drawn about the independent effects—the “value added”—of the unique features of the S/IUCRC Program – the technology transfer activities, inclusion of small and medium-sized firms, and the local economic impact expectation. As a consequence, SRI’s evaluation of the S/IUCRC Program has two elements: a description and analysis of the outcomes and impacts of the Program itself (which can be compared with the Program’s objectives), and a description and analysis of the Program’s outcomes and impacts relative to those of the I/UCRC Program. These two primary elements of the evaluation were supplemented by impact data obtained from annual reports of the nine S/IUCRCs studied, and by interviews with the State Representatives to seven of these centers. The results of the latter interviews, combined with the historical and political analyses presented in Chapter II, provided the primary basis for recommendations to NSF about future programs of partnerships with the states.

B. Expectations, Results, And Explanations

The S/IUCRC and I/UCRC Programs are structurally similar programs that encourage university-industry cooperation through the formation of university-based groups of firms pooling some of their resources to support fundamental research. Thus, some of the patterns of involvement in centers by member firms and the results experienced by them should be similar. Differences in these patterns will be due primarily to:

- Unique features of the S/IUCRC Program, as described in Chapter I;
- Features of individual centers such as leadership, organization setting, level of financial and other support, staffing, etc.; and
- Characteristics of center member firms and their representatives.

Only the first and third of these types of factors were considered in this evaluation.

Activities. As a requirement of membership in either type of center, member firms provide fees that are pooled to support a program of fundamental, generic research. Virtually by definition, most member firms would be expected to participate at some minimal level in core research (S/IUCRCs) and fundamental research (I/UCRCs). Participation in all other center activities is discretionary, although the program of non-core research is required of S/IUCRCs, whereas its assumed counterpart, sponsored research, is not required of I/UCRCs. If these two activities are, in fact, reasonably similar, then it might be expected that member participation in non-core research in S/IUCRCs will occur relatively more frequently than participation in sponsored research in I/UCRCs. But in at least one obvious respect, stemming from the unique intellectual property provisions of the S/IUCRC non-core program, the two activities are not comparable. Specifically, while I/UCRCs are not encouraged to develop intellectual property protection for products of their research, the opportunity to grant exclusive licenses for the products of non-core research was expected to provide an incentive for S/IUCRC member firms that does not exist for members of I/UCRCs.

Nearly all members of the nine S/IUCRCs studied participate in core research—at minimum they pay their dues, participate in research project selection, and are sent information about research results. Forty-three per cent of the members participate in non-core research, about 60 per cent use center facilities and receive technical advice or consulting from center personnel, and just under a third received training from their center. In the case of the I/UCRC Program, essentially all members of the I/UCRCs studied participate in fundamental research as a consequence of their membership fees. Sixty per cent support sponsored research; 42 per cent use center facilities; 66 per cent receive technical advice or consulting; and about a quarter receive training. Although the profile of participation in center activities is roughly similar for both types of centers, one difference that stands out is the significantly larger proportion of I/UCRC member firms that participates in sponsored research (61 per cent) relative to the proportion of S/IUCRC member firms that participates in non-core research (43 per cent). This is particularly surprising given that non-core research was designed to be attractive to member firms as a source of solutions to problems, cost savings, and commercially applicable ideas and technology. None of the other potential explanations (given the data available in this study)—the location of member firms, the size of the firm, the length of the firm’s membership in the center—accounts for this difference. This puzzling result is thus due to a factor not included in the analysis, and may indicate that there are substantial differences between S/IUCRC non-core research and I/UCRC sponsored research, differences that offer greater incentives to I/UCRC member firms.

Outcomes and Impacts. Two formal requirements of the S/IUCRC Program not shared by the I/UCRC Program are state financial support and the inclusion of technology transfer activities as part of the program of research. Both of these requirements reflect the S/IUCRC Program’s goal of state economic development, and predict that, relative to I/UCRC member firms, S/IUCRC member firms might be more likely to be located in the same state as the center with which they are involved (as a consequence of the center’s recruiting strategies and explicit attention to technology transfer). The proportion of small firms choosing to become members of S/IUCRCs would also be expected to be greater than in the case of I/UCRCs, since other research has suggested that large firms are more likely to join university-based groups of firms than are small firms, for reasons related to the kinds of benefits firms more frequently experience from such involvement (longer term, less tangible benefits such as access to students, ideas, expertise, and know-how rather than shorter term problem solving and new technology).³⁴ In particular, the S/IUCRC Program’s differential emphasis on technology transfer and on the involvement of small and medium-sized firms should produce this result. Despite these differences, however, both Programs share the common core of fundamental research, so it would be surprising if the profile of results obtained by member firms of these two types of centers differed widely from the profile of results recorded in studies of other industry-university cooperative research activities: the most frequently experienced results have longer term and relatively intangible benefits for the involved firms; students are highly valued; specific, tangible results such as new products and processes, licensed technology or software, and patentable technology are relatively infrequent outcomes (but highly valued when they do occur).

³⁴ David Roessner and H. Roberts Coward, *An Analytical Synthesis of Empirical Research on U.S. University-Industry and Federal Laboratory-Industry Research Cooperation*, Arlington, VA: SRI International, January 2000. Final report to the Research on Science and Technology Program, National Science Foundation.

The pattern of participation by S/IUCRC member firms yields a wide range of specific results within them. By far the most frequently reported result was “obtained access to new ideas or know-how,” a result deriving primarily from technical advice, core research, and training (between 90 and 95 per cent of those participating in these activities). Following this was product or process improvement, a result reported by between 60 and 70 per cent of the member firms that participated in core research, access to facilities, or receiving technical advice. Only a small proportion—19 per cent or fewer—of representatives of members participating in center activities reported that their firm received the following specific results:

- Licensing technology or software developed by the center;
- Patenting or copyrighting technology and/or software developed as a result of interacting with the center;
- Making unexpected operational changes;
- All other direct results.

In the case of the I/UCRC Program, by far the largest proportion of member representatives (82-95 per cent) reported that, as a result of their firm’s participation in center activities, they obtained access to new ideas or know-how. About 30 per cent of the representatives reported that their firm developed a new product or process, with project research as a the primary route to this result, although other activities except training led to new products or processes at just a slightly lower rate. Less than 9 per cent reported licensing technology or software developed by the center, or patenting or copyrighting technology or software developed as a result of interacting with the center. Between 10 and 20 per cent reported making unexpected operational changes.

There is a significant difference between the two Programs in the extent to which participation in center activities of any kind results in more tangible outcomes related to intellectual property: new product/process development and licensing technology or software developed by the center. For each activity, S/IUCRC member representatives report these relatively tangible results more frequently than do their I/UCRC counterparts. One possible explanation for this is the difference in the guidelines for intellectual property protection provided by each type of center to its member firms.³⁵ However, as noted in the previous chapter, the higher frequency of results related to intellectual property outcomes reported by representatives of S/IUCRC member firms was not confined to non-core and sponsored research activities, where effects of the difference in intellectual property provisions of the two Programs should be most evident. Introduction of other factors such as member firm location, firm size, and length of center membership factors failed to account for the pattern of results observed. Although it seems reasonable to expect that the difference in intellectual property provisions plays a role here, the nature of the research actually undertaken and the actual practices regarding intellectual property protection in each type of center probably better explain this difference in results between the two Programs.

³⁵ Note, however, that between a quarter and a third of the members of both types of centers are not private firms, so explanations associated with the value of new products or processes and, especially, intellectual property may not be relevant.

Representatives of member firms of both types of centers value center activities and the specific results that derive from participating in those activities roughly equivalently. As measured by these representatives' qualitative assessments of the benefits of center membership compared with the costs, a slightly larger proportion of S/IUCRC member representatives estimated that the benefits their firms derive exceeded the costs (62 per cent vs. 50 per cent), but this difference is not statistically significant. A large majority—about three-quarters--of representatives to both types of centers consider the benefits of membership to at least equal the costs.

Geographic proximity is clearly a factor in the levels of member participation in center programs and, consequently, in the benefits derived from participation. When member representative reports of specific results associated with their firms' participation are analyzed by geographic location, it is clear that in-state location is a major influence on the type and number of specific results realized. Regarding member participation in center activities, a significantly larger proportion of in-state members of S/IUCRCs participates in non-core research than out-of-state members (60 per cent vs. 26 per cent), suggesting that S/IUCRCs are more responsive in their research program to in-state members, as the Program's economic development goal anticipates. Representatives of in-state members of S/IUCRCs report a much wider range of beneficial outcomes than do out-of-state representatives. Further, these in-state member firms' participation in non-core research was clearly the activity most likely to yield beneficial results relative to out-of-state members; and their participation in this activity resulted in a higher frequency of reports of access to new ideas, improved products or processes, improved technical information for customers or suppliers, and influence on R&D agendas.

Although regional economic development is not an objective of the I/UCRC Program, SRI analyzed the survey results by I/UCRC member location so that data on the regional impact of the S/IUCRC Program would have a meaningful basis for comparison. Most (71 per cent) of the members of the I/UCRCs included in the study were out-of-state, so unless in-state members enjoy considerably greater benefits than out-of-state members, it is clear that the economic payoffs from member-derived impacts of I/UCRCs are relatively greater for the nation as a whole than the region in which the center is located.³⁶ Both in-state and out-of-state members participate in fundamental and project research at the same high levels (between 87 and 100 per cent). Participation in the other three categories of activity is, as described above, at a lower rate, and in the case of the I/UCRC Program there are no significant differences in participation rates between in-state and out-of-state members. With respect to specific results obtained from participation in center activities, out-of-state members are more likely than in-state members to report a wide range of beneficial results. But no single program activity stands out as the path to a wide range of beneficial results. There was no clear pattern in the rating of the benefits derived that distinguished in-state from out-of-state members.

Although less prominent than regional economic development as a program goal, the S/IUCRC Program encouraged centers to recruit and retain small and medium-sized firms as members. The mean percentage of small firms represented across the nine centers studied was 41.2; looking only at the in-state members, 45 per cent are small businesses. Small firms

³⁶ Member-derived benefits represent only a portion, perhaps even a minor proportion, of the total benefits generated by university-based industrial research consortia and other forms of university-industry interaction.

participate in center activities in about the same proportion as larger firms and, although the differences are not large, non-core research and technical advice are slightly more highly valued than core research and access to facilities by small and medium-sized firms (representatives of only three small firms assigned a value to the training they received, and the mean value was very high). Representatives of small firms assessed their overall ratio of benefits to costs in about the same way that representatives of larger firms did. Eleven per cent of the I/UCRC member firms are small businesses. A somewhat larger proportion of these small firms is in-state than out-of-state: 14 per cent vs. 10 per cent. Across center activities, slightly fewer small firms seek training than do larger firms, and slightly more participate in project research. Representatives of small firms assess the comparative costs and benefits of center membership in the same way that representatives of larger firms do.

Economic Impacts. Despite SRI's efforts to use other measures of regional economic impact, lack of reliable data limited this study to reports of various types of benefits by representatives of member firms, classified by region—whether or not the member firm was in the same state as the center in which it participated. First, with respect to member representatives' qualitative assessments of the benefits and costs they associated with center membership, the differences between the two Programs are striking. In the case of the S/IUCRC Program, representatives of in-state members consider center membership to provide far greater benefits than costs than do representatives of out-of-state members (76 per cent vs. 47 per cent), whereas the reverse is true for I/UCRC member firms, although the difference is not as dramatic (46 per cent vs 52 per cent). If only the extreme categories are considered, differences in impact by region (at least by this measure) are even more pronounced. Nearly 40 per cent of the in-state S/IUCRC member representatives, compared with 17 per cent of the out-of-state member representatives, regard membership benefits to be much greater than the costs, while for the I/UCRC Program, 25 per cent of the out-of-state member representatives vs. 18 per cent of the in-state representatives consider membership benefits to be much greater than costs. Only 6 per cent of the in-state S/IUCRC member representatives regard the benefits to be much less than the costs, while 18 per cent of the in-state I/UCRC representatives consider the benefits to be much less than the costs; 20 per cent of the out-of-state member representatives of S/IUCRCs and 12 per cent of the out-of-state representatives of I/UCRCs had this negative response.

Regarding member firm participation in specific programmatic activities by region, a considerably greater proportion of in-state S/IUCRC members participates in non-core research than out-of-state members (96 vs. 64 per cent), whereas both in-state and out-of-state members of I/UCRCs participate in sponsored research in about the same proportion (87 vs 93 per cent). Geographic proximity matters (positively) to members of S/IUCRC in obtaining technical advice or consulting (71 per cent vs. 53 per cent) but much less so for members of I/UCRCs (71 per cent vs. 64 per cent). This general pattern of more positive results for in-state members of S/IUCRCs is repeated and reinforced at the level of specific types of outcomes. In the case of the S/IUCRC Program, representatives of in-state members report a much wider range of types of beneficial outcomes than do representatives of out-of-state members, but the opposite is largely true for I/UCRCs.

Another measure of the economic impact of centers is the number of center graduates or students hired by member firms, and the geographic pattern of those hires. Neither the S/IUCRC

nor the I/UCRC Program has an explicit educational component, so that the hiring of center students and graduates is not an expected outcome of either Program. However, several studies of the impact on industrial firms of participation in university-industry cooperative research consistently show that companies value human capital—the staff with whom they interact and the students and graduates they hire—more than many other products of university research (e.g., SRI's study of the impact on industry of participation in ERCs). By this measure, the S/IUCRC program does not do as well as does the I/UCRC Program. Proportionately fewer members of S/IUCRCs hire center graduates or students (17 per cent vs. 33 per cent); and in-state members are no more likely than out-of-state members to hire students or graduates (although all members who hired them value them highly). In contrast, 43 per cent of the I/UCRC member firms that hired center students or graduates were in-state, while 28 per cent were out-of-state. This result is not readily explainable but may be a consequence of the higher concentration of small firms—small firms that are not apparently hiring or can attract center graduates—in the S/IUCRC program.

C. The S/IUCRC Program In The State Context

Comprehensive, reliable information is unavailable about recent trends in, and the current political and financial status of, state S&T programs. The most recent data on programs and budgets for state S&T covering all the states are from 1996. Discussions of trends in these programs by different analysts are not entirely consistent. The State Science and Technology Institute's financial data indicate significant funding increases for state programs in the mid-1990s, while other researchers (e.g., Eisinger) show cutbacks in economic development programs and a disenchantment with S&T as a lever for economic development (largely because of the long time frame for payoff). Some trends in state S&T program emphasis have been identified, but their persistence is unclear. First, there appears to be a general lessening of state emphasis on university-industry centers focused on technology development. Second, university-industry centers that have survived state budget cuts are being pressured to do more applied, industrially-relevant research and to emphasize technology transfer. Third, university-industry centers are focusing on problem solving for existing firms rather than encouraging spin-offs. Relatedly, state economic development strategies are focusing more on technical assistance to small manufacturers rather than stimulation of technological innovation. Finally, states are investing more in the fundamental infrastructure of universities, recognizing (perhaps inconsistently, if the other trends are occurring simultaneously) the importance of university research and human capital (graduates) for long-term state development.

SRI's limited review of state S&T and economic development plans and strategies revealed a lack of consistency and integration between the two in many states. In the small number of states in which both kinds of planning occurred formally, often the groups and agencies involved were different, and the resulting plans had different emphases. Typically a structural and political gap exists between state economic and S&T strategies and activities. Only a few states have successfully integrated S&T quickly, smoothly, or permanently into existing agencies responsible for economic development; in other states the loci of political support and stakeholders involved in S&T differ from those involved in economic development.

The nature of payoffs from university-industry collaboration in research mitigates against state financial support. The precompetitive, generic research usually associated with university-industry research centers is “footloose” in that its results are widely available, and any economic impacts are long-term as well as unlikely to be confined to the state hosting the center. Not only are the economic benefits of this fundamental research difficult for individual firms or states to capture, most of the larger, more visible university-industry cooperative research centers such as ERCs and Science and Technology Centers tend to attract large, national firms as members. The benefits that accrue to industrial members of these centers tend to be long-term, intangible, and largely independent of the member firm’s proximity to a center.

This situation provides a rationale for federal incentives for states to invest more in industry-university research collaboration, a nationally-acknowledged means of strengthening industrial competitiveness. To increase the appropriability of the payoffs for states from such collaboration, the federal government can encourage state-based firms to join university-industry research centers, encourage the conduct of shorter-term, industrially-relevant research, facilitate the transfer of results from university research to industry, and encourage intellectual property guidelines that offer incentives for industry to collaborate with university researchers. The S/IUCRC Program was designed to accomplish all of these results. Unique among federally-supported, university-industry collaborative research programs is the S/IUCRC Program’s requirement for state matching of federal (NSF) and industrial funds for centers. This requirement implies a more systematic integration of this Program into state S&T and economic development plans than is the case for other state-supported industry-university cooperative research programs. At least initially, the S/IUCRC Program must compete for state funds with other federal programs that require matching. The formal matching requirement, which calls for new money in state agency budgets rather than a reallocation of university funds or passthroughs, can result in tension between economic development agencies or S&T agencies and state Boards of Regents.

SRI’s interviews with State Representatives to S/IUCRCs provided additional information about the complex setting in which state-supported university-industry collaborative research programs exist. Over the more than seven years that the nine S/IUCRCs that SRI studied have been in existence, State Representatives initially designated to oversee the centers have remained largely stable in both organizational location and identity. About half the Representatives (and thus the oversight activity and initial budget justifications for matching funds) are located in state or nonprofit agencies responsible for economic development, and about half are located in some form of state S&T agency. Representatives report that matching funds typically were approved initially as part of a larger agency budget request to the state legislature (e.g., the Ohio Edison Program, the New York State Centers for Advanced Technology within the NY State Office of Science, Technology and Academic Research). Subsequent budget requests proved somewhat easier to justify, since they often occurred within the request of a larger, more well-established entity. Yet justification for S/IUCRC matching funds was not straightforward, either initially or subsequently.

The difficulties that State Representatives associate with justifying matching funds for S/IUCRCs are revealing. They reflect the tensions discussed briefly above and more fully in Chapter II, and provide suggestions for ways in which future NSF partnerships with states that

involve university-industry collaborative research programs might be designed. First, from the states' perspective, the leverage that the S/IUCRC matching requirement provides is not high relative to other opportunities. It is seen as one-to-one: one state dollar leverages one federal dollar. Second, the typical S/IUCRC budget is not large, about \$1 million. States regard this as too small to generate many jobs or result in significant economic impact relative to other university-industry programs such as ERCs or Science and Technology Centers. Third, small and medium-sized businesses are hard to attract to S/IUCRCs because they are viewed as needing a broad range of support, especially business assistance, which is difficult or impossible to provide within the requirements of the S/IUCRC Program. A state appears to be better able to incorporate an S/IUCRC into its own priorities and agendas if the center can be folded into a broader state program intended to foster university-industry cooperation.

D. Conclusions And Observations

Based on the analyses conducted in this study, the S/IUCRC Program has been a modest success as measured against its goals and objectives and compared with the outcomes and impacts of the I/UCRC Program that served as its model. The S/IUCRC Program attracted considerably more in-state firms than out-of-state firms and a much greater proportion of small firms. Participation rates in center activities were similar for both Programs, but the frequency and range of beneficial results related to more tangible research outcomes were greater for members of S/IUCRCs than members of I/UCRCs. Some of the S/IUCRC Program's outcomes and impacts can be attributed to its unique features, some to the more general nature of university-industry cooperative research activities, and some to the characteristics of center member firms. Others remain unexplained, at least by the data available in this study. For example, the low participation rates of S/IUCRC member firms in non-core research, relative to the participation rates of I/UCRC members in sponsored research, its assumed counterpart, are puzzling and call for further investigation. Outcomes related to intellectual property occurred more frequently for S/IUCRC member firms than for I/UCRC member firms, but could not be clearly identified with the unique intellectual property provisions attached to S/IUCRC non-core research.

What lessons for NSF does this study suggest for future partnerships with the states? NSF's prior experience with formal intergovernmental partnerships is limited primarily to the series of programs initiated by the Intergovernmental Science and Public Technology Program in 1967 and extending until 1982, and the EPSCoR Program, begun in 1978 and continuing today in expanded form. The latter Program's survival can be attributed in large part to its use of the merit review process for proposal review, its focus on research universities as the award recipients, the fact that research is a primary output from the Program's awardees, and its focus on states that have been relatively less successful in attracting NSF research money. All this is consistent with NSF's mission, and it is likely that any future programs involving partnerships with states would have to incorporate these elements.

In future partnerships with states, should NSF, presumably in collaboration with representatives of states, design programs around ends or means? The S/IUCRC Program was designed around means: industry-university research collaboration was the vehicle for

implementing the partnership, and the assumption was that the success of the I/UCRC model made it a suitable guide, with some modification, for a state partnership program. The goal of state economic development came second and seemed entirely appropriate at the time of the NSF/NGA meetings from which the S/IUCRC Program's features emerged. It proved more difficult than expected to modify the I/UCRC model, intended to increase the national competitiveness of industrial firms, in a way that would achieve regional economic development through industry-university cooperative research. The difficulties were of two types. First, the model itself probably was inappropriate for the goal of regional economic development. Second, wide variations across states in the organizational and political relationships between science and technology-related programs and strategies on the one hand, and economic development programs and strategies on the other hand, were incompatible with the inflexible requirement for annual state matching linked to an economic development goal.

Two decades of state experience with using science and technology as a lever for economic development has led to mixed results, widely varying strategies across the states, highly uneven levels of political and financial support over time, and no clear lessons—other than the obvious one that state political timetables and criteria do not mesh well with the timetables for payoffs from university research, or with the intangible forms that those payoffs typically take. If there is any single ingredient that seems necessary, if not sufficient, for a successful state program of S&T-leveraged economic development, it is continuing political commitment from successive administrations. The design of the overall strategy seems less important than the level and stability of commitment. Some states appear to have accepted the theory that investment in S&T infrastructures pays off, thus integrating current economic development theory into concrete state programs intended to promote economic development. In other states, economic development plans and S&T plans remain isolated politically and organizationally, and in still other states there is only limited commitment to S&T. Some states have made university-industry cooperation an integral part of their S&T and/or economic development plans (e.g., New York), while others have not. The S/IUCRCs studied faced quite different environments when it came to justification for matching funds. In some cases the Center Director developed the rationale and made the case before the legislature; in others, the organization charged with providing the matching funds in the state (e.g., the New York State Office of Science, Technology, and Academic Research; the Ohio Department of Development) included the request in a larger budget request, shielding it somewhat from close scrutiny.

States such as Ohio and New York, which have made a considerable and stable commitment to the support of university-based research centers whose goal is state economic development, provided a more hospitable atmosphere for S/IUCRCs. The Edison Centers in Ohio and the Centers for Advanced Technology in New York offered existing homes for the S/IUCRC budget and a relatively well-accepted rationale for state investment in university-industry collaborative research. Beyond this, state-supported programs of university-based centers such as CAT³⁷ can provide the greater flexibility and broader range of program elements that are more consistent with the requirements of regional economic development than were the features of the S/IUCRCs. Despite the Program's relative success in attracting small businesses

³⁷ The CAT Program was established in 1982 by the New York State legislature. There are now 14 CATs being supported; the state's investment in 1997-98 was \$13 million.

and state-based firms as members, it could not, alone, provide the business assistance and spin-off assistance so often needed by firms and entrepreneurs approaching the university for help.

The EPSCoR Program did not face the uncertainties and variable political environment across states that the S/IUCRC Program did. With no explicit connection to state economic development via formal matching requirements, NSF/EPSCoR could work with the state agency in each state most closely associated with supporting research universities. The political and organizational links to economic development either had already been made or were forged as part of larger state plans for developing the state's university-based research capabilities. Although a strong university research system is a means to larger state goals, it has increasingly been accepted by states as virtually an end in itself, requiring little further justification. Thus there is an advantage to partnering with states with programs that either do not prescribe the means, or that emphasize means that have achieved the status of ends.

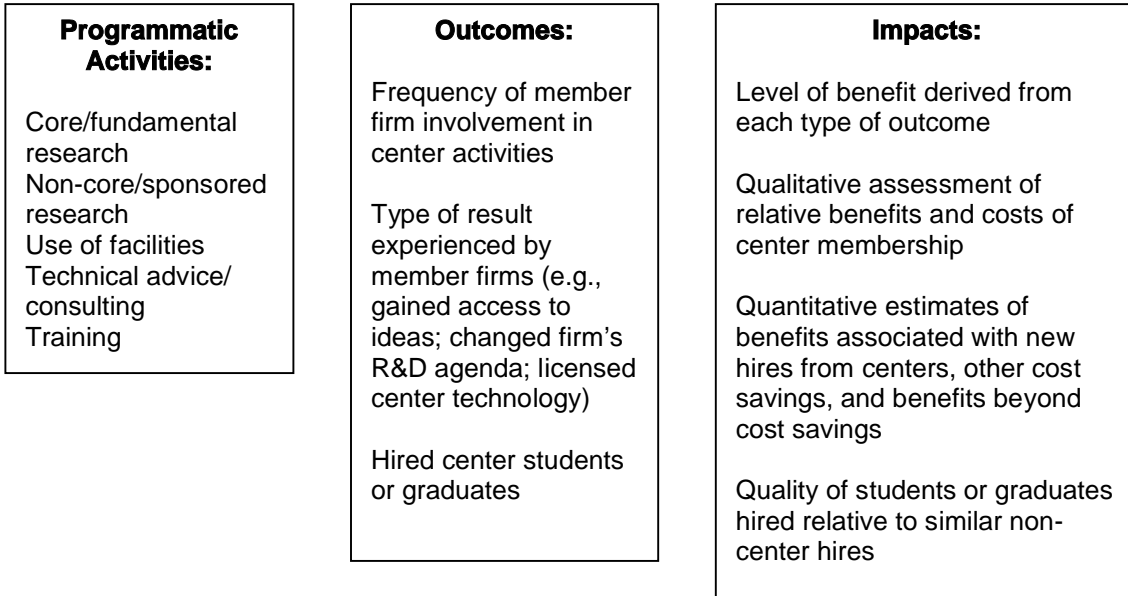
Does an "EPSCoR" for university-industry cooperative research make sense for NSF? There is little doubt that a rationale for federal support of state efforts to create or strengthen university-industry cooperation in research exists, nor is there much doubt that such cooperation pays off both regionally and nationally. The argument for an NSF-state partnership that targets industry-university cooperation is as valid now as it was when the NGA and NSF first discussed such a program. The design of such a future program, however, must account for the lack of integration in many states between economic development plans and programs and S&T plans and programs, and for variations in the nature of state agencies responsible for support of universities. Given the experience of the S/IUCRC Program, it would seem prudent to design such a program as one whose goal is to strengthen state S&T infrastructures rather than promote regional economic development, with university-industry cooperative research as the means. The form that such cooperative research programs might take would vary considerably, depending on state priorities and needs, and on existing state commitments to such cooperative arrangements. A winning proposal to New York or Ohio would look quite different from one from, say, Oklahoma, where universities only recently have been encouraged by the state to engage in cooperative research with industry.

To sum up, the S/IUCRC Program was a valuable experiment in NSF-state partnerships. The Program succeeded in at least two ways. It accomplished, to a modest degree, its goal of promoting state economic development. And it demonstrated that explicit requirements such as state matching, explicit attention to technology transfer, industry-oriented intellectual property provisions, and encouragement of small and medium-sized firms as center members, can contribute to the achievement of this goal, even if applied to a program model that may not have been ideally suited to the context. The findings and conclusions from this study suggest that NSF can continue to develop partnerships with the states that will lead to benefits valued highly by both partners.

APPENDIX A

A conceptual diagram of the analytical framework employed in the study follows:

**Figure A-1
Analytical Framework of the Study**



Copies of the survey instruments appear in Appendices B and C. The survey instruments, which were virtually identical for the two Programs except for the labeling of center activities, were designed to elicit data to address each of these elements of the analysis plan. Table A-1 lists the definitions used in the survey instrument to describe the various activities within each of the two Programs.

**Table A-1
Definitions of Center Activities Used in Member Surveys, S/UCRC and I/UCRC**

S/UCRC	I/UCRC
<i>Core research:</i> generic, fundamental research, relevant to industry needs, funded by member and affiliate dues	<i>Fundamental research:</i> generic, fundamental research relevant to industry needs, funded by member and affiliate dues
<i>Non-core research:</i> research projects sponsored by one or more firms	<i>Sponsored research:</i> research sponsored by one or more firms
<i>Use of facilities:</i> use of center facilities by member firms and affiliates	<i>Use of facilities:</i> use of center facilities by member firms and affiliates
<i>Technical advice or consulting:</i> technical consultation by staff of member firms with center staff in-person, by phone, or other means	<i>Technical advice or consulting:</i> technical consultation by staff of member firms with center staff in-person, by phone, or other means
<i>Training:</i> training services provided by center personnel to member firms, including short courses and one-on-one training from center staff	<i>Training:</i> training services provided by center personnel to member firms, including short courses and one-on-one training from center staff

Respondents to the surveys were identified by each center participating in the study as the member firm's primary representative to the center. These representatives were asked whether or not their firm participated in each of the five activities offered by centers and, if the response was yes, to rate the value to the firm of particular results (outcomes) associated with that participation. The categories of outcomes are listed below in Table A-2; the categories were identical in both surveys. Respondents were asked, for each result their firm experienced, to rate the level of benefit (i.e., impact) that their unit derived on a scale from 1 to 4: little or none, some, moderate amount, a great deal.

Table A-2
List of Direct Results of Member Participation in Center Activities, S/IUCRC and I/UCRC

We obtained access to new ideas or know-how.
Our R&D agenda was influenced
We licensed technology or software developed by the Center.
We patented or copyrighted technology or software we developed as a result of interacting with the
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 Center 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).
Other direct results (please specify)

In addition to the activity-related outcomes, member representatives were asked whether their firm had hired center students or graduates and, if so, how many. They were also asked to rate the quality of center hires relative to similar, non-center hires, for each of the following characteristics:

- depth of technical knowledge;
- breadth of technical knowledge;
- contribution to the firm's technical work;
- firm-funded training required before they became a new contributor to the firm's work;
- ability to apply knowledge from different disciplines and use technologies in an integrated fashion to solve problems;
- ability to solve problems within constraints of time, money, and human resources;
- ability to work in interdisciplinary teams;
- ability to use knowledge to develop technology;
- overall preparedness for working in industry.

Since one objective of the S/IUCRC program is to promote regional economic development, an objective not shared with the I/UCRC program, it was essential to the evaluation to obtain data on the regional impact of both types of centers. SRI addressed this requirement by obtaining the addresses of all center member firms surveyed and coding member firms according to whether they were located in the same state as the center in which they

participated or were located out-of-state. Thus it was possible to compare the various measures of outcomes and impacts both within and between Programs, and to examine patterns of participation in center activities, detailed results of participation, the value assigned to results by member representatives, and hiring of center graduates and students by location of member firms. To the extent that qualitative and quantitative measures of benefits and costs could be obtained, these, too can be analyzed by member firm location within and between Programs. The following paragraphs describe measures of the benefits and costs of center membership that SRI obtained during the study.

Several kinds of data on the benefits and costs of center membership were sought in the surveys. First, member representatives were asked to assess, in a qualitative manner, the overall benefit/cost value that their unit had received from the center. Possible response categories were:

- benefits much less than costs;
- benefits somewhat less than costs;
- benefits about the same as costs;
- benefits somewhat greater than costs;
- benefits much greater than costs;
- have no idea.

Quantitative estimates of the dollar value of various categories of savings were also sought:

- reduced training costs incurred for new hires who are center students and graduates compared with training costs typically necessary for similar employees who are non-center students and graduates;
- savings from benefits other than those associated with reduced training costs;
- financial benefits of interacting with the center beyond cost savings, such as revenue streams from new products, licenses, etc.

Finally, estimates of the costs of membership were requested for the following:

- cash support;
- “in-kind” support;
- fees for use of facilities;
- fees for training;
- fees for technical assistance;
- other; and
- total amount paid.

APPENDIX B

APPENDIX C