

**Measuring the Economic Impacts of the NSF Industry/University Cooperative
Research Centers Program:
A Feasibility Study**

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About the IUCRC Program

The IUCRC Program began as an experimental program in the early 1970s and was formally launched during 1979-80. It is one of several partnership-based programs supported by the Industrial Innovation and Partnerships (IIP) Program in NSF's Engineering Directorate¹. IUCRC Centers are university-based industrial consortia; member firms provide financial support, help steer the research agenda and share all results. The program has initiated more than 140 Centers. IUCRCs were designed to serve as institutional structures to promote and sustain scientific cooperation between industry and universities. It has been quite successful in achieving this objective for more than three decades and is believed to be the longest operating partnership-based program sponsored by NSF. More detailed description of program goals and objectives can be found in its current announcement² and recent DVD³. A management guide is also available⁴.

Current Status

For FY 2010-11 the IUCRC program had a budget of approximately \$15 million (with roughly \$4million of this support coming from the CISE Division of NSF). This funding was allocated to 56 centers with sites at over 160 universities. IUCRCs have been launched in virtually every state in the country. Centers receive 5-year awards that can be renewed for a second five year period⁵. The average multi-site IUCRC receives approximately \$220,000/year from NSF; the average university site within an IUCRC receives approximately \$75,000/year. Centers address a variety of topics, including alternative energy (e.g., biofuels and photovoltaics), advanced materials and manufacturing, energy and environment, advanced electronics, homeland security (identification technology) and many others. A complete list of IUCRCs by technological thrust can be found at <http://www.nsf.gov/eng/iip/iucrc/directory/index.jsp>.

Organizations support IUCRCs by paying an annual membership fee to support Center research and operation. Approximately 700 organizations hold 1000 memberships (a significant number of organizations are members of multiple IUCRCs). Large firms hold roughly half of all memberships. The percentage of memberships held by small firms has doubled over the past four years and stands at 28 percent. Government agencies (including many defense labs) and non-profit organizations hold the balance of the memberships. Most IUCRC funding provides support for faculty and students to conduct Center research. For the most recent fiscal year, IUCRCs supported about 900 faculty, 1500 graduate students, and 350 undergraduates.

Program Evaluation

The evaluation strategy has been multi-faceted and includes a strong "improvement-oriented" focus designed to assist local center managers⁶. Formal program evaluation has been built into center operations since the program was launched by providing support for on-site evaluators who follow a standardized evaluation protocol⁷. In addition to traditional monitoring data on issues like personnel and budgets, data on program processes, outcomes and impacts are obtained on an annual basis via direct observation and industry and faculty questionnaires. The IUCRC Evaluation Team based at North Carolina State University, is responsible for supporting this activity and providing NSF with program-wide analyses and summaries. In addition, periodic targeted studies address specific evaluation issues in more detail.

This report summarizes the findings of one of the evaluation project's targeted studies. Over the years, the evaluation effort has demonstrated a wide range of scientific, technological and human capital benefits. However, quantifiable estimates of economic impacts have been difficult to obtain. The current project had three main objectives: *To assess the strengths and weaknesses of the current impact assessment strategy; to assess the feasibility of improving the program's ability to obtain credible and persuasive quantitative estimates of economic impact; based on these findings, to make recommendations for a strategy for routinizing the collection of such impact data on an ongoing basis.*

¹ Program website found at: <http://www.nsf.gov/eng/iip/iucrc/>

² http://www.nsf.gov/publications/pub_summ.jsp?WT.z_pims_id=5501&ods_key=nsf09565

³ http://www.nsf.gov/eng/iip/iucrc/iucrc_video.jsp

⁴ Gray, D.O. & Walters, G.W. (1998). Managing the IUCRC: A Guide for Directors and Other Stakeholders. Columbus, OH: Battelle. <http://www.ncsu.edu/iucrc/PurpleBook.htm>

⁵ A recently approved Phase 3 funding mechanism will allow centers to apply for a third five-year funding period and receive \$15,000/year.

⁶ Gray, D.O. (2008). Making team science better: Applying improvement-oriented evaluation principles to the evaluation of cooperative research centers. *New Directions for Evaluation*, 118, 73-87.

⁷ The IUCRC Evaluation Project website can be found at: <http://www.ncsu.edu/iucrc/>

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Abstract

This report summarizes findings from a study designed to strengthen the impact evaluation efforts of the NSF Industry/University Cooperative Research Centers (IUCRC) program. With modest annual financial support from NSF in combination with membership fees from industry, IUCRCs perform industrially-relevant research that is carried out primarily by faculty and graduate students. The NSF IUCRC's current evaluation strategy calls for the collection of data primarily through the assistance of on-site evaluators and episodic documentation of "breakthroughs." The study had three objectives: 1.) *To assess the strengths and weaknesses of the current impact assessment strategy;* 2.) *To assess the feasibility of improving the program's ability to obtain credible and persuasive quantitative estimates of economic impact;* and 3.) *To make recommendations based on these findings for a strategy for routinizing the collection of such impact data on an ongoing basis.*

Based on our analysis of impact data collected, we found that the current evaluation approach appears to do a good job of addressing the program's explicit partnership and capacity building objectives. Data currently collected documents the leveraging effect of IUCRC financial support, the establishment of valuable partnerships, immediately realized R&D impacts and descriptions of technology "breakthroughs". Unfortunately, most informants who had benefited were unwilling or unable to provide economic impact estimates for R&D and commercialization outcomes. When estimates were provided they were often given as forecasts of future impacts.

In order to try and remedy these shortcomings, we examined the value of an alternative assessment strategy: rather than interview all possible beneficiaries, we conducted interviews with firms that had been nominated as potential "high impact beneficiaries" at mature IUCRCs and we provided those informants with confidentiality to protect sensitive information. Although no assessment effort will be able to quantify the economic impact of all the important impacts of the IUCRCs. This new assessment strategy proved to be very successful in obtaining credible quantitative estimates of the economic impact of IUCRCs. We approached three mature IUCRCs and found informants were able and willing to provide estimates of the economic value of a number of specific impacts, including improved R&D efficiencies; improved or new processes; improved or new products; and spillover benefits to technology adopters. Aggregating results across the three centers we found a total present value of realized impacts of \$1.28B, generated from NSF program investments of approximately \$18.5M in present value in these three centers. Each dollar invested by NSF helped to create \$69.4 in benefits, with a net present value of \$1.27B. Since many of the technologies referenced by the informants were in the earliest stages of being deployed and/or sold, informants also provided us with forecasted economic impacts for the next two to five years which were sometimes multiples of what had already been realized.

Our analyses strongly indicate that the IUCRC program is having a significant and measurable economic impact on member companies and other external beneficiaries. Since we picked centers that were judged to be "successful," we do not know how representative these findings are. However, if one takes a portfolio approach to evaluating the IUCRC program at a national level, these findings alone, based on a very small percentage of the currently funded centers and participating members, appear to provide sufficient justification for NSF's investment in the overall IUCRC program over many years.

Although there are a few methodological challenges to overcome before the approach we used in this assessment can be employed on a routine basis to collect data from IUCRCs, we believe the program's on-site evaluators are in a very favorable position to continue this type of assessment on an ongoing basis. Several recommendations are made to try to achieve this objective.

Executive Summary

Beginning with the passage of the Government Performance and Results Act (GPRA) enacted in 1993, there has been increasing pressure on federal Science, Technology and Innovation (STI) agencies to develop and implement strategies for evaluating the impact of their programs (Cozzens, 2000). The need for such metrics would seem to be particularly important for various “partnership-based” programs including the NSF Industry/University Cooperative Research Centers (IUCRC) (and other programs including the Engineering Research Centers, SBIR/STTR, GOALI and PFI programs⁸) that work closely with industry and focus on supporting transformational or translational research that aids industrial commercialization.

In light of congressional oversight and executive branch requirements related to program management, questions about *how* to best evaluate specific STI programs, particularly societal and/or economic impact (as appropriate) have occupied the attention of STI policy makers, administrators, evaluators, and scholars. In spite of various efforts over the past two decades (Ruegg & Feller, 2003), we continue to operate in an environment where we have no widely accepted and implemented framework, methodologies or measures for STI impact evaluation (Link & Scott, 1998; Tassej, 2003).

Given the increased importance and urgency currently attached to providing impact data on STI programs, this study focuses on how to extend current evaluation activities of a specific partnership-based program—the NSF Industry/University Cooperative Research Centers (IUCRC) program—to incorporate economic impact metrics.

A. NSF IUCRC Program and Goals

The NSF IUCRC Program was initiated as a pilot initiative in 1973 and launched as a formal program in 1980. It aims to develop long term partnerships among industry, academe and government. In essence, IUCRCs are university-based industrial consortia that receive modest annual support from NSF (about \$250,000). Historically, the research performed in the centers has tended to be strategic or pre-proprietary fundamental research that is carried out primarily by faculty and graduate students.

The objectives of the IUCRC program are contained in its current solicitation and include the following:⁹

- promote research programs of mutual interest [to industry and university]
- contribute to the Nation's research infrastructure base
- enhance the intellectual capacity of the engineering or science workforce through the integration of research and education
- as appropriate, NSF encourages international collaborations that advance these goals within the global context

The announcement indicates these goals will be achieved through the following mechanisms:

- Contributing to the nation's research enterprise by developing long-term partnerships among industry, academe, and government;
- Leveraging NSF funds with industry to support graduate students performing industrially relevant research;
- Expanding the innovation capacity of our nation's competitive workforce through partnerships between industries and universities; and
- Encouraging the nation's research enterprise to remain competitive through active engagement with academic and industrial leaders throughout the world.

⁸ SBIR=Small Business Innovation Research; STTR=Small Business Technology Transfer; GOALI=Grant Opportunities for Academic Liaison with Industry; PFI=Partnership for Innovation

⁹ See weblink at: <http://www.nsf.gov/pubs/2010/nsf10595/nsf10595.htm>

IUCRC's stated goals primarily emphasize partnership and capacity building (e.g., research infrastructure, S&T workforce, international collaboration). Thus, it is important to note that the IUCRC program does not have an *explicit* goal to have a direct economic impact. However, since the program is supposed to "contribute to the Nation's research infrastructure" and encourage "the nation's research enterprise to remain competitive," the program might have an indirect, but measurable impact on various economic outcomes. Our goal was to see if this indeed the case.

Given this background, this project had three goals:

1. *To assess the strengths and weaknesses of the current impact assessment strategy*

The objective was addressed during Phase 1 of our project and involved analysis of existing IUCRC impact evaluation data.

2. *To assess the feasibility of improving the program's ability to obtain credible and persuasive quantitative estimates of economic impact*

This objective was addressed during Phase 2 of our project and involved collecting additional impact data via a more targeted and interview-based format.

3. *Based on these findings, to make recommendations for a strategy for routinizing the collection of such impact data on an ongoing basis*

B. Phase 1: Strengths and Weaknesses of Current Assessment Strategy

We examined three types of IUCRC impact data collected via the ongoing evaluation effort (www.ncsu.edu/iucrc): structural data about funding and basic outputs like patents, students and papers; self-report questionnaire data collected from members by on-site evaluators; interview-based data collected from firms via the program's "technology breakthrough" analysis.

Structural data collected from centers appear to demonstrate that the IUCRC program and individual centers are promoting the creation of partnerships, leveraging the IUCRC program's investment through investments from industry and other government stakeholders, producing scientific papers, graduating students and producing IP. For instance, these data show that over the past 3 years for every dollar the IUCRC program invests, the average center secures \$2.9-\$3.8 dollars in industry funding and between \$7.3-\$10.9 of total funding (industry and other government). Because of IUCRC requirements, centers cannot drop below a one-to-one match and some individual centers leverage NSF funding twenty-to-thirty fold. Leveraging for individual members can reach two-to-three hundred to one. Centers also produce highly valued graduate students and IP. These data are best viewed as output indicators.

Process-Outcome Questionnaire data collected directly from members also suggest firms benefit from participation in IUCRCs in a variety of ways. Importantly, members often report benefits, including networking, student recruitment, and knowledge transfer and impacts on their research strategy, that are potentially very important but difficult if not impossible to quantify. However, these data sometimes provide quantitative estimates of impacts. Questionnaire data suggest member firms are more likely to report R&D-related than commercialization-related impacts. For instance, about 32% of members report center research has had a "high" or "very high" impact on various R&D activities while roughly 7% report similar impacts on commercialization.

However, it seems likely R&D impacts may translate into commercialization impacts down the road. In fact, members sometimes talk about anticipated commercial benefits and impacts. Although some members do provide economic estimates of the value of these impacts in the form of R&D cost savings and/or the economic impact of new or improved processes and products, the overwhelming majority do not. When quantitative economic impacts and benefits are provided, their distribution and size can be very uneven and skewed. For instance, most members report no follow-on funding triggered by center research in a given year but a few members report millions of dollars in such activity with one firm reporting \$50 million.

Interview-based data collected from nominated beneficiaries included in the *Compendium of IUCRC Technology Breakthroughs (CTB)* assessment (Scott, 2009) provide narrative descriptions of various scientific, R&D and technological breakthroughs and yield a much higher percentage of commercially relevant impacts related to products and processes. About 43% of the 173 cases describe breakthroughs that were in the process of commercialization or already commercialized. The vignettes provided in *CTB* were very valuable in communicating the nature of the breakthroughs, who the potential adopter and/or beneficiary was and their qualitative impact. Unfortunately, many of these breakthroughs were still in their early stages and respondents were frequently unwilling or unable to provide economic impacts: In only five percent of the reported cases did informants provide an estimate of the economic impact of the technology. However, some impacts may be very significant, with at least one informant describing the market for a center-derived technology as exceeding \$10 billion/year.

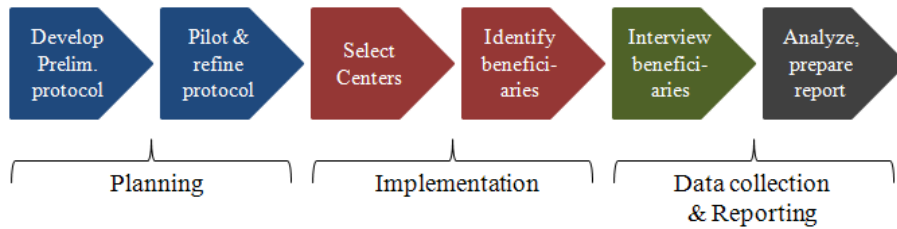
In summary, structural data document IUCRC leveraging and outputs measures and support the establishment of valuable partnerships. Questionnaire data collected from participants on a regular basis appear to provide substantial documentation of relatively immediately realized R&D impacts but much less evidence of and information about commercialization outcomes. Targeted interview-based data collection that looks back over a longer time-frame has produced strong qualitative evidence that IUCRC research is contributing to and/or resulting in commercialization outcomes. Unfortunately, most informants were unwilling or unable to provide economic impact estimates for R&D and commercialization outcomes. When estimates are provided they are often given as forecasts of future impacts. In short, these data provide considerable evidence that the IUCRC program and individual centers are achieving their central partnership and capacity-building objectives; they also demonstrate that firms and other stakeholders are benefitting from their participation in and contact with IUCRCs. However, these data typically do not provide a credible and persuasive estimate of the economic impact of the centers.

C. Phase 2: Impact Assessment of Targeted Centers and Beneficiaries

Our Phase 2 assessment efforts built on the Phase 1 findings and were driven by a couple of data collection principles: concentrate assessment efforts on a few relatively mature centers; concentrate data collection on a small number of potentially “high impact beneficiaries” in those centers; concentrate on collecting economically quantifiable R&D and commercialization-related impacts; differentiate between realized impacts and forecasted impacts; and encourage cooperation by collecting data via interviews and by providing informants with complete confidentiality about the impacts they reported.

As Figure 1 demonstrates, Phase 2 played out over four stages. During our planning stage we developed preliminary research protocol and conducted pilot data from two centers. During the implementation stage, we selected three different centers to assess and asked center personnel to nominate five-to-six potential beneficiary firms. Our target centers were the Center for Intelligent Maintenance Systems (IMS), the Berkeley Sensors and Actuators Center (BSAC), and Industry-University Center for Surfactants (IUCS). During the data collection stage we conducted telephone interviews with informants from the nominated firms. Finally, we analyzed our data and prepared this report. In the next section we summarize our key findings, as well as practical and methodological barriers to obtaining economic impact information on a more routine basis.

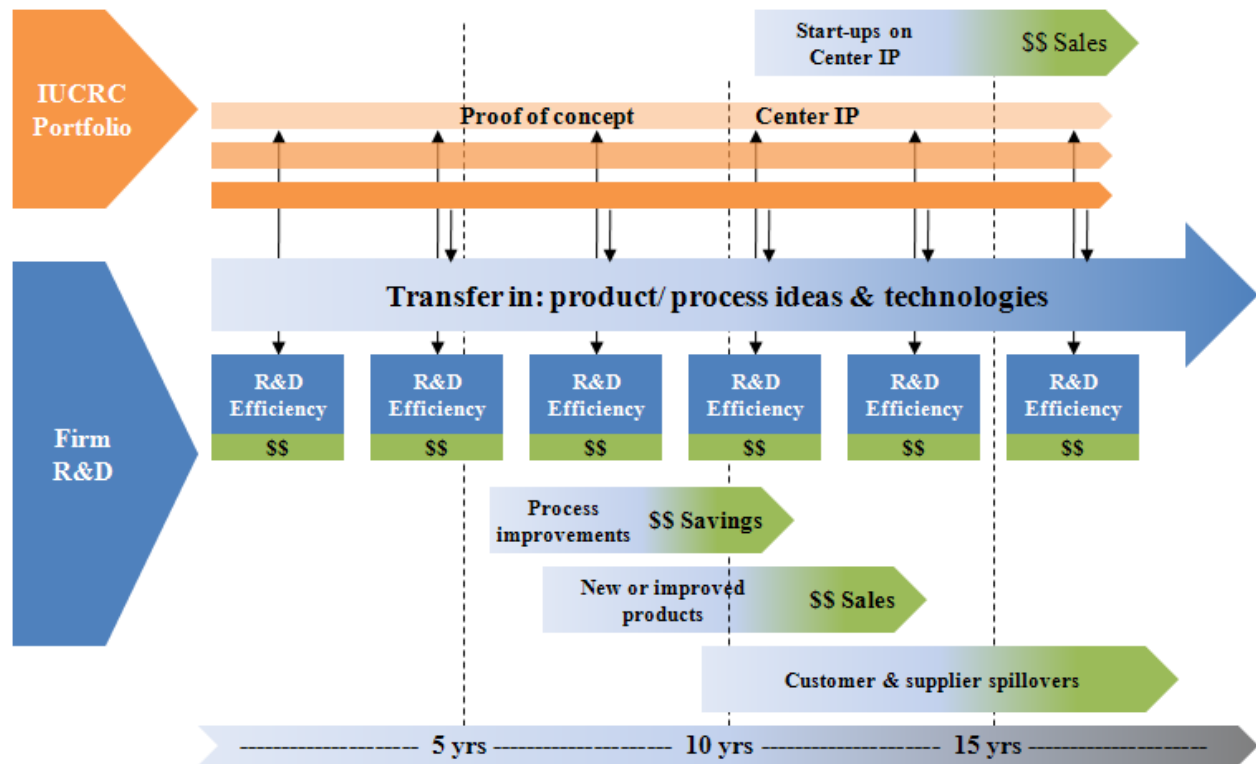
Figure 1: Phase 2 Assessment Activities



1. Impact Assessment

Based on our interviews with nominated beneficiaries, it is apparent that members and to some extent non-member firms are receiving economically quantifiable benefits from IUCRCs with which they are affiliated. Clearly, some of the impacts firms report and value quite highly, including access to pre-competitive research that influences the direction of corporate research strategy, are difficult if not impossible to translate into quantifiable economic estimates. However, with the promise of confidentiality and strong encouragement from our interviewers, most of the respondents included in our assessment were able to provide quantitative economic estimates of at least some of the impacts they received. Figure 2 provides a graphic representation of the kinds of impacts these firms typically reported.

Figure 2: Model of the Types of IUCRC Impacts



R&D Cost Savings and Efficiencies. A number of respondents indicated that center research had a significant and quantifiable impact on their R&D operations. As Figure 2 demonstrates, these impacts

tend to be realized from the ongoing research portfolio soon after the research is done and could be monitored on an ongoing basis. These impacts tended to be reported in terms of cost savings, cost, avoidance or related efficiencies. Consistent with data provided via the IUCRC Evaluation Project's Process/Outcomes Questionnaire, some respondents reported cost avoidance savings based on not having to address certain issues in-house or because internal projects were able to complete their objectives more quickly because of center research. Other respondents indicated that they saved money by recruiting center students either via improved recruitment processes and/or because center students were significantly more productive when they began their jobs.

For instance, the six member organizations interviewed for the Center for Advanced Surfactant Studies were found to realize roughly \$3,000,000 in returns related to R&D efficiencies over the past five-year period. This included between \$400k-\$800k in cost savings related to student hires and over \$2M in avoided person-year costs by leveraging center research capabilities rather than conducting research internally.

New and Improved Processes. Some respondents indicated that center research had a significant and quantifiable impact on the development of new or improved processes. As the lower part of Figure 2 illustrates, the typical commercialization event happened after a number of years of center research, a subsequent "proof-of-concept" finding or prototype followed by several years of corporate R&D. Since these technologies tended to be deployed internally within the adopting firm they were described in terms of operational or production cost savings. Less frequently, firms reported new processes based on center IP or that they developed internally that could be sold or licensed to customers and result in sales income and/or job growth. Since it takes so long for these developments to evolve from center research and then be commercially deployed, respondents often described technological breakthroughs that were just in the process of being deployed or about to be deployed. Significantly, in these cases, respondents could only provide forecasts of economic value of the process.

Nonetheless, the economic value of these kinds of impacts was often quite significant. For instance, a member of the Center for Intelligent Maintenance Systems has applied center-related ideas and technologies to various processes through its global operations. The firm estimates that its involvement with the center was at least partially responsible for these developments and enabled an estimated \$500,000,000 annually in returns related to improved productivity and avoided maintenance costs.

New or Improved Products. Some respondents indicated that center research had a significant and quantifiable impact on the development of new or improved products. As the top half of Figure 2 illustrates, these product-related impacts tend to follow a similar development trajectory to the process developments: commercialization after a long period of center and corporate research; and emergent commercialization that requires forecasted estimates of economic value. In contrast, if the product was based on center IP (see "IP" event on Figure 2), the commercialization might happen relatively soon after the center's contribution. Product impacts were more likely to be quantified in terms of increased sales and/or job creation.

Once again the economic impact of these impacts can be significant. For instance, a start-up company based on ideas and technology from Berkeley Sensor & Actuator Center generated an estimated \$90M in revenue in 2009. The founder and former BSAC student anticipates strong growth in the coming years. The company employs about 120 workers in the United States.

Spillover Impacts for Technology Adopters. As the technology impact literature suggests, significant economic impacts can accrue for the adopters of new or improved processes and products (Jaffe, 1996). There is evidence these kinds of positive spillovers are also triggered by center research and subsequent commercialization efforts. Since these impacts do not happen until after the technology has been marketed and deployed to downstream customers, they are also characterized by a great latency (See "customer productivity" on top of Figure 2) but can be of significant value.

For instance, a single start-up food processing firm licensed technology that originated in the Center for Advanced Processing and Packaging Studies in one of our pilot cases. Importantly, this played out over a 15-year period. The firm employs around 40 workers and is estimated to have earned more

than \$7M in revenue in 2010. To the extent that this technology is licensed to additional processors, these impacts could be multiplied many-fold.

Summary

The three IUCRC study cases provide significant insight into the feasibility of obtaining credible and persuasive estimates of the economic impact of IUCRCs. Table 1 shows the results. We combined results across the three centers following Powell's (2006) suggested aggregation approach and found a total present value of realized impacts of \$1.28B, generated from NSF IUCRC program investments of approximately \$18.5M in present value in these three centers. Each dollar invested by the NSF helped to create \$69.4 in benefits, with a net present value of \$1.27B. Since many of the technologies referenced by the informants were in the earliest stages of being deployed and/or sold, informants also provided us with forecasted economic impacts for the next two or three years which were sometimes multiples of what had already been realized.

Table 1: Summary of benefits and costs across three IUCRCs (in 2010 dollars)

	Combined I/UCRCs	IMS	BSAC	IUCS
Total benefits (present value)	\$1,284.0M	\$859.0M	\$415.4M	\$9.6M
Total investments (present value)	\$18.5M	\$3.6M	\$11.5M	\$3.4M
BCR =	69.4:1	238.3:1	36.2:1	2.8:1
NPV =	\$1,265.5M	\$855.4M	\$403.9M	\$6.1M

BCR: Benefit:Cost Ratio; NPV: Net Present Value

2. Data Collection and Methodology Issues

On balance, the data collection strategy we used appeared to be effective and allowed us to collect credible impact data. Overall, the following elements of our assessment strategy appeared to work very well and should be continued in future assessment efforts: targeting mature IUCRCs for this kind of assessment activity; enlisting the help of directors and staff in nominating potential "high impact beneficiaries"; restricting impact assessment to such beneficiaries; providing informants with confidentiality related to the economic estimates they provided us; and collecting impact data via relatively brief telephone interviews.

Probably the biggest methodological issue that will need to be attended to in subsequent assessments will involve establishing clear criteria for making a causal attribution between research and related activities the center performed and some of the technological developments and economic impacts the beneficiaries told us about. In some of our cases, the informant was able to describe an unambiguous causal path from the center's research efforts to the R&D or commercialization activity and to the economic estimate they provided us. However, in other cases, often involving significant product or process outcomes that took a long time to reach commercialization, informants often attributed part of the impact rather than all of the impact to the IUCRC. In these cases, the center served as a catalyst or key player in the development and commercialization of the technology, but typically served as one of several actors in the development process. In dealing with these streams of benefits we must resolve questions about the counterfactual scenario: could these benefits have occurred without the involvement of the center, and if so, would there have been substantial delay in the commercialization process without the center's involvement?

3. Conclusions

Current IUCRC evaluation strategy and related evaluation efforts have resulted in the collection of data that demonstrate the IUCRC program is reaching its intended goals of establishing valuable

partnerships and building capacity in the institutions and organizations involved. The current evaluation effort does a better job of documenting the R&D impacts that happen relatively soon after the research had been performed rather than actual commercialization impacts which may take years to become manifest. Our highly targeted, interview-based pilot assessment of several mature IUCRCs and nominated beneficiary firms has produced a much higher yield of documented economic impacts. Our analyses strongly indicate that at least some individual centers are having a significant and measurable economic impact on member companies and other external beneficiaries. On balance, our data collection efforts appeared to work well and documented realized impacts that could be estimated in economic terms. These impacts stem from a mix of R&D efficiencies, process-related cost savings, new/improved products, and the spillover of center-derived ideas and technologies into the broader market. We were also able to obtain forecasts of future impacts that might be validated with subsequent follow up assessments. Since we picked centers that were judged to be “successful,” we do not know how representative these findings are. However, if one takes a portfolio approach to evaluating the IUCRC program at a national level, these findings alone appear to provide sufficient justification for the entire IUCRC program investment for multiple years of operation.

Nonetheless, given the current policy discussion about the value of government-funded STI partnership programs, there would be great value to IUCRC program administrators and individual centers to be able to document these kinds of impacts in a systematic way and on an ongoing basis. Toward this end, we make the following recommendations about how to increase the likelihood of obtaining comparably credible and persuasive impact reports on an ongoing basis.

4. Recommendations

1. Continue the existing IUCRC evaluation effort but modify the responsibilities of on-site evaluators to include collection of economic impact data.

The current evaluation protocol appears to do a good job of providing center directors and NSF with feedback on IUCRC partnering metrics and outputs, as well as member and faculty satisfaction and early and objective signs that firms are benefiting from center involvement. We believe the impact evaluation dimension of this evaluation effort could be improved by modifying some of the responsibilities of the evaluator and modifying some elements of the evaluation protocol. These changes should be implemented by the IUCRC Evaluation Project team at NC State.

2. Modify the Process/Outcome Questionnaire to emphasize relatively proximate quantitative economic impacts.

Member firms tend to notice and report R&D efficiency benefits relatively quickly and to report them when they respond to the Process/Outcome Questionnaire. However, they infrequently provide quantitative economic impacts estimates of this benefit. We recommend that this oversight be remedied by adding/modifying questions that will help member respondents provide these estimates more readily.

3. Develop a standardized protocol and training system that facilitates collection of the kind of economic impact data collected in this assessment by local evaluators.

Evaluators are in an almost ideal position to collect the kind of data collected in this assessment because they know the center, its management team and its members. In order for impact data to be collected efficiently and effectively by the on-site IUCRC evaluators, a detailed and easy-to-follow data collection protocol and training program should be developed. Since centers graduate from the IUCRC program and these mature centers are likely to be promising sources of transfer-derived economic impact, provisions must be taken to include graduated centers in this procedure.

4. Develop a simple and compelling methodology for reporting the impact data to important stakeholder groups.

The IUCRC Evaluation Project should assume responsibility for developing a standardized set of reporting forms and reports. These reporting documents should be developed in close consultation with Industrial Innovation and Partnerships (IIP) and provide for feedback to both the local center and to NSF in a way to protect the confidentiality of the informants.

5. Link the revised assessment activities with the efforts to periodically collect “technology breakthrough” cases.

In part because we provided our respondents with confidentiality, our efforts succeeded in producing economic estimates of impact. However, this approach might prevent us from obtaining the success stories that can be very compelling to external stakeholder groups like congress and the general public. As a consequence, we recommend that efforts be taken to coordinate the regular and routine collection of economic impact data with periodic attempts to document the success stories that have been documented in the Compendium of IUCRC Technology Breakthroughs in the past.

I. Introduction

Beginning with the passage of the Government Performance and Results Act (GPRA) enacted in 1993, there has been increasing pressure on federal Science, Technology and Innovation (STI) agencies to develop and implement strategies for evaluating the impact of their programs (Cozzens, 2000). STI outcome or impact evaluation can be defined as attempts to measure the proximal (outputs) and/or distal outcomes or impacts of government STI programs on industries, firms and society more broadly (Gray, 2000). While impact evaluation requirements had been relatively normative for most federal agencies, the expectation that the outcomes or impacts of (STI) programs and initiatives should or could be meaningfully evaluated was initially met with some skepticism and resistance (Cozzens, 1999).

In spite of these objections, concerns about whether STI programs *should* be evaluated have long since passed. GPRA has been in force for almost two decades and the expectation of evaluation for STI programs is now well established. Unfortunately, questions about *how* to best evaluate STI programs, particularly based on their societal and economic impact, continue to preoccupy STI policy makers, administrators and scholars. In spite of various efforts over the past two decades, we continue to operate in an environment where we have no established framework, methodologies or measures for STI impact evaluation (Link & Scott, 1998; Tasse, 2003). Nonetheless, expectations for delivering impact evaluations have neither vanished nor diminished. Recent initiatives that demonstrate the importance attached to developing rigorous and useful STI impact evaluations include the creation and continuing support for the NSF Science of Science & Innovation Policy (SciSIP) program with its focus on developing better STI metrics (NSF, 2008), a new \$1 million award for the STAR METRICS program (NAS, 2010) and the recently released R&D Dashboard tool (OSTP, 2011). Consistent with this trend, in mid-April 2011, the Board of Science, Technology and Economic Policy at the National Academies sponsored a workshop on “Measuring the Impacts of Federal Investments in Research”¹⁰.

These initiatives will undoubtedly contribute to our ability to evaluate various STI programs in the future. However, current circumstances including the most serious economic downturn since the Great Depression, arguments supporting an “innovation-driven” recovery strategy, and continuing debate in Congress about the value of various STI initiatives, suggest a need for additional targeted efforts to develop credible and persuasive assessment strategies and impact metrics.

The need for such metrics would seem to be particularly important for various “partnership-based” programs including the NSF Industry/University Cooperative Research Centers (IUCRC) (and other programs including the Engineering Research Centers, SBIR/STTR, GOALI and PFI programs¹¹) that work closely with industry and focus on supporting transformational or translational research that aids industrial commercialization. In spite of the fact that these programs have been relatively pro-active in conducting evaluations in the past (Gray, 2000; Boardman & Gray, in press), Executive, Congressional and agency executives are now looking for evidence of long-term, economic impacts from these programs. In other words, expectations to produce and document tangible societal and economic outcomes have never been higher.

A. IUCRC Program

The Industry/University Cooperative Research Centers (IUCRC) Program was initiated in 1973 to develop long term partnerships among industry, academe and government. It is believed to be the longest running partnership-based program sponsored by NSF. In essence, IUCRCs are university-based,

¹⁰ See weblink at: <http://sites.nationalacademies.org/PGA/step/FederalResearchReturns/index.htm>

¹¹ SBIR=Small Business Innovation Research; STTR=Small Business Technology Transfer; GOALI=Grant Opportunities for Academic Liaison with Industry; PFI=Partnership for Innovation

industrial research consortia that receive modest annual support from NSF (about \$250,000/year) to attract and leverage industrial support in the form of annual membership fees to augment the activities of the centers (Gray & Walters, 1998). Historically, the research performed in the centers has tended to be strategic or pre-proprietary fundamental research that interest industrial members and is carried out primarily by faculty and graduate students.

In order to assess the impact of a STI program it is critical to understand its goals. The objectives of the IUCRC program are contained in its current solicitation and include the following:¹²

- promote research programs of mutual interest [to industry and university]
- contribute to the Nation's research infrastructure base
- enhance the intellectual capacity of the engineering or science workforce through the integration of research and education
- as appropriate, NSF encourages international collaborations that advance these goals within the global context

The announcement indicates these goals will be achieved through the following mechanisms:

- Contributing to the nation's research enterprise by developing long-term partnerships among industry, academe, and government;
- Leveraging NSF funds with industry to support graduate students performing industrially relevant research;
- Expanding the innovation capacity of our nation's competitive workforce through partnerships between industries and universities; and
- Encouraging the nation's research enterprise to remain competitive through active engagement with academic and industrial leaders throughout the world.

IUCRC's stated goals primarily emphasize partnership and capacity building (e.g., research infrastructure, S&T workforce, international collaboration) and its evaluation activities have been designed to address these areas. It is important to note that the IUCRC program does not have an *explicit* goal to have a direct economic impact. However, since the program is supposed to "contribute to the Nation's research infrastructure" and encourage "the nation's research enterprise to remain competitive," the program could be expected to have an indirect but measurable impact on these types of outcomes. Our goal was to see if this expectation is indeed the case.

B. IUCRC Evaluation Effort

During its 30 years of operation, the IUCRC Program and its centers have engaged in an ongoing evaluation effort. This evaluation is described in more detail elsewhere (Gray, 2009; www.ncsu.edu/iucrc). In brief, the IUCRC evaluation strategy has been multi-faceted and has involved collection of output, process, outcome and, to some extent, impact data. Most of the data on program operations and outputs is provided by center personnel and is collected by an external research team at North Carolina State University. Most of the process, outcome and impact data are provided by center faculty and industry members and is collected on an annual basis via the "Process/Outcome Questionnaire" by on-site external evaluators associated with each center. In addition, specific outcomes and impacts have been the subject of targeted studies undertaken by specific researchers.

¹² See weblink at: <http://www.nsf.gov/pubs/2010/nsf10595/nsf10595.htm>

C. Project Goals

Given the importance and urgency currently attached to providing impact data on STI programs, this project focused on strengthening the impact evaluation for a specific partnership-based program – the NSF Industry/University Cooperative Research Centers (IUCRC) program. This project had three goals:

- *To assess the strengths and weaknesses of the current impact assessment strategy;*
- *To assess the feasibility of improving the program's ability to obtain credible and persuasive quantitative estimates of economic impact; and*
- *Based on these findings, to make recommendations for a strategy for routinizing the collection of such impact data on an ongoing basis.*

D. Brief Review of the STI Impact Literature

Researchers have attempted to estimate the economic impact of innovations for more than half a century. Early influential work comes from Griliches (1958), who set out to measure the social rate of return from hybrid corn. This early work influenced later authors like Mansfield (1977), large partnership-based government programs like the Advanced Technology Program (e.g., Powell, 2006), and government programs more generally (e.g., Tassej, 2003).

Public policy research institution, Rand, published a review (Popper, 1995) of approaches to assess economic impacts of basic science. Popper outlines two general approaches to economic impact assessment: those based on a production function and those based on a social rate of return. Those using a production function seem to treat technical knowledge as an input along with capital and labor investments. A productivity measure serves as the output. Early applications of the production function treated technical knowledge as a residual in the function; that is, technology progress explained that part of productivity that could not be explained by either labor or capital inputs.

Approaches that follow a social rate of return compare accrued benefits related to an innovation to the costs or investments made to develop that innovation. Popper refers to this as a fundamental cost/benefit analysis, and this is the approach recommended for US government program economic evaluations (Office of Management & Budget, Circular A-94). The former Advanced Technology Program (ATP) applied a benefit:cost methodology as one of several evaluation methodologies it used to address program impact (Powell, 2006), and much of the published work under the ATP informed the design of the current feasibility study for the IUCRC program.

Benefit:cost analysis allows for the calculation of specific financial impact metrics. These are described in detail by Tassej (2003) and Powell (2006) as well as by ATP contract researchers (Link & Scott, 2004; Pelsoci, 2005, 2007). The core metrics include the benefit:cost ratio (BCR), the net present value (NPV) of benefits, and the internal rate of return (IRR) from investments. The table below offers a short summary of these metrics, taken mainly from Tassej (2003), Link & Scott (2004), and Powell (2006). The underlying formulas for the calculation of metrics can be found in Appendix 1- *Benefit:Cost methodology impact metric formulas*.

Table 2: Summary of Impact metrics under a Benefit:Cost Methodology

<p>Benefit-Cost Ratio (BCR) <i>Good for comparisons among different “projects”</i></p>	<p>The ratio of the present value of estimated benefits to the present value of costs. Both benefits and costs are inflation-adjusted to the initial operating year of the center. Real benefit and cost dollars are brought forward to present values using a 7% discount rate. A BCR greater than 1 indicates a project that performed above a breakeven threshold.</p>
<p>Net Present Value (NPV) <i>Considered the most (theoretically) accurate measure of economic value (Tassey, 2003). Result depends on the selected discount rate.</i></p>	<p>This is the net benefit of the investment in the center or program. We use the same information from the BCR calculation to calculate the NPV. The present value of costs is subtracted from the present value of estimated benefits.</p>
<p>Internal Rate of Return (IRR) <i>Good for assessing project returns against a benchmark rate; is biased toward projects that begin generating returns quickly (i.e., process innovations)</i></p>	<p>This is the discount rate that makes the NPV equal to 0 or BCR = 1; in other words, this is the opportunity cost of capital that would make the investment a breakeven venture. The IRR can be compared against the recommended 7% discount rate applied to NPV and BCR calculations: an IRR that exceeds 7% could represent a worthwhile investment. Since the IRR requires streams of costs and benefits, we were unable to calculate an IRR.</p>

1. Theoretical issues

Public returns are effectively the gap between social returns and private returns; the benefits of an innovation that could not be wholly captured by the innovator, and therefore spilled over to the market. The spillover gap—the difference between social returns and private returns—serves as the logic behind market failure arguments for public investments in R&D: firms are unlikely to make investments in socially beneficial research when those benefits cannot be fully captured by the innovating firm. As a consequence, R&D funding decisions could be evaluated *ex post* by measuring the level of social returns relative to private returns, with the former exceeding the latter, suggesting the investment was worthy of public expenditures.

This market failure framework guided selection of projects and their subsequent evaluation under ATP (Jaffe, 1996; Powell, 2006). Salter & Martin (2001) discussed an alternative to a market failure framework for program design and evaluation: an evolutionary framework. In this case, evaluation is less about applying benefit:cost analysis and more about evaluating the impact on the broader system’s innovation capacity. This is similar to Bozeman et al.’s (2001) focus on Science & Technology Human Capital (S&THC), where the human capital of tacit knowledge, skills, and training are complemented with social capital, or the connections a researcher has to others holding complementary skill sets. This combination of human and social capital enhances the innovation capacity of the broader system.

According to Salter & Martin (2001), program evaluation should not ignore these capacity-building factors in favor of pure economic valuations. The IUCRC program has been tracking several measures related to capacity building and S&THC (see www.ncsu.edu/iucrc), including student and faculty involvement, membership information, center structure, publications, and similar training, knowledge production, and collaboration information. Complementing these existing measures with economic impact data will offer NSF program managers a broad perspective on program impacts. Practical issues associated with the application of economic studies are discussed next.

2. Practical issues

Benefit:cost analysis utilizes relatively straight-forward financial analysis tools and can provide an insightful narrative of the innovation process when combined with qualitative data. This has made the approach more accessible to policy makers and program stakeholders compared to more intensive methods (e.g., production functions). While some researchers have criticized cost:benefit analysis as too simple account for the complexities of the innovation process (Popper, 1995; Salter & Martin, 2001), the approach offers practitioners the ability to compare across projects and aggregate project-level results to gauge impacts at the program-level (Powell, 2006). This section provides a short list of challenging topics confronted when conducting benefit: cost analysis.

Investments and costs. Decisions must be made on what investments should be incorporated into the calculation of impact metrics. These decisions may not be straight-forward. For example, Griliches (1958) made a distinction between basic and applied research investments, and argued that more accurate assessments of social return would include investments in failed attempts in the development of new technology. Mansfield (1991) recognizes the cumulative nature of science; however, in calculating social rates of return from academic research, the author considers only investments made in the year in which findings from research were made public. The logic is that investments in year t are what made the research available; investments at year $t-1$ and before are considered sunk costs. An evaluation must consider not only the sources of investments but also the duration of investments relevant to estimating returns.

Attribution of economic impacts. New, complex technologies emerge from communities marked by networks and collaboration (Rycroft & Kash, 1994). Assigning credit to one of many community actors is a persistent challenge in economic impact studies. Further, different actors are involved at different stages of technology development, and the development process itself can take many years. For example, Mansfield (1991) found an average 7-year lag between academic research findings and the commercial application of those findings. Similarly, for ATP new products and processes were not expected until 3-7 years after a project start date (Stanley & Shipp, 2006). Writing generally about economic impact studies, Tassef (2003) stated the ideal time to begin assessing economic impacts is 3-10 years after a technology has its first impact on the market.

To address this complexity, benefit:cost analysis uses a counterfactual scenario to help isolate the unique influence of particular investments and actors. In the literature there appears to be two main tactics here. One approach is to present a hypothetical scenario to subject matter experts about what would have happened in the absence of the investment. This is similar to Mansfield's (1991) approach: the author asked R&D executives and their staff whether any new products or processes in their firms could not have been developed without substantial delay in the absence of academic research findings. A second approach is to match the innovating firm with a similar firm that did not receive public funding. This approach found application in the ATP, where funded firms could be matched with applicants in the same industry as the participant but did not receive ATP investments. The goal is the same; discover what would have happened in the absence of funding, with the benefit of a real case rather than a hypothetical scenario to try to isolate the effect of program funding (see for example Watkins & Schlie, 2006). Of course, identifying and researching a real counterfactual case is far more intensive than asking a subject matter expert for a judgment.

Retrospective and prospective impacts. Impacts that have already occurred come with some certainty (attribution aside), and can help form more accurate estimations of future impacts. Even so, prospective impacts could be linearly related to past impacts, exponentially related (e.g., fast growth markets), negatively related (e.g., dynamic markets with rapidly displaced technologies), or even unrelated. We find two general approaches for estimating prospective benefits: an upper/lower bound method and a

consensus method. Examples can be found in ATP work by Pelsoci (2005, 2007). First, through interviews with subject experts Pelsoci collected both a conservative estimate and what he called a “step-out” estimate (or best case scenario) of prospective benefits. Further, these upper and lower bound estimates could be complemented with a probability estimate—what is the likelihood that these scenarios will be realized? A second approach is to achieve consensus on future expectations. Through a series of interviews, Pelsoci collected estimates from several experts with the goal of achieving some consensus in outlook.

Firm, project or center, and program impacts. Gray (2000) has highlighted that STI evaluations of cooperative research centers can make assessments at the program, individual center, and even the firm-level of analysis. In evaluating a program like the IUCRC one must decide on the appropriate level of analysis to use. For instance, should one expect every member of an IUCRC to benefit, or every center in a program to reach some criterion or should one take a portfolio approach? Ruegg (2006) outlined a Composite Performance Rating System (CPRS) approach (<http://www.atp.nist.gov/eao/gcr06-891/gcr06-891report.pdf>) to measure returns from portfolios of projects. The CPRS provides for consistent metrics across projects within a portfolio, which allows for aggregation among projects into a portfolio outcome. Similarly, the STAR Metrics project (<https://www.starmetrics.nih.gov/>) seeks to create consistency in reporting data and structure across research institutions. This consistency should allow for aggregation across institutions. Metrics appear to include economic growth indicators (the website cites patents and start-ups as two possible measures here). However, consistent metrics does not always translate into consistently reliable data. In their pilot study on ERCs economic impacts, Roessner et al. (2010) cautioned against comparisons of metrics across centers, noting that differences across ERCs is due more to variation in success in collecting data than to variation in performance outcomes. While combining data across centers might balance out the variation in data gathering success (and indeed errors in estimating retrospective or prospective impacts), comparing each center to an average performance could be misleading.

Non-quantifiable outcomes. Roessner et al. (2010) found retrospective impacts between \$100M and \$200M from each of three ERCs. Even so, the authors drew two conclusions: first, impacts from these centers take many years to be manifest and even after 10 years are just beginning to materialize. Second, many impacts are non-quantifiable and likely significant. The authors contended that the quantified impacts likely dramatically under-represent actual center impacts. These non-quantifiable impacts are represented in Jaffe’s (1996) spillover channels and in Ruegg’s (1999) direct and indirect channels of technology diffusion.

In general, while a benefit:cost methodology and its associated metrics are explicitly recommended for government program evaluation, these are arguably best implemented and interpreted alongside other performance metrics. Importantly, such metrics should align with and help support program goals and objectives (Popper, 1995; Tassej, 2003). The IUCRC program’s initial mandate and purpose centered on building collaborations and increasing innovation capacity of our nation’s workforce. Currently collected data on memberships, industry investments, student training, joint publications, etc. provide evaluative information on program performance. Following a logic model framework, positive performance on these outcomes should theoretically lead to longer-term economic impacts; as such, benefit:cost analysis should serve to complement these existing metrics and provide additional evidence of program performance.

Summary. As this summary of the literature suggests, measuring economic impacts of STI investments is a challenging task with many complexities. There is continuing debate and disagreement about the merits of using different theories, metrics, criteria for causal attribution or valuing forecasted impacts, and levels of analysis. As a consequence, we continue to operate in an environment where we have no established framework, methodologies or measures for STI impact evaluation (Link & Scott, 1998; Tassej, 2003). However, given the exploratory nature of this study, we will attempt to judiciously apply

the standard metrics found in this literature and take a conservative and cautious approach to asserting causality.

E. Project Assessment Strategy

Since the IUCRC program has been subject to an ongoing systematic evaluation effort for over 25 years (Gray, 2009; www.ncsu.edu/iucrc), our project strategy involved two sets of activities: analysis of existing IUCRC impact data and collection of new primary data on program impacts. During the first phase of the project, we analyzed archival IUCRC for evidence of economic impact. The purpose of this step was to assess the strengths and weaknesses of existing evaluation methods and to use these analyses to guide our subsequent data collection. During the second phase of the project, we engaged in a targeted primary data collection effort involving interviews with IUCRC centers and potential beneficiaries to determine whether we could produce additional and more quantitative economic impact estimates by using alternative methods and tools.

II. Phase 1: What Can We Learn from Archival Data on IUCRC Impacts?

Objective: *To assess the strengths and weaknesses of the current impact assessment strategy*

A. Analysis of Available IUCRC Program Data

In order to explore the strengths and weaknesses of the current evaluation effort, we leveraged three archival data sources from the IUCRC Evaluation Project: operational data reported by center directors on outputs and, to some extent, outcomes; outcome data collected from member companies via the annually administered Process/Outcome Questionnaire (that focused on relatively immediate outcomes and impacts); reports of actual technology impacts or “success stories” documented in the two most recent editions of the *Compendium of Technology Breakthroughs* (Scott, 2007; 2009)¹³. These data can be used to provide program-level, center-level and in some cases, member-level outcome/impact assessments. Review of these data provided important information for setting expectations and structuring the interview guide with beneficiaries in the present study.

1. Outputs and Outcomes from Structure Report

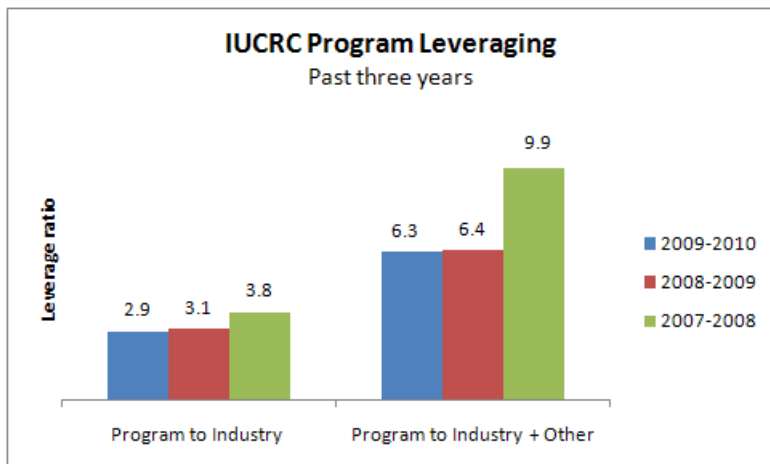
One source of relevant data on IUCRCs is its Structure Report (Gray et al., 2010). These data are provided by IUCRC center directors and cover a number of areas including: funding; personnel; membership; operations; and outputs/outcomes. While the focus of this report is primarily center operations and outputs, several variables included in this report are relevant to assessing outcomes and program impacts.

Partnership Funding and Leveraging

Since IUCRCs are supposed to be partnership-based, leverage NSF funds to support graduate students, and result in long-term partnerships, one measure of the success of a center and of the program as a whole is the extent to which NSF IUCRC funding triggers funding from various stakeholders and how much leveraging results. Data on these issues are collected annually and have been summarized in the “NSF IUCRC Structural Report”. These reports are produced annually and contain data submitted by center directors on center operations and outputs. Historic reports can be found on the IUCRC Program Evaluation website (<http://www.ncsu.edu/iucrc/NatReports.htm>). Figure 3 displays program-level leveraging. Over the past three years one dollar invested by NSF IUCRC has resulted in 2.9 to 3.8 dollars of industry funding and 6.3 to 9.9 dollars in total funding (member fees plus all other funding).

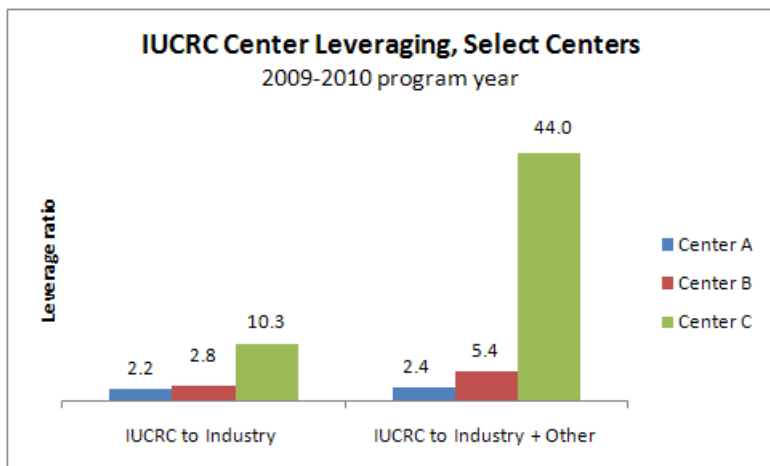
¹³ See IUCRC Evaluation Project website for more information: www.ncsu.edu/iucrc.

Figure 3: IUCRC leveraging, 2007-08 to 2009-10 program years



Obviously, the leveraging achieved varies from center-to-center. Since center-level funding can fluctuate dramatically from year-to-year, centers are typically not evaluated on this metric. However, center leveraging could be evaluated at the 5-year and 10-year renewal periods. Figure 4 displays the leveraging realized for three IUCRCs over the past year. Centers were selected to represent the low, average, and high level in total funding. As the data demonstrate, Center A (low-end of total funding) produced 2.2 industry dollars for every IUCRC dollar, while Center C (high-end of total funding) produced considerably more at 10.3 industry dollars and 44.0 industry plus other dollars for every IUCRC dollar.

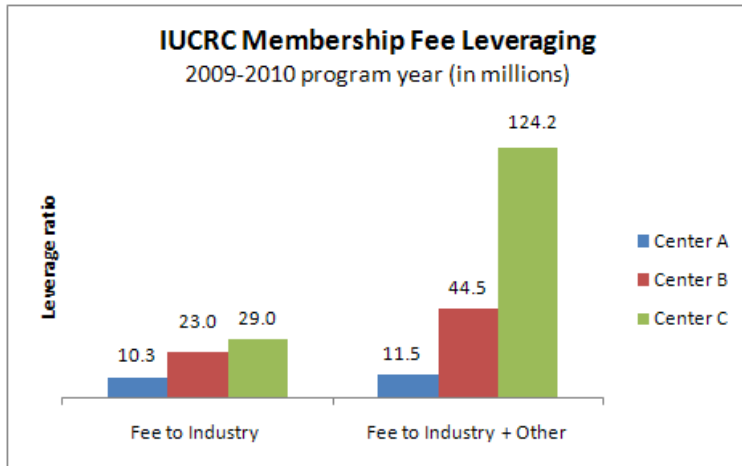
Figure 4: Leveraging of NSF-IUCRC investments at three centers



Centers could also be evaluated based on the leveraging for individual members. Annual membership in an IUCRC can range from \$25,000 to \$75,000 depending on the center. This fee allows the member to influence through voting which research projects get funded by the center, and also gives the member access to ideas and technologies produced by center research. Figure 5 displays the leveraging data for the same three centers as shown in Figure 4, and considers the primary membership as the leverage point. As the data demonstrate, the leveraging for an individual firm can range from 10.3 total industry dollars

for every membership dollar (up to 124.2 total funding dollars for every membership dollar. This assumes a member firm would be interested in all research projects within a center; however, even when just 40% of research projects are of interest to a member (the average reported by IUCRC members on the Process Outcome Questionnaire), leveraging would still range from 4.1 to 49.7 times the membership fee for these centers in Figure 5.

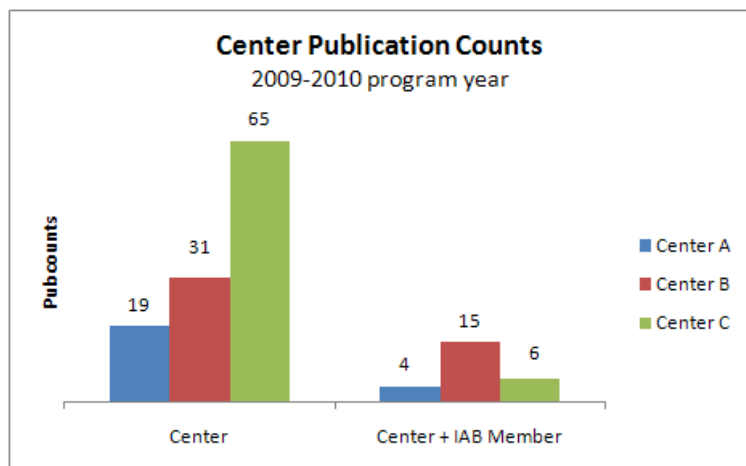
Figure 5: Leveraging of IUCRC primary member fee at three centers



Publications, Students and IP Events

Virtually all STI programs are evaluated based on outputs in the form of published papers, graduated students and intellectual property (IP) events. The IUCRC program has been no different. Program-level outputs are reported on an annual basis in the “NSF IUCRC Structural Report”. Figure 6 displays these outputs for Project Year 2009-10 for the same three centers as above. While it is difficult to assess the economic value of these outputs, joint publications between center staff and IAB members provide an indication of collaborative R&D. For example, though Center C excels in total publication counts, Center B has 2.5 times the number of joint publications with IAB members compared to Center C. See Figure 6 below. Since these center-level outputs can fluctuate dramatically from year-to-year, these outputs do not weigh heavily in annual reviews of center performance, but could affect a center’s evaluation at the end of Phase 1 or Phase 2 funding.. However, centers could be evaluated at the 5-year and 10-year renewal periods on these metrics.

Figure 6: Publication counts for select IUCRCs



2. Outcome and Impacts from Process-Outcome Questionnaire

The NSF IUCRC Process/Outcome Questionnaire is administered annually by center evaluators to member organizations. It is designed to provide local center stakeholders relatively real-time feedback on center operations (e.g. satisfaction with different features of the center) and various outcomes that are reported by member firms. While some outcomes, including “networking with other scientists” are difficult to translate into quantifiable impacts, others like R&D and commercialization impacts might be converted into economic terms. Unfortunately, although all members receive the questionnaire and evaluators are proactive following up with respondents, the questionnaire is typically completed and returned by about 40% of all eligible members. Since our data only contains outcomes from a percentage of all members, one must be careful in interpreting these results.

We examined recent Process/Outcome survey responses to gain insight into the types of, and pervasiveness of, quantifiable impacts stemming from IUCRC activities. We pulled survey data from the 2008-2009 period and looked at three specific survey questions:

- 1) Internal R&D stimulated by center research. The relevant question asks members whether they have supported internal research projects that were triggered by IUCRC research and the dollar value of this research¹⁴.
- 2) Center impact to R&D, commercialization, and professional networking. These questions ask members to rate on a five-point scale (no impact (1) – very high impact(5)) how much impact center research has had on various R&D and commercialization outcomes¹⁵.
- 3) Description of benefits received. If members have indicated that they benefited technically from center research they are invited to describe that benefit and try to quantify it in monetary or other terms¹⁶.

¹⁴ Item text: *During the past year, approximately how many center-stimulated research projects were supported by your organization (include internal projects and projects contracted to outside performers)? Please estimate the dollar value of all center-stimulated research projects. Exclude center membership fee.)*

¹⁵ Question text: *During the past year, to what extent has participation in the center contributed to the following benefits for your organization? A) Research & Development: Enhanced via increased technical awareness, accelerated or new projects or development of intellectual property in my organization. B) Commercialization: Enhanced via improved or new products, processes, services, improved sales, or new or retained jobs*

Internal R&D spending based on center research could be viewed as confirmation of the relevance of the center research to firms and as an indicator of future, potential economic impacts derived from ideas and technology stimulated by the center. During 2008-2009 members responding to the Process-Outcome Questionnaire reported total spending of \$81M of internal funding on center-stimulated research. Conservatively, every dollar of IUCRC funding stimulated roughly \$8 in R&D spending by member companies¹⁷. Since we only have data from 40% of members, the value of internal R&D spending is almost certainly much higher. How much higher is difficult to say. If the non-responding members made investments at the same rate as responding members, the figure could be as high as \$200 million and the multiplier effect as high as 20-to-1.

Survey respondents also provide a forced choice rating of the impact of the center on *R&D, commercialization, and professional networking activities* (1=no impact; 5=very high). Response distributions to these items provide insight into where centers have the greatest impact and the extent of impact on commercialization specifically. The table below shows response distributions (including “not applicable” and “missing” responses) regarding R&D, commercialization and professional networking impacts. About 43% reported “High” or “Very High” impact on Professional Networking while 32% gave the same ratings on R&D and 7.7% said the same about commercialization. The average rating for Professional Networking was 3.39 (between “Moderate” and “High” impact), on R&D was 3.12 (or a “Moderate” impact); the average rating for commercialization came in a full point lower at 2.14 (or a “Slight” impact). Thus, centers appear to be having a greater impact on Professional Networking and R&D than on commercialization.

Table 3: Perceived impacts on member firms, Process/Outcome survey results

	No	Slight	Moderate	High	Very high	n/a	(missing)
a. R&D	7.7%	20.1%	26.9%	19.7%	12.4%	3.0%	10.2%
b. Commercialization	32.9%	15.9%	19.2%	5.1%	2.6%	12.8%	11.5%
c. Professional Networking	5.6%	12.4%	28.6%	30.3%	13.2%	1.7%	3.9%

Firms were also asked to describe in their own words the *kinds of impacts* they received, and were encouraged to “try to quantify benefits (e.g., dollars saved, months saved, water/scrap reduction, etc.)”. These comments were submitted by fewer than 1 in 3 survey respondents. While it is not clear how representative these comments are for the total membership population, they are a rich source of information about what types of benefits members are receiving and their willingness and ability to translate them into quantifiable terms. We coded responses into several categories in order to get a fine-grained view of member perceptions of impacts. A full list of benefits cited by respondents appears in the Table 5 below¹⁸.

A summary of some of the major trends reflected in this table includes:

- 70% reported what appeared to be knowledge and transfer impacts on R&D activities or processes (row 1, 2, 3, 4, 5, 6, 7)

¹⁶ Question text: *If your organization has benefited technically from its participation in the center, please describe how (e.g. brief description of research advance or product/process improved, etc.) and, where possible, try to quantify benefit (e.g. dollars saved, months saved, waste/scrap reduced, etc.)*

¹⁷ However, it is important to note that this figure includes an outlier value of \$50M in internal spending. Removing the outlier we get \$31M in aggregated spending, and a mean value of roughly \$149K.

¹⁸ Responses could be coded into more than one category; responses total 124%.

- 31% reported R&D benefits that looked like they could be translated into quantitative economic terms but were not (row 2, 5, 6)
- 10% of these R&D impacts were cited as resulting in cost savings (row 3)
- 10% reported new or improved product or process impacts (row 9, 10)
 - 1% of reports involved new products or processes (row 10)
 - 5% provided actual dollar estimates of impacts (row 8)
- 16% anticipated future benefits but did not clarify if they were R&D or commercialization (row 11)
- 14% report other benefits (row 12, 13, 14)

Table 4: Open-end reports of member benefits, Process/Outcome survey results

Row	Percent	Description
R&D Related Benefits		
1	15.4%	Knowledge transfer, new knowledge or understanding; stay current in area/field
2	14.3%	Stimulating new internal R&D projects, ideas, products, market directions, possibilities, etc.
3	9.9%	Cost savings or reduction; time/resources saved (due to avoided R&D or other reason)
4	9.9%	General technical influence on internal R&D projects (or not specified)
5	8.8%	Accelerated or helped move forward an existing internal research program; helped to secure R&D funding
6	7.7%	Access to facilities or equipment otherwise unattainable; access to tools
7	4.4%	Joint projects with center or with other members
8	5.5%	*Actual dollar estimate of impact provided
Commercialization Related Benefits		
9	8.8%	Improved product, process, system, method, application, operations
10	1.1%	New product, process, system method, application (either in development, planned or already launched)
Future Benefits		
11	16.5%	See, expect or forecast future benefits; optimistic about future benefits;
Other Benefits		
12	8.8%	Networking, collaborating with other organizations
13	3.3%	Recruiting new employees ; access to or interaction with students
14	2.2%	Consultation from center staff
No Benefits		
15	4.4%	Too new to center to experience or identify benefits
16	1.1%	No or limited impact; limited commercial impact

3. Technology Breakthroughs Analysis

The final archival source of outcome/impact data on IUCRCs can be found in the three volumes of *Compendium of Technology Breakthroughs (CTB) of NSF IUCRCs* disseminated by NSF (Scott, 2004, 2007 and 2009). The methodology for collecting these reports is summarized in the CTB itself. In brief, the investigator followed a series of steps that included: contacting and interviewing key informants within each center (e.g., director, key industry representatives), follow up contacts with members who were nominated as potential beneficiaries of center research, a more detailed interview with members to document the value and significance of the breakthrough for this external stakeholder and, in some cases, a site visit to the industrial or research setting. This approach to collecting impact data is different on a couple of dimensions: it uses a targeted approach by concentrating on nominated beneficiaries; by focusing on any breakthrough that might have happened during a center’s life span, it covers a longer time frame; and it uses an interactive interview method of data collection.

Each CTB contains a collection of brief descriptions of scientific and/or technological breakthroughs derived from center research listed by center. A typical CTB entry includes a graphic or photographic representation of the technology breakthrough accompanied by a short narrative description of the nature of the technology breakthrough, its genesis within the center, and its current stage of development and usage.

Since a quick review of the CTBs revealed that individual entries ranged from recent research/scientific breakthroughs by center scientists to fully deployed and commercialized processes and/or products, we decided it would be useful to review the entries, try to code them on several dimensions and provide a more systematic analysis that reflected their degree of commercialization and economic evaluation.

a. Method

We took a look at the 173 technologies described in the 2009 *Compendium of Technology Breakthroughs*. We coded each technology on four dimensions, each with a set of underlying categories. Since our interest rested on gauging whether IUCRC-related innovations could be economically quantified, we coded on dimensions that would support this objective. The four dimensions included:

1. *Type of research output*—for example, new knowledge, new process, or new product
2. *Stage of development or closeness to commercialization*—for example, basic principles observed, proof-of-concept in simulated environment, or commercialized
3. *Adopter named*—for example, no adopters named, a general sector or industry, or a specific firm(s)
4. *Economic value of the technology*—for example, no economic value estimated, speculation of potential value, or already realized value

We reviewed a sample of cases in the CTB to derive potential codes within each of the dimensions. The coding within the stage of development dimension was influenced by the Technology Readiness Levels (Technology Readiness Assessment Deskbook, Department of Defense, July 2009). After we created the underlying codes, the remaining cases in the CTB were coded along each of the four dimensions. A complete list of code definitions can be found in Appendix 2-*Compendium coding scheme*.

Despite a structured and rigorous approach to capturing technology break-through information, we found wide variation in the level of detail across cases. For example, some case summaries offered extensive details on the technology and its beneficiaries; others provided limited information or failed to speculate whatsoever on potential markets and beneficiaries. Further, while some case summaries maintained a highly technical tone, others were more accessible to the non-technical reader. These inconsistencies across case summaries left many gaps in the coding process, and likely resulted in modest reliability in the final coding.

b. Findings

If we take the CTB as representative of successes across the IUCRC program, our coding would provide a sense of whether an economic impact study is feasible and what percentage of successes could be assigned an economic impact. For *type of research output* we found that nearly half of the breakthroughs involved new knowledge (32%) or the discovery of a new research method or technology (15%). See Table 6 below. Other breakthroughs could be more directly tied to economic impacts: 42% of breakthroughs had implications for new or improved processes, while 10% had implications for new or improved products. For example, the Center for Precision Metrology developed a processing technique that deposits thin layers of diamond on machine tools which *could* increase manufacturing efficiencies at the tool/workpiece interface. The processing techniques have led to patent pending development work, and a beneficiary company is further refining the techniques for application in the aerospace industry (2009 CTB, p. 114).

Table 5: Code frequencies from CTB, type of research output

Pct	Cnt	Category description
42%	79	A new process, tool, device, software, or algorithm that replaces or works with one or many components of an existing commercial process
32%	59	The discovery of new knowledge (e.g., regarding the properties or characteristics of relevant materials)
15%	27	A new research method or technique that could help accelerate technological progress
10%	19	A new product, system, or component that improves or replaces an existing one, or opens a new market or industry
1%	2	Undetermined

While the type of output may narrow the gap between IUCRC research and economic impact, the *stage of development* may determine whether an impact assessment could be conducted. We interpreted about 15% of cases to be at initial stages of development; that is, basic principles have been observed and, in some of these cases, general applications speculated. See Table 7 below. In 25% of cases the breakthrough appeared to have reached a proof-of-concept stage, whether in a simulated or a relevant environment. In 15% of cases the breakthrough was under implementation for commercial application, arguably having proved to stakeholders its viability for market applications. In 28% of cases we found the breakthrough in question to have already been commercialized in some capacity (and therefore potentially generating returns for beneficiaries). For example, researchers at the Center for Advanced Computing and Communication (CACC) developed a method to monitor computer memory leak and to predict when problems will occur so that preventative steps could be taken. The technology has been adopted by IBM and Microsoft. In 17% of cases we were unable to interpret the technology stage.

Table 6: Code frequencies from CTB, stage of development

Pct	Cnt	Category description
28%	51	Technology or concept has been commercialized or applied to commercial products
17%	30	Commercial applications or proof-of-concept shown under experimental conditions
15%	28	Basic principles have been observed and/or general applications speculated
15%	27	Technology or concept is currently being implemented for commercial applications
8%	15	Commercial applications or proof-of-concept shown under simulation or relevant environment
17%	30	Undetermined

We also considered whether *technology beneficiaries* and *economic impact data* were recorded in the case summaries. We found this information to vary. In about 1 in 5 cases no beneficiaries or technology adopters were identified. Forty-two percent of cases referenced a sector or industry as either a potential adopter or as a current beneficiary of the technology. Thirty-four percent of cases offered more details, naming specific firms or institutions as adopters, and another 5% of cases referenced a start-up or spin-out firm as the adopter.

Table 7: Code frequencies from CTB, adopters

Pct	Cnt	Category description
20%	35	No adopters or potential adopters named or speculated
42%	75	Adopters or potential adopters named – general sector, industry or group of firms
34%	61	Adopters or potential adopters named – specific firm(s) or institution(s)
5%	8	Adopters named – start-up or spin-off firm

For economic impact data a large majority of cases (76%) either did not attempt to estimate benefits or provided only qualitative speculation on potential benefits of the technology. In 16% of cases we found realized impacts were speculated in non-financial terms or broader societal benefits. Specific financial estimates of impact were offered in about 5% of cases. For example, simulation tools for non-destructive evaluation reportedly saved an organization \$1M in the first year applying the technology, and another organization is said to have saved \$0.5M in avoided manufacturing costs (2009 CTB, p. 105).

Table 8: Code frequencies from CTB, economic impacts

Pct	Cnt	Category description
36%	62	No attempt estimate economic benefits or value
40%	68	Potential economic impact is speculated in general non-financial or societal terms
16%	28	Realized economic impact is speculated in general non-financial or societal terms
5%	8	Realized economic impact is provided in specific financial terms
2%	4	Undetermined

A summary of some of the major trends reflected in these tables includes:

- About half the CTB entries reflected research outputs that appeared to involve process or product improvements rather than just scientific findings
 - The remaining half reflected research or scientific developments that did not appear to reflect commercial development
- About 43% of the cases described the breakthroughs that appeared to be in the process of commercialization or already commercialized
- About 40% of the cases described either potential or actual adopter organizations or a start-up associated with the technology
 - Rarely was it clear if the adopter was a center member or an outside licensee
- Estimates of financial impacts were only offered in about 5% of the cases

B. Summary of Analyses of Archival Impact Data

Data collected through the current IUCRC evaluation system have produced considerable evidence that the IUCRC program is achieving many of its important objectives and is having an impact on member firms and other external stakeholders. However, in terms of documenting the economic impact of these centers, these data also have their limitations.

Structural data collected from centers appear to demonstrate that the IUCRC program is promoting the creation of partnerships, leveraging the IUCRC program's investment through investments from industry and other government stakeholders, producing scientific papers, graduating students, and producing IP. These data are best viewed as output indicators.

Questionnaire data collected directly from members provide impact evaluation evidence and suggest firms benefit from participation in IUCRCs in a variety of ways. Not surprisingly, members often report benefits, including networking, student recruitment, and knowledge transfer and impacts on their research strategy, that are potentially very important but difficult if not impossible to quantify. Questionnaire data also suggest firms are more likely to report R&D-related than commercialization-related impacts. However, it seems likely R&D impacts may translate into commercialization impacts down the road. In fact, members sometimes talk about anticipated benefits and impacts. Although some members do provide economic estimates of the value of these impacts in the form of R&D cost savings and/or the economic impact of new or improved processes and products, the overwhelming majority do not. When quantitative economic impacts and benefits are provided, their distribution and size can be very uneven and skewed. For instance, most members report no follow-on funding in a given year but a few members report millions of dollars in such activity with one firm reporting \$50 million.

Targeted interview-based data collection from nominated beneficiaries continued to highlight scientific and R&D impacts but also produced a much higher percentage of commercially relevant impacts related to products and processes. Not surprisingly, many of these activities were still in their early stages and respondents were frequently unwilling or unable to provide economic impacts. The vignettes provided in CTB were very valuable in communicating the nature of the breakthroughs, identifying the potential adopter and/or beneficiary, and revealing their qualitative impact. Clearly, some beneficiaries were non-members who acquired technology via licensing or other arrangements. Some impacts may be very significant, with at least one informant describing the market for a center-derived technology as exceeding \$10 billion per year.

In summary, questionnaire data collected from participants on a regular basis appear to provide substantial documentation of relatively quickly realized R&D impacts but much less information about commercialization outcomes. Targeted interview-based data collection that looks back over a long time-frame has produced strong qualitative evidence that IUCRC research is contributing to and/or resulting in commercialization outcomes. Unfortunately, most informants were unwilling or unable to provide economic impact estimates for R&D and commercialization outcomes. When estimates are provided they are often given as forecasts of future impacts. As a consequence, it would be difficult to document the economic value of center activities based on the data obtained from current evaluation strategies.

The next section of this report provides a summary of the results of efforts to improve our ability to obtain this kind of data.

III. Phase 2: Impact Assessment with Targeted Centers and Beneficiaries

Objective: *To assess the feasibility of improving the program's ability to obtain credible and persuasive quantitative estimates economic of impact*

A. Project Assumptions

Given the issues that surfaced in our review of the STI impacts literature and the findings of Phase 1 of this study, we began our Phase 2 assessments by making a number of assumptions about how to proceed.

- Since it may take years for IUCRCs to conduct research that influences a member firm's internal R&D and then produce economically significant impacts, our pilot assessment should concentrate on a few relatively mature and/or graduated centers.

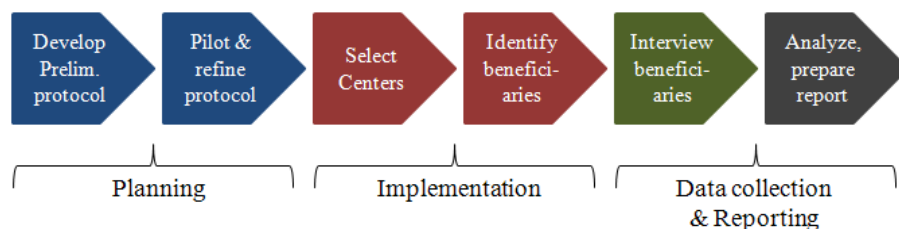
- Since evidence suggests a disproportionate percentage of the total economic impact from centers is attributable to a small number of “high impact findings/inventions,” our pilot evaluation efforts should be targeted at obtaining feedback from these high impact beneficiaries.
- Data collection efforts should concentrate on capturing outcomes/impacts that past data collection efforts suggest can be quantified. These include: R&D cost savings; cost savings from process and product improvements; sales and job creation from new processes and products; and spillover benefits to users and adopters of center technology.
- Data collection should attempt to differentiate between impacts realized from already commercialized processes and products and forecasted impacts.
- Since firms that report benefiting from IUCRCs often do not volunteer quantitative economic impacts, data collection efforts should utilize a more interactive interview-based methodology and should provide all informants with complete confidentiality about the impacts they report.

B. Overall Strategy

A more detailed description of the assessment strategy can be found in Appendix 3-*Overview of methodology*, with associated documentation in Appendices 4 – 12. In brief, the strategy involved 6 steps (See Figure 7):

1. Develop Preliminary Assessment Protocol. Based on literature review and Phase 1 findings, we developed a preliminary assessment protocol that emphasized the identification and documentation of high value and economically quantifiable impact estimates.
2. Pilot Assessment Protocol. In order to test and refine our protocol, we identified two beneficiary firms that had been identified from various assessments at other IUCRCs and conducted interviews with them. These were intended as pilot cases and our assessment protocol was revised and refined based on our experience interviewing the respondents.
3. Center Selection. Based on feedback from NSF and other informants, we selected three mature IUCRC centers (e.g., 9 years in operation or older) that appeared to have a high likelihood of including some high impact beneficiaries.
4. Beneficiary Identification. We asked directors and other informants of these centers to nominate three to five “high impact” beneficiaries and make introductions to these firms.
5. Conduct Impact Interviews. We conducted in-person or telephone interviews with beneficiaries. In order to promote cooperation beneficiaries were promised confidentiality for the information they provided. Interviewers took extensive notes during the interview and prepared a detailed case summary based on these notes.
6. Data Analysis & Report Preparation. Data collected via the interviews were summarized and analyzed. We used the data we collected as the basis for the findings we report in Section E below.

Figure 7: Assessment strategy from development through reporting



C. Interview Strategy

The primary purpose of the interviews was to assess the extent to which the nominated beneficiary firm reported economic impacts that were attributable to IUCRC research. A structured interview guide was used to gather this information (See Appendix 12-*Guide for interview with beneficiary*). The beneficiary did not receive a copy of the guide but was made aware of the general purpose of the interview and the type of information of interest (See Appendix 9-*Draft email from project team to beneficiary*). Since the time allotted for the interviews was generally quite short (about 30 minutes), we typically did not attempt to obtain a comprehensive cataloging of all possible impacts by using the whole interview guide. Instead, interviewers initially focused their assessment on documenting whether and to what extent the beneficiary had realized very large economic impacts via the development of new or improved processes and products; beneficiaries were also asked to describe the extent to which they attributed the development of these innovations to the IUCRC. If time allowed, interviewers also asked about other impacts, like R&D efficiencies (e.g., cost avoidance, student hires, etc.), that were likely to be more modest in size. Thus, we did not attempt to document every type of impact for each of our interviewees.

Our findings are organized by Center below.

D. Center Impacts – Pilot Stage

As suggested above, our assessment strategy was piloted with beneficiary firms who were identified at two mature IUCRCs. These firms were picked because there was anecdotal information that they had realized measurable economic impacts. Since the economic value of these impacts had not previously been quantitatively estimated, we decided to apply our assessment strategy and methods with these organizations prior to using them with our study sample.

1. Pilot A: Center for Advanced Processing and Packaging Studies.

Background and description of center

The Center for Advanced Processing and Packaging Studies (CAPPS) was launched in 1987 by Dr. Ken Swartzel at NC State University. CAPPS eventually evolved into a multi-university center (adding Ohio State University and UC-Davis) with Ohio State becoming the managing site in 2003 and was given a new NSF award as a “recompeted center”. In 2003, CAPPS graduated from IUCRC funding but was recently granted support as a Phase 3 center. CAPPS’ mission is to “conduct industrially relevant research directed at developing methods and technologies for the production of safe, marketable, high-quality food products”. Its technical foci include work on: enhancing safety, quality and nutritional properties of food using new technologies; characterizing emerging, aseptic and extended shelf-life processes; and assuring integrity and functionality of food packaging. Much of CAPPS research on advanced food processing technologies appears to have an effect on internal firm processing practices. However, center research can also lead to new process inventions that can and have been licensed to firms. During the time CAPPS was supported by NSF (1987-2003) it received \$1.37M (actual dollars) funding from the IUCRC program. During this same period it generated an additional \$5.39M in membership support and \$1.69M in funding from other sources.

Collection of Impact Data

We selected CAPPS as a pilot site because it was known to have produced newly patented technology. This technology has been licensed to an industrial partner and sublicensed to a food processing operation. Some of these activities have been documented in university press releases and stories in local newspapers. This technology provides ultra rapid, aseptic processing of natural and pureed food products. The processing technology results in minimum loss to color and to nutrient content and creates an extended shelf-stable product requiring no freezing or refrigeration. CAPPS faculty inventors agreed to

cooperate in our assessment efforts and provided introductions to both the firm that partnered in the patenting efforts and the firm that had sublicensed and was using the technology. Data were collected from the co-inventing/licensing firm via telephone interviews and emails. Data were collected from the sub-licensee food producer during a site visit and face-to-face interview at their production facility.

Findings

We discovered impacts through three different sources. The work initiated by CAPPS and later developed into patentable technology outside the center had been licensed to a local engineering firm with intentions of sublicensing the technology to industrial customers. Through written response to our interview questions, the firm representative reported invoices of \$550,000 in the first half of 2010. The sub-licensee agreed to be interviewed by the research team. The management team at the sublicensing firm did not report specific revenue figures; however, we were able to generate an estimate based on annual production yield and per-unit sales prices. Otherwise, we found the management quite open and excited about discussing their challenges and successes with the technology. The third source involved a technology designed to provide real-time validation data related to the processing of food products. The technology was developed by the former CAPPS director, received a patent with help from the university TTO, and subsequently launched as a spin-out company. We interviewed the inventor and company owner, who reported that this recently commercialized technology had produced roughly \$200k in system sales in 2010. It is worth noting that if either of these technologies becomes successful the economic impact would be many times what was reported to us. Since neither sub-licensee was a member of the center, they were unable to confirm the connection between the technology and the center's research. However, the inventor indicated the inventions would not have been possible without the benefit of the initial research conducted in the center. The table below summarizes these various impacts.

Table 9: Summary of impacts related to CAPPS

	Channel	Impact
1	Licensee of NC State technology	2010 sales estimate: \$550,000 Employees: unknown
2	Sublicensee	2010 sales estimates: \$7,300,000 Employees: 40
3	NC State spin-out	2010 sales estimate: \$200,000 Employees: 2 FT, 2 PT

Methodology and Data Collection Issues

Our research protocol appeared to work fairly well for this pilot case, but a number of issues did surface that warrant mention. First, although the CAPPS investigator was certain there was a direct link between center research and the impacts we assessed, neither the co-inventor/licensee nor the sub-licensee were ever members of CAPPS nor knew much about the center. This has implications for the type of questions one can ask when one examines this type of beneficiary. In addition, while generally cooperative the co-inventor/licensee would never agree to participate in a formal telephone interview. Instead, they asked that we provide them with our questions in writing and they chose to answer these questions via an email message. When we asked to get clarification on some of the information they provided us in writing via a phone interview, they again declined and indicated they would only provide information in writing. In contrast, our site visit and interview with the sub-licensee went very well and lasted several hours. In part based on this experience, we concluded we should be able to collect most of the data we needed via telephone interviews.

2. Pilot B: Center for Integrated Pest Management

Background and description of center

The Center for Integrated Pest Management (CIPM) was launched in 1991 by Dr. Harold Coble at NC State University. CIPM remained a single-site center throughout its 10 years of NSF funding. CIPM's mission states that it "fosters the development and implementation of pest management programs based on a high level of knowledge of pest biology coupled with choices of monitoring tools and control technology, resulting in economically sound, environmentally compatible, and sociologically responsible pest management in diverse systems including both crop production and urban settings." The center continues its operations at NC State. The center works closely with industry and federal sponsors, and maintains a global network of government agencies, academic institutions, and non-profit organizations. During its time with the IUCRC program (1991-2000), CIPM received \$615k (actual dollars) in NSF-IUCRC funding. During this same period it generated an additional \$3.21M in membership support and \$1.36M in funding from other sources.

Collection of Impact Data

We interviewed a faculty PI at the center regarding a patented technology based on naturally occurring pest deterrent found in tomato plants. According to the PI, the patented technology had been licensed and sub-licensed, and was currently marketed and distributed by a North Carolina business. The PI could not make an introduction to the owner of the business. We investigated the patent through the university's Technology Transfer Office (TTO). While TTO staff could not disclose any information regarding company financials, the TTO offered to make an introduction into the licensing and sub-licensing organization. Despite several follow up emails, neither of the organizations responded to a request for an interview. As a result, some impact data were retrieved through archival sources. Due to the licensing company's large size and breadth of products, no sales data could be associated with the technology. The sub-licensing company however seemed to depend largely on the technology for its sales, based on review of their website.

Findings

According to online database of small businesses (www.manta.com), the sub-licensing company generates \$720,000 in annual revenues and employs 8 workers. Since the company's website URL is based on the brand product using the licensed technology, we take revenue figures to largely represent sales from the licensed technology.

Methodology and Data Collection Issues

While the inventing PI was very cooperative in our follow up assessments, we once again experienced some difficulties obtaining cooperation from beneficiaries who were not members of the center but simply licensed the technology from the inventing university. In this case, the inventor did not have a personal relationship with the licensee, and the TTO office could only provide us with contact information. However, we were able to use an archival data source to obtain impact information for the start up beneficiary but not the larger firm that licensed the technology.

E. Center Impacts – Post-Pilot, Three Target Centers

As suggested above, the three centers that were included in our assessment effort were selected because they were relatively mature centers that had been in existence long enough for at least some members to have realized benefits that might take several years to percolate up through a firm's own R&D and commercialization system. In addition, there was anecdotal evidence that firms were actively using center research and had already reached a commercialization outcome with their efforts. Three centers that focused on very different industries and technologies were selected for this purpose.

1. Case A: Center for Intelligent Maintenance Systems

Background and description of center

The Center for Intelligent Maintenance Systems (or IMS) was launched in 2001. IMS is a multi-university center, with its primary site at the University of Cincinnati and partner sites at University of Michigan and Missouri University of S&T. According to the IMS website, the vision "is to enable products and systems to achieve and sustain near-zero breakdown performance, and ultimately transform the traditional maintenance practices from "fail and fix " to "predict and prevent" methodology. The Center has been focused for most of its ten years of operation on frontier technologies in embedded and remote monitoring, prognostics technologies, and intelligent decision support tools and has coined the trademarked Watchdog Agent® prognostics tools and Device-to-Business (D2B) infotonics platform for e-maintenance systems.

Collection of Impact Data

The impact evaluation team approached IMS directors about this impact study, and requested to be introduced to 4-6 organizations considered to be significant beneficiaries of IMS knowledge and technology. The three directors collaborated together to identify six such organizations, and during the semi-annual center meeting with IAB members approached representatives from the identified organizations to encourage their participation. Our team subsequently interviewed each of the three IMS directors in order to gain additional information about the cases. The director working most closely with each of the organizations made an email introduction to their contact on our behalf, we then followed up directly with an email introducing the study and to schedule an interview time. Interviews were ultimately scheduled with all six organizations. Interviews ranged between 30 and 60 minutes. A semi-structured interview format was followed, in order to maintain focus on quantifiable, economic impacts; however, the interview also covered non-quantifiable impacts particularly in cases in which tangible financial outcomes had not yet been realized.

Findings

The nature of IMS process-related technologies allows for pervasive impact across an organization's operations. These impacts are generally cost-savings, and become quite significant in firms with large and/or numerous operational facilities. Our six interviews discovered \$570M in retrospective impacts enabled by IMS knowledge and technology. Impacts ranged widely, from \$0 to \$500M. The \$0 impact comes from a supplier of predictive maintenance products and services that is currently market-testing IMS Watchdog technology for sale as a packaged product: it is too soon to estimate potential sales. The \$500M impact was reported by a global manufacturer that has deployed IMS-based technology across its operations. Beneficiaries varied widely in attributing their technology advances to IMS, with some granting partial credit and others indicating the advance would not have happened without IMS' involvement.

Table 10: Summary of IMS beneficiaries

Case	Impacts	Short Description
A	\$0.4M	The company discovered the IMS center through a university relationship involving the company's core technology. Five years later the company is applying IMS technology to predict and prevent machine failures and improve operational efficiencies.
B	\$4.8M	This company captures benefits from IMS through several channels, including faculty consulting, technology transfer, and student hires. Early work with a co-director at the center ultimately led to a patent and product launch with a supplier partner. Further, prospective cost savings through operational efficiencies are estimated at more than \$6.5M annually.
C	\$65.0M	This global manufacturer leverages IMS technology to weed through enormous amounts of process-related data to identify potential threats to downtime and to increase process yield. Annual savings estimates top \$65M and are expected to continue rising.
D	\$0.1M	This five-year member of IMS has two early-stage yet promising projects using IMS-based technology. Pilot projects indicate significant cost savings; once fully deployed this technology could saving the company more than \$41M annually in improved machine performance and avoided downtime.
E	\$500.0M	This company is deploying IMS-based knowledge and technology throughout its global network of manufacturing facilities. Improvements in predictive maintenance and machine performance have resulted in an estimated several million dollars per plant in savings, or about half a billion dollars annually.
F	\$0	This company is a supplier of tools and technologies complementary to IMS technology. This company is in the process of market-testing a packaged version of IMS Watchdog technology. Market acceptance (and potential) is uncertain, though the company is optimistic.

Funding of the IMS Center started in 2001. Total IUCRC investments were \$2.24M in actual dollars and \$1.96M in real 2001 dollars. See Table 11 and Table 12 below.

Table 11: Summary of funding for IMS (actual dollars)

Fiscal year start	Total funding	NSF/IUCRC	Other NSF	Member fees and other industry	Other funding*
2001	\$1,001,168	\$85,000	\$143,500	\$500,668	\$272,000
2002	\$1,543,000	\$135,000	\$187,500	\$415,000	\$805,500
2003	\$889,410	\$130,000	\$7,000	\$500,000	\$252,410
2004	\$619,000	\$130,000	\$5,000	\$484,000	\$0
2005	\$2,034,431	\$337,714	\$126,270	\$813,250	\$757,197
2006	\$2,079,432	\$252,753	\$295,998	\$1,384,003	\$146,678
2007	\$2,750,118	\$153,686	\$567,535	\$1,352,000	\$676,897
2008	\$2,438,154	\$281,578	\$599,999	\$960,000	\$596,577
2009	\$1,997,880	\$162,000	\$500,000	\$1,000,080	\$335,800
2010	\$2,453,008	\$570,999	\$944,398	\$804,000	\$133,611
TOTALS	\$17,805,601	\$2,238,730	\$3,377,200	\$8,213,001	\$3,976,670

*Note: Other funding includes state, federal, university, non-federal, and other

Multiple informants indicated that cost savings have been accruing for several years, though accurate recall of impacts proved difficult, particularly in cases where the impact was pervasive across operations. We took impact estimates as an aggregate value in the current year, and then converted values to real 2001 dollars. Present value (2010) estimates were calculated using a 7% discount rate.

Table 12: Summary of IMS economic impacts and metrics

	2001 dollars	Present value
Benefits	\$467,264,024	\$ 859,045,850
NSF/IUCRC program costs	\$1,961,018	\$ 3,605,251
Benefit:Cost Ratio		238.3:1
Net Present Value		\$ 855,440,599

Overall, we find for every dollar invested in IMS, the NSF receives \$238 in return. Subtracting the present value of the IUCRC investment from the present value of estimated impacts, we find a NPV of more than \$855M.

Prospective Benefits

Anticipated future benefits are similarly impressive. Informants already enjoying sizable cost savings expect these cost savings to continue into the future (for example, Organizations C & E). For others, preliminary testing results support the deployment of IMS technologies across operational facilities. Assuming full deployment over the next five years, Organization D could enjoy more than \$41M in annual cost savings. Ultimately, based on the interview data we estimate prospective benefits through 2015 of more than \$1.4B.

Representative Beneficiary Case

Organization A has been a member of IMS for five years. The organization's relationship to IMS is through an applied research group charged in part with testing and implementing university-based technologies into factory operations. The group is focused on the machine-level rather than the process-level, with a goal of preventing and/or delaying machine degradation. In this sense, impact is related to the avoidance of machine break-down and/or failure rather than improved efficiencies. As such impacts tend to be difficult to assess and may often be delayed for several years depending on the current health of machinery: machine lifecycles could be measured in decades. Further, internal projects related to center technology are several stages from commercial application: the organization is either collecting test data or working with center students to analyze data.

Four transfer events or projects were identified and discussed in the interview. Economic impact estimates could be derived for two of the four events (totaling \$200,000 in retrospective impacts, and another \$800,000 in expected cost savings through 2015). These impacts came in the form of avoided maintenance costs and avoided downtime. In addition, the organization had hired two PhD graduates from IMS (with an estimated \$100,000 in avoided mentoring costs for each hire). Taken together, the organization has experienced \$400,000 in retrospective impacts, and an estimated \$1.2M in anticipated total impacts through 2015.

The contact at the organization indicated that the predictive maintenance technologies of IMS had not been an interest area for the organization, and if not for discovering IMS the organization probably would not have realized these impacts. IMS came to the attention of the organization through an existing research partnership with a university involving the organization's core technology. If not for this

somewhat serendipitous discovery, the organization would not have pursued research into predictive maintenance.

Outlier Beneficiary Case

Organization E has been a member of the IMS Center for 8 years. The informant characterized the organization as highly engaged in the center, and appreciated the center directors' problem-solving orientation toward its industry members. Organization E has transferred elements of the center's Watchdog Agent technology internally for further development and application toward predictive maintenance and machine health. The organization appears to be at different stages with different projects. As such, the informant could provide only a general overview of technology transfer benefits. It was estimated that ideas and technologies have helped achieve roughly \$10M in cost savings on average per plant, with roughly 50 plants across the enterprise. When asked about impacts on downstream customers and consumers, the informant noted that the reduction in costs due to process innovations helps to make the organization and U.S. industry more competitive in a global market, which translates into saved U.S. jobs; however, these cost savings are difficult to pass directly on to customers.

The informant noted additional benefits in several areas. First, research leveraging: the center conducts about \$2-3M in research each year, about one-fourth of which is of interest to the organization. While this included research cost avoidance, no specific estimates were made. Second, increased R&D capacity: the organization has enhanced its capabilities due to working with center staff and to exposure to other members' applications. Third, networking: the organization has opportunities to connect with other manufacturers facing similar and different problems. The informant noted that the company invests significant time and resources to adapting the technology for application within the organization. Like other interviewees, the informant views the center as an enabler of internal innovations; assigning a precise attribution of these benefits to the center is difficult if not impossible.

Methodology and Data Collection Issues

Attribution: A persistent theme from the interviews was the challenge of attribution. Informants typically cited internal investments in further testing and developing IMS technology for application within their own facilities and operations. The transfer process could be 2 years or more before the technology is tailored to fit an organization's particular context and needs. A more accurate assessment might include a proportional estimate of attribution. One option is to reflect the NSF investment relative to the firm's investment. However, firms are unlikely to disclose their investments. Another option is to apply a counterfactual, and consider whether the NSF accelerated commercialization and if so, by how much time. Attribution is given for a defined period of time. In either case, assigning attribution will likely require a dialogue between the evaluator and the commercializing agent.

Streams of Impacts: The IMS technology seemed to allow for estimates of continued streams of impacts resulting in process improvements at year 1 and continuing onward. The extent to which these streams are estimated to continue should depend on how the question of attribution is resolved.

Prospective benefits: In addition to ongoing cost savings, informants identified potential future benefits from IMS technology, whether from implementation of machine monitoring or the launch of a new product, these events yield forecasted benefits that could provide significant returns on the NSF investment. One approach to dealing with these forecasts would be to ask the informant to provide a best case estimate and a conservative scenario (based on his or her knowledge of the implementation of innovations within the organization). Another approach would be to ask the informant for a probability of implementation: what is the likelihood that these forecasts will be realized? While these methods provide some indication of future returns, their fruition remains highly uncertain.

Coverage: In some cases beneficiaries may be multi-national corporations that have implemented center-based innovations outside US borders. For purposes of the pilot program we did not bound center impacts geographically; however, this is arguably an important consideration when evaluating public returns.

Conclusions

IMS impacts come almost entirely in the form of process efficiencies, like avoided downtime and maintenance costs, and subsequent increases in process yield. This is clearly in line with the center's vision "to enable products and systems to achieve and sustain near-zero breakdown performance..." While informants were unable to translate these process improvements directly to customer benefits, there seemed to be consensus that these improvements lead to increased market competitiveness, which in turn translates to a stronger national economy and greater employment rates. Additional impacts came in the form of the occasional student hire or the launch of a new product. Specifically, in one case an IMS director contributed to early phases of product development, which led years later to a patent and commercial product. In another case, an industry supplier reported to be in early stages of launching IMS technology in packaged form, but the organization had yet to engage in market testing to establish acceptance and price points.

In general, NSF investments in the IMS center appear to be generating significant public returns. This is not to say that these innovations would never have happened in the absence of IMS. In fact, several informants described the center as an enabler and catalyst: the center provided important knowledge and foundational technology that the firm could then translate into commercial applications with further investments into commercial applications. This view is consistent with descriptions of the innovation process and the notion of team science.

2. Case B: Berkeley Sensors and Actuators Center

Background¹⁹

BSAC was founded in 1986 as the NSF Center for Microsensors and Microactuators, and is devoted to interdisciplinary engineering research on micro- and nano-scale sensors, moving mechanical elements, microfluidics, materials, and processes that take advantage of progress made in integrated-circuit technology. It has successfully re-competed for continuing IUCRC funding on at least two occasions. In 1998, BSAC expanded to a multi-campus NSF I/UCRC with the addition of UC Davis, a major campus of the University of California 60 miles from UC Berkeley. BSAC continued with the NSF I/UCRC program through 2008, and continues to operate as a graduated center.

BSAC includes a multi-disciplinary research team of 120 graduate students and post-doctoral researchers led by 10 BSAC Directors from the engineering faculties of electrical, mechanical, and bio engineering at UC Berkeley and UC Davis. BSAC Directors oversee nearly 100 projects with cooperation, collaboration, and guidance of 30 industrial member companies and government laboratories and 15 additional Affiliated Faculty from UC Berkeley and Davis. BSAC utilizes research laboratories throughout the engineering campuses at UC Berkeley and UC Davis, including intensive use of the UC Berkeley micro fabrication facility (MicroLab).

Collection of Impact Data

We approached the BSAC executive director about this impact study, and requested to be introduced to 4-6 organizations considered to be significant beneficiaries of BSAC knowledge and technology. Our team later interviewed the executive director regarding the proposed beneficiaries and to gain initial insight into

¹⁹ Information on BSAC pulled from the center's website at: <http://www-bsac.eecs.berkeley.edu/>

each case. The executive director subsequently made an email introduction to each of five beneficiaries introducing the study and our interviewer, who then followed up directly to schedule an interview time. Interviews were ultimately scheduled with all five beneficiaries. Interviews ranged between 30 and 60 minutes. A semi-structured interview format was followed, in order to maintain focus on quantifiable, economic impacts; however, the interview also covered non-quantifiable impacts particularly in cases in which tangible financial outcomes had not yet been realized.

Findings

Based on the five interviews we estimated a total impact of \$144M. At the company level, impacts ranged from \$0 to \$85M. Interviewees who reported no current economic impacts (\$0) provided non-quantifiable impacts significant enough, according to their view, to fully justify their investments in the center. These impacts included exposure to MEMS (micro-electrical-mechanical systems) technologies and accelerated research timelines—in Case A, the informant believed that BSAC saved the company 7 years in research; however, we were unable to ascribe a financial value to this benefit. Table 14 below summarizes the cases related to BSAC.

Table 13: Summary of BSAC beneficiaries

Case	Impacts	Description
A	\$0	The company is currently in the process of transitioning a segment of its operations to technology based on BSAC research. The new manufacturing process will enhance the competitiveness of a \$26M business unit with aggressive growth targets for the coming years. The informant is optimistic that the new technology will also help the company enter new markets.
B	\$11.0M	The company launched a successful spin-off company based in part on technology linking back to BSAC. Revenues are estimated at over \$10M. Further a former BSAC student and now current employee of the company has developed a new technology for the vehicle safety market. If successful, the new technology could generate several hundred million dollars in revenue for the company in the next 5 years.
C	\$48.0M	This company has a long standing relationship with BSAC, and includes multiple student hires and licensed technology. The informant estimates that as much as 50% of the company's MEMS business could be attributable to BSAC research. We conservatively estimate that the company generates nearly \$100M in MEMS revenue.
D	\$85.0M	This start-up company was founded by a former BSAC student. A recently landed large contract with a global consumer brand accelerated the company's growth, with revenues nearing \$100M mark. Double-digital growth rates are expected in the coming years.
E	\$0	A relatively new member of BSAC, the company leverages its exposure to BSAC research and technology to help guide their R&D strategy. The company is currently tracking multiple projects at BSAC for potential commercial application within the next 3-5 years.

BSAC IUCRC-specific investments totaled \$2.96M in actual dollars, or \$2.26M in real 1986 dollars. The table below shows actual dollar investments.

Table 14: Summary of funding of BSAC

Fiscal year start	Total funding	NSF/IUCRC	Other NSF	Member fees and other industry	Other funding*
1986	\$668,991	\$100,000	\$0	\$489,991	\$79,000
1987	\$979,125	\$100,000	\$0	\$695,000	\$184,125
1988	\$1,043,750	\$125,000	\$0	\$794,422	\$124,328
1989	\$1,134,167	\$200,806	\$0	\$760,000	\$173,361
1990	\$1,264,351	\$120,806	\$0	\$545,000	\$598,545
1991	\$1,098,370	\$153,255	\$0	\$490,085	\$455,030
1992	\$1,271,830	\$151,293	\$0	\$696,343	\$424,194
1993	\$1,614,937	\$183,150	\$0	\$684,930	\$746,857
1994	\$1,719,845	\$149,785	\$0	\$927,359	\$642,701
1995	\$3,584,760	\$165,495	\$0	\$1,103,995	\$2,315,270
1996	\$5,685,534	\$124,874	\$319,261	\$1,728,213	\$3,513,186
1997	\$8,824,883	\$44,700	\$448,679	\$2,190,869	\$6,140,635
1998	\$10,608,155	\$202,650	\$557,300	\$1,266,064	\$8,582,141
1999	\$7,968,345	\$80,000	\$0	\$1,805,000	\$6,083,345
2000	\$7,968,345	\$80,000	\$0	\$1,805,000	\$6,083,345
2001	\$11,469,913	\$130,000	\$0	\$1,546,263	\$9,793,650
2002	\$9,778,332	\$130,000	\$0	\$2,543,332	\$7,105,000
2003	\$9,390,016	\$83,000	\$6,000	\$1,526,257	\$7,774,759
2004	\$7,105,238	\$83,000	\$380,000	\$2,653,088	\$3,989,150
2005	\$7,105,238	\$83,000	\$380,000	\$2,653,088	\$3,989,150
2006	\$8,900,212	\$233,000	\$0	\$3,972,642	\$4,694,570
2007	\$12,554,190	\$233,000	\$260,000	\$3,902,265	\$8,158,925
TOTALS	\$121,738,527	\$2,956,814	\$2,351,240	\$34,779,206	\$81,651,267

*Note: Other funding includes state, federal, university, non-federal, and other

The long history of BSAC and its focus on MEMS (micro-electrical-mechanical systems) technology—which continues to expand into new markets—made the identification of streams of impacts over time difficult to capture in the interviews. Since BSAC lists a total of 26 “BSAC-inspired Start Ups” on their website, and we conducted interviews with one or two of these, our impact estimates are very conservative. Further while two start-up firms were identified in the interviews, these firms only recently (in the past few years) have generated significant revenues. As a result, impacts were aggregated as a current-year return. Both a benefit:cost ratio (BCR) and a net present value (NPV) were calculated.

Table 15: Summary of BSAC economic impacts and metrics

	1986 dollars	Present value
Benefits	\$81,886,138	\$ 415,356,541
NSF/IUCRC program costs	\$ 2,262,333	\$11,475,383
Benefit:Cost Ratio		36.2:1
Net Present Value		\$403,881,158

Overall we find for every dollar investment in BSAC, the NSF receives \$36.2 in return. Subtracting the present value of the IUCRC investment from the present value of estimated impacts, we find a NPV of more than \$400M.

Prospective Benefits

Most informants were unable to provide complete estimates of future benefits. The spin-out associated with Organization B will likely continue operations; however, the informant could not disclose financial information or growth prospects. Both Organization C and Organization D will likely continue their MEMS-based product lines, much of which can be linked back to BSAC. While Organization A has near-term plans to implement BSAC technologies, Organization B and Organization E are likely several years from their first BSAC-related product lines. While prospective benefits could be significant, it is still too early to hazard an estimate.

Representative Beneficiary Case

Organization B has been a member of BSAC for more than 10 years. The company is a market leader in several industries that apply MEMS technologies. The informant noted several areas in which the company has benefitted from its membership in BSAC, including a spin-off company based on two technologies: one contributed by Organization B and one by a former BSAC director. The use of the latter technology likely accelerated the launch of the spin-off by two years. While the informant could not provide financial data on the spin-off’s performance, Hoover’s Online reports the company generated \$10.8M in 2009 and employs 70 workers.

Other benefits reported by the informant were largely prospective. The company has hired two Ph.D. students from BSAC. One of these former students is developing a MEMS-based accelerometer for the automotive market. The product is currently under regulatory review for commercial application; it could be two or more years before commercialization. Organization B already holds a strong position in this market, and the launch of this product could potentially generate several hundred million in revenue. The organization is also working closely with BSAC to develop gyroscopic technology for smartphone applications. While the organization is not a player in this market, this new technology holds advantages over existing market technologies. Networking and access to BSAC facilities are additional advantages cited by the informant.

Overall, we recognize spin-off revenues and student hires as quantifiable impacts totaling \$11M. Prospective benefits, if realized, could exceed \$250M or more in the next 5 years.

Outlier Beneficiary Case

Organization D is a start-up firm based on BSAC MEMS knowledge and technology. The company was founded by a former BSAC student who maintains close ties with the center, both for continued research and collaboration, as well as for a stream of employees with relevant training and expertise. Including the founder, the company has hired seven students from BSAC. The informant acknowledges that the

company probably would not exist in the absence of BSAC; the center is one of only a few institutions doing advanced research in MEMS gyroscopic technologies.

According to the informant, the company generated nearly \$90M in revenue in 2009, and employed 120 workers in the United States. Strong growth is anticipated in the coming years.

Methodology and Data Collection Issues

Technical complexity: BSAC and all other IUCRCs explore the cutting edge of technology. Understanding how center knowledge and technology translates to commercial application can be difficult for someone outside this technology community. An ongoing impact evaluation program should consider leveraging the knowledge and experience of the embedded NSF evaluators. While evaluators may not have S&T training, their ongoing relationship with the center has created a degree of shared understanding and common language. This is critical for two reasons: first, the evaluator will know the right questions to ask regarding technology transfer events; two, the evaluator will have established a level of trust with center members, and this trust will allow for greater information sharing.

Historic impacts: Several informants maintained long-term relationships with BSAC. In one case, the relationship dated back 10-15 years. Not surprising the informant had significant difficulty recounting the various impacts related to the center. In another case, the company's relationship with BSAC extended beyond the number of years in which the informant had worked for the company. Documenting these historic impacts will be challenging if an impact evaluation is launched late in the life of a center. Tracking impacts throughout the life of a center will provide for a more accurate assessment of lifetime center impacts. While significant process and product innovations may not materialize for beneficiaries until midway through a center's lifecycle, beneficiaries will likely experience R&D efficiencies and begin to recognize prospective benefits within a few years. Regular follow-up with beneficiaries on prospective benefits will help ensure significant impacts are captured throughout the center's life.

Coverage: BSAC beneficiaries often represent large, multi-national corporations. In one case, the beneficiary resided outside the United States, but the company maintained offices and research facilities in the United States. Further, the company sells its products to a global market. As noted in the IMS case study, a program evaluation on impacts will need to set parameters on what constitutes a public return on NSF investments.

Conclusions

Interviews with beneficiary informants and our own cursory research indicate that MEMS technology continues to expand into new market areas. A common benefit cited by informants is the exposure to new applications of MEMS technology, and how this insight could influence their organization's R&D roadmap. It seems the many commercial applications of MEMS have yet to be discovered, though BSAC was contributing to early development of MEMS technology more than 25 years ago. While we had uncovered more than \$400M in net present value of BSAC knowledge and technology, it is likely that much of the center's economic impact has yet to materialize.

Unlike the IMS center's process monitoring and maintenance technologies, BSAC's impact more often comes in the form of new companies and new products. Two of our interviews included start-up firms, with combined revenue estimated at over \$100M (though executive director John Huggins reports that BSAC has inspired more than two dozen start-ups in recent years²⁰). Both start-ups are expected to grow significantly as the MEMS market expands. Informants from large organizations talked about new

²⁰ See Huggins, John (circa 2010). BSAC: Secrets of a Legendary MEMS/NEMS Research Center. Berkeley Sensor & Actuator Center (BSAC), University of California Berkeley

product lines and new market applications for MEMS technology. We think the most significant economic impacts of BSAC are yet to be seen.

3. Case C: Center for Advanced Surfactant Studies, IUCS

Background

The Center for Advanced Surfactant Studies, IUCS, launched in 1998 at Columbia University and continued in the NSF I/UCRC program through 2007. It operated as a single university center for all of that time. The aim of the IUCS was to develop and characterize novel surfactants for industrial applications such as coatings, dispersions, deposition, gas hydrate control, personal care products, soil decontamination, waste treatment, corrosion prevention, flotation and controlled chemical reactions. After graduating from the program IUCS was absorbed into a new center with significant changes to its research focus. In 2009 the center merged with the Particulate and Surfactant Systems Center at the University of Florida. Since the research program examined in our interviews began during the last year or two of the IUCS activities, we focused only on the Columbia University site in our assessment.

Collection of Impact Data

A member of our team interviewed Dr. Somasundaran—the founder of the Center for Advanced Surfactant Studies at Columbia University and current site director for Particular and Surfactant Systems—to identify companies that might have benefitted significantly from involvement in the center. Data collected from the Process/Outcome Questionnaire assessment indicated, there was a great deal of excitement about a relatively recent thrust within the center – green surfactants – so most of the nominated beneficiaries had an interest in this area. Dr. Somasundaran identified six companies, and subsequently provided an email introduction for one of our team, who then contacted and interviewed the named representative at each of the six companies.

Findings

The six companies interviewed reported an estimated combined impact of \$5.5M to–date. Estimated impacts ranged from \$150k to \$4M. See Table 16.

Table 16: Summary of IUCS beneficiaries

Case	Impacts	Description
A	\$0.15M	This company is a long-standing member of the center. The informant sees great value in knowledge transfer and consultation with center staff, which inform the ongoing development of the company's methods and processes. Knowledge transfer, including student hires, helps keep the company competitive and healthy in an industry faced with environmental challenges.
B	\$0.5M	This small company leverages its relationship with the center to complement its limited R&D staff. Several joint publications have given the company credibility in the market and have directly helped close sales deals estimated at \$.5M.
C	\$0.3M	This multi-billion dollar company turns to the center for research work in green chemistry-- an important growth area for the company. The Center's expertise in this area has saved the company several hundred thousand dollars in avoided research costs. The informant is optimistic that center involvement will lead to new products and processes for the company.
D	\$0.15M	This start-up firm benefits from the center's expertise in surfactants and their evaluation capabilities. The company has benefited from research cost avoidance, and is also preparing to launch a surfactant product based on center technology around 2012.

Case	Impacts	Description
E	\$0.4M	This multi-national corporation takes advantage of the center's facilities and expertise in surfactants. The company now employs several center graduates, and also benefits from applying center knowledge toward the enhancement of existing product lines. These product benefits could not be quantified.
F	\$4.0M	This relatively new member of IUCS applies center knowledge and technology toward reducing production costs. The impacts are pervasive, but the informant estimates about \$3M from improved product performance, and about 0.5M in saved research costs per year.

We include NSF IUCRC funding from the original 10-year lifecycle of Novel Surfactants and the recent two years under the Particulate and Surfactant Systems Center. IUCRC-specific investments totaled \$1.79M in actual dollars, or \$1.52M in real 1998 dollars.

Table 17: Summary of funding for IUCS

Fiscal year start	Total funding	NSF/IUCRC	Other NSF	Member fees and other industry	Other funding*
1998	\$520,000	\$100,000	\$105,000	\$315,000	\$0
1999	\$404,500	\$100,000	\$0	\$279,500	\$25,000
2000	\$389,854	\$70,000	\$14,479	\$305,375	\$0
2001	\$389,854	\$70,000	\$14,479	\$305,375	\$0
2002	\$292,000	\$100,000	\$0	\$192,000	\$0
2003	\$222,495	\$92,995	\$0	\$129,500	\$0
2004	\$306,495	\$92,995	\$0	\$213,500	\$0
2005	\$581,438	\$242,938	\$0	\$338,500	\$0
2006	\$673,000	\$93,000	\$0	\$580,000	\$0
2007	\$625,000	\$95,000	\$25,000	\$505,000	\$0
2008	\$1,256,150	\$340,000	\$0	\$859,500	\$56,650
2009	\$1,018,540	\$260,000	\$0	\$592,500	\$166,040
2010	\$1,392,492	\$130,000	\$370,029	\$680,000	\$212,463
TOTALS	\$8,071,818	\$1,786,928	\$528,987	\$5,295,750	\$460,153

*Note: Other funding includes state, federal, university, non-federal, and other

Most informants focused on impacts related to the center's more recent orientation toward green technologies. This emergent area of research has yielded mainly knowledge transfer and R&D efficiency benefits. Streams of benefits from product sales or process cost savings were not evident. We took impact estimates as an aggregate value in the current year, and then converted values to real 1998 dollars. Present value estimates were calculated using a 7% discount rate.

Table 18: Summary of IUCS impacts and metrics

	1998 dollars	Present value
Benefits	\$4,245,736	\$9,562,210
NSF/IUCRC program costs	\$1,522,690	\$3,429,390
Benefit:Cost Ratio		2.79:1
Net Present Value		\$6,132,820

Overall we find for every dollar investment in IUCS, the NSF receives \$2.79 in return. Subtracting the present value of NSF IUCRC investments from the present value of estimated impacts, we find a NPV of \$6.13M.

Representative Beneficiary Case

Organization E has been a member of the IUCS for 12 years. The company generates annual revenues of more than \$50B and employs more than 100,000 workers. The informant was very positive about his relationship with IUCS and the director in particular. The informant reported that the Center is used primarily for their equipment, instrumentation, and for their expertise on the molecular interactions of surfactants with proteins, lipids and other biomolecules. As such, IUCS could not be associated with a major role in any new products or processes, but the technology delivered by the Center plays a "small but subtle underpinning" on most of the company's new products and process changes.

As expected, the informant could not identify any products or processes that evolved directly from the Center research. Much of what they transfer from the Center contributes to the performance enhancement of existing products. The informant estimated the company has hired 5 or 6 people out of the Center, and likely saves one man-year annually on internal research costs. Because he couldn't identify specific products attributed to IUCS, he wouldn't even guess at the number of current employees associated with Center work. Assuming center students hired by Organization E held a minimum BA degree, we estimate²¹ \$50,000 saved in mentoring costs per each of five hires, or \$250,000 is saved mentoring costs. Further, savings of one full-time scientist is estimated at \$150,000 in the most recent year. Total savings to-date are \$400,000.

Outlier Beneficiary Case

Organization F is a medium-sized company and third-year member of IUCS. The company generates about \$3B in revenues and employees roughly 3,500 workers. Most of their business and technology is centered on sodium carbonate, which is marketed to consumer product manufacturers (e.g., odor absorbers, toothpastes, cleaners, etc.) and to industrial markets. According to the informant, the main benefit of the collaboration is the interaction with a very bright group of people on a subject of great interest across their business (e.g., nano-particulates, dispersions, interactions with proteins, enzymes, etc.). The technology has gone into many of their products in helping (minor) reformulations to be more effective at lower concentrations. The informant could not speculate on the number of products or portion of impact attributable to the center. When asked for a rough estimate of the center's effect on their \$3B annual sales figure—for example, 0.1%, 1%, or 10%--the informant believed that 0.1% was a good guesstimate, or about \$3M annually.

²¹ These estimates are supported by results of surveys conducted by the Semiconductor Research Corporation (SRC). Companies that hire students supported by SRC contracts estimate cost savings of at least \$100,000 per student. See http://www.src.org/member/students/mem_benefits.asp. We use \$100,000 for PhD hires, \$75,000 for MS hires, and \$50,000 for BA hires.

When asked him how many of their people were involved with Center-type changes, the informant emphatically said 2-3 full time people. The informant also stated that the cost avoidance for his lab on essential needs was about \$500K annually, or roughly 2-3 people at their fully loaded cost of about \$175K(per person) annually. Total impacts on Organization F are estimated between \$3M and \$5M to date.

Methodology and Data Collection Issues

Stage of development: While the original Novel Surfactants center had completed its 10-year cycle, the current IUCS research program on green chemistry is only a few years old. The center and its members are just beginning to explore this nascent area of research; the absence of large economic impacts—as in the IMS center and BSAC—is not surprising. We mainly find R&D efficiencies and general product enhancements, rather than whole new product lines or dramatic improvements in process efficiencies. A program evaluation must consider not only the center age, but also the stage of development for each of the research thrust areas.

Societal benefits: While the prospective benefits from IUCS knowledge and technology could be significant, there are also societal or environment benefits created by IUCS. This category of benefits did not emerge with either IMS or BSAC, and though very difficult to quantify, could reflect a more significant public return than any financial benefit. A program evaluation should attempt to capture in some form this type of societal benefit—for example, amount reduction in dependency on hazardous materials, or the number of non-environmental products displaced by IUCS-inspired products.

Conclusions

In the case of IUCS there have been no major new products for the informant, but one is in the pilot stages, a new “green” surfactant based on soybeans, and may produce significant new product and significant employment in 2012. One of the companies points to about \$3M in annual value attributed to changes in existing products. There is evidence of technology being utilized commercially, but no single, major breakthrough. The Center, however, exhibits very close interactions with its members and between members and students. In fact, two of the interviews took place as member representatives were preparing to visit the Center. Eight students have been hired from the Center and 6-8 people-costs have been avoided by Center use. In this case there is evidence of a high level of interaction and partnership stability as demonstrated by key inputs to the Center research activities, long average membership time (7.5 out of 12 possible years), high level of internships, generally very favorable comments by member representatives, and lack of negative comments by all of the interviewees.

F. Summary and Conclusions

The three IUCRC study cases provide significant insight into the feasibility of obtaining credible and persuasive estimates of the economic impact of IUCRCs. We followed Powell (2006) in aggregating our results across the centers. First, we adjusted benefits and NSF/IUCRC program investments for all three centers back to 1986; the first operating year of the earliest center in our study (BSAC). To do this, we took the real dollar benefits and investments for IMS and IUCS and discounted those values back to 1986 dollars using a 7% discount rate. We then aggregated all benefits and investments in 1986 values and brought them forward to 2010 using a 7% discount rate. Table 19 shows the results.

We found a total present value of realized impacts of \$1.28B, generated from NSF investments of approximately \$18.5M in present value in these three centers. Each dollar invested by the NSF helped to create \$69.4 in benefits, with a net present value of \$1.27B. See Table 19. The economic impact would have been considerably larger if we adopted a more systematic assessment of forecasted impacts during

our interviews. While we did find potentially sizable prospective benefits with some beneficiaries, we did not consistently capture these benefits, and when these benefits were captured, we did not apply a structured approach for evaluating their probability of actually occurring. We should note that forecasted impacts have been included in economic estimates for other federal programs (White & Connor, 2004; Pelsoci, 2005).

Table 19: Summary of impacts and metrics across the three study cases

	Combined I/UCRCs	IMS	BSAC	IUCS
Total benefits (present value)	\$1,284.0M	\$859.0M	\$415.4M	\$9.6M
Total NSF/IUCRC program costs (present value)	\$18.5M	\$3.6M	\$11.5M	\$3.4M
BCR =	69.4:1	238.3:1	36.2:1	2.8:1
NPV =	\$1,265.5M	\$855.4M	\$403.9M	\$6.1M

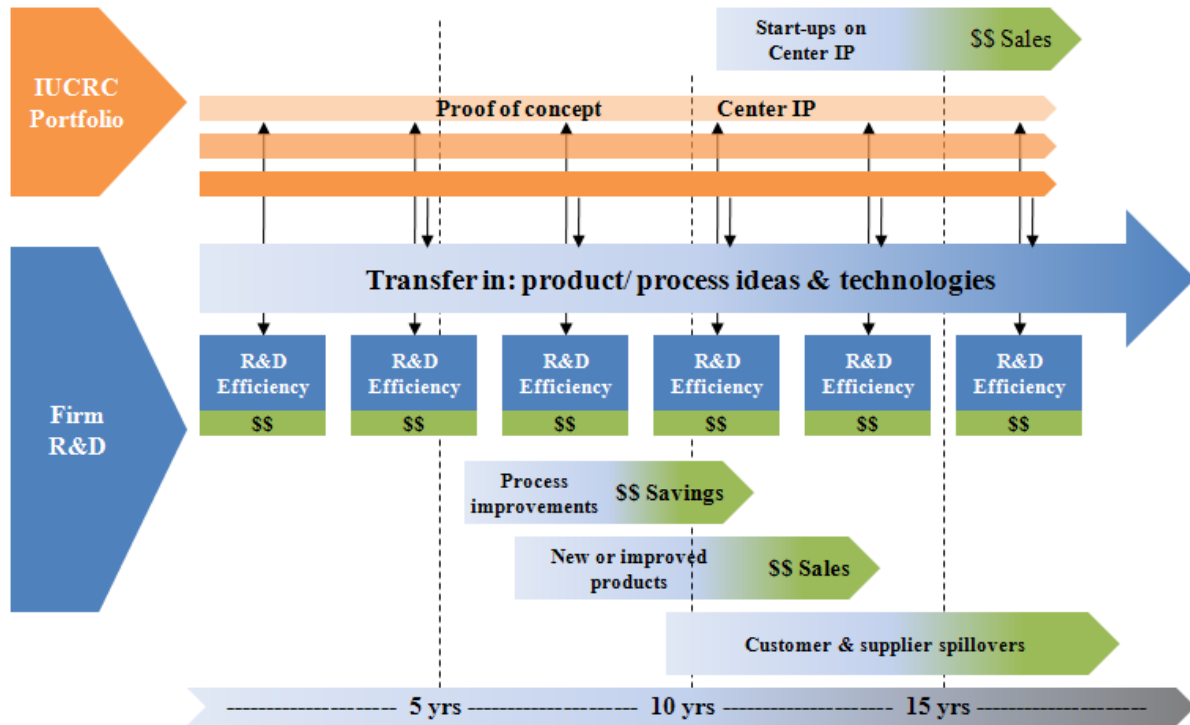
In cases involving significant product or process outcomes, the typical informant gave some rather than all of the credit for the development to the IUCRC. In these cases, the center served as a catalyst or key player in the development and commercialization of the technology, but typically as one of several actors in the development process. Further, we have considered here only realized benefits; both IMS and BSAC technologies have created streams of benefits that are forecasted to continue while the IUCS center prospective benefits are highly uncertain though admittedly potential quite large. In dealing with these streams of benefits we must resolve questions about the counterfactual scenario: could these benefits have occurred without the involvement of the center, and if so, would there have substantial delay in the commercialization process without the center’s involvement? How these questions are resolved will determine how much and for how long these ongoing benefits can be linked back to a particular center.

In the next section we review the types of economic impacts we discovered in the case studies, as well as the practical and methodological barriers we experienced in obtaining this information.

1. Impact Assessment

Based on our interviews with nominated beneficiaries, it is apparent that members and to some extent non-member firms are receiving benefits from IUCRCs they are affiliated with or have had interactions with. Clearly, some of the impacts firms report and value quite highly, including access to pre-competitive research that influences the direction of corporate research strategy, are difficult if not impossible to translate into quantifiable economic estimates. However, with the promise of confidentiality and persistent encouragement from our interviewers, most of the respondents included in our assessment were able to provide quantitative economic estimates of at least some of the impacts they received. Figure 8 provides a graphic representation of the kinds of impacts these firms typically reported.

Figure 8: Model of the Types of IUCRC Impacts



- a. R&D Cost Savings and Efficiencies. A number of respondents indicated that center research had a significant and quantifiable impact on their R&D operations. As Figure 8 demonstrates, these impacts tend to be realized from the ongoing research portfolio soon after the research is done and could be monitored on an ongoing basis. These impacts tended to be reported in terms of cost savings, cost avoidance or related efficiencies. Consistent with data provided via the IUCRC Evaluation Project’s Process/Outcomes Questionnaire data, some respondents reported cost avoidance savings based on not having to address certain issues in-house or because internal projects were able to complete their objectives more quickly because of center research. Other respondents indicated that they saved money by recruiting center students either because of improved recruitment processes and/or because center students were significantly more productive when they began their jobs.

For instance, the six member organizations interviewed for the Center for Advanced Surfactant Studies were found to realize roughly \$3,000,000 in returns related to R&D efficiencies over the past five-year period. This estimate included between \$400k-\$800k in cost savings related student hires and over \$2M in avoided person-year costs by leveraging center research capabilities rather than conducting research internally.

- b. New and Improved Processes. Some respondents indicated that center research had a significant and quantifiable impact on the development of new or improved processes. As the lower part of Figure 8 illustrates, the typical commercialization event happened after a number of years of center research, a subsequent “proof-of-concept” finding or prototype, followed by several years of corporate R&D. Since these technologies tended to be deployed internally within the adopting firm, they were described in terms of operational or production cost savings. Less frequently,

firms reported new processes based on center IP or that they developed internally that could be sold or licensed to customers and result in sales income and/or job growth. Since it takes so long for these developments to evolve from center research and then be commercially deployed, respondents often described technological breakthroughs that were just in the process of being deployed or about to be deployed. Significantly, in these cases respondents could only provide forecasts of economic value of the process (See Figure 8).

Nonetheless, economic value of these kinds of impacts was often quite significant. For instance, a member of the Center for Intelligent Maintenance Systems has applied center-related technologies to various processes through its global operations. The firm estimates that its involvement with the center was at least partially responsible for these developments and enabled an estimated \$500,000,000 annually in returns related to improved productivity and avoided maintenance costs.

- c. New or Improved Products. Some respondents indicated that center research had a significant and quantifiable impact on the development of new or improved products. As the top half Figure 8 illustrates, these product-related impacts tend to follow a similar development trajectory to the process developments: commercialization after a long period of center and corporate research; emergent commercialization requiring forecasted estimates of economic value. If the product was based on center IP (see “IP” event on Figure 8), the commercialization might happen more quickly. Product impacts were more likely to be quantified in terms of increased sales and/or job creation.

Once again the economic impact of these impacts can be significant. For instance, a start-up company based on ideas and technology from Berkeley Sensor & Actuator Center generated an estimated \$90M in revenue in 2009. The founder and former BSAC student anticipates strong growth in the coming years. The company employs about 120 workers in the United States.

- d. Spillover Impacts for Technology Adopters. As the technology impact literature suggests, significant economic impacts can accrue for the adopters of new or improved processes and products (Jaffe, 1996). Our pilot assessments provided some evidence that these kinds of impacts are also triggered by center research and subsequent commercialization efforts. Since these impacts do not happen until after the technology has been marketed and deployed to end users, they are also characterized by a great latency (See “customer productivity” on top of Figure 2) but can be of significant value.

For instance, a single start-up food processing firm licensed technology that originated in the Center for Advanced Processing and Packaging Studies. Importantly, this played out over a 15-year period. The firm employs around 40 workers and is estimated to have earned more than \$7M in revenue in 2010. To the extent that this technology is licensed to additional processors, these impacts could be multiplied many-fold.

2. Data Collection and Methodology Issues

On balance, the data collection strategy we used appeared to be effective and helped us collect credible impact data. Below we describe different elements of that strategy and discuss what strategies and practices appeared to work well and what might need to be improved.

- a. Targeting Mature IUCRCs. Although the centers included in this assessment were selected because they were thought to be very productive and thus are not representative of all centers,

the strategy of targeting established, mature centers for impact assessment efforts appeared to pay off. It was apparent, even with these highly successful centers, that center research takes a long time (probably 5-10 years) to be translated into commercially viable products and processes. This conclusion was reinforced by the fact that the relatively mature Surfactant center primarily demonstrated R&D benefits in large part because the program of research firms were excited about was only 2 years old.

- b. Gaining Cooperation of Center Directors and Staff. Directors quickly saw the value of documenting impacts and were very cooperative in our data collection efforts. All five directors/PIs recruited for this project (two for pilot and three for study) were very willing to nominate potential beneficiaries, contact them on our behalf, and encourage them to cooperate in the study.
- c. Gaining Cooperation of Nominated Beneficiaries. Since all beneficiary firms who were contacted by center directors about our study agreed to cooperate in our data collection effort, this referral process appeared to work well. We suspect this level of cooperation was related to the firms' ties to the center and relationship with the director. In contrast, we were not able to get our calls returned by two firms included in our pilot assessment that simply licensed center technology and had no personal connection to the center or director.
- d. Obtaining Impact Estimates and Confidentiality. Most but not all of the respondents were willing to at least attempt to estimate the economic value of various R&D and process and product impacts realized by their firm. However, in some cases, informants made it clear that it was too early or the impacts were too diffuse to be able to estimate their impact in economic terms. Based on conversations with informants, allowing them to maintain confidentiality contributed to their willingness to share economic estimates with us. Even with this assurance, one of the pilot firms was only willing to respond to and give information in writing and then declined to clarify the information they had already provided. Several of the informants indicated, even if they were willing to share the impact estimates with us without confidentiality, they would have to go through a long protracted approval process within their firm to get permission to do so. Most indicated they would be reluctant to go through this process. The up-side of our strategy is we were able to get estimates from almost all potential beneficiaries. The down-side is we are unable to share the success stories of specific successful members. However, it is worth noting, that at least some of the informants indicated they might seek such approval so that we could highlight the contribution the center made to their company. In addition, we were sometimes able to obtain economic data on small businesses or start ups from archival business sources and data bases.
- e. Collecting Data via Phone Interviews. Besides our initial piloting interview, all interviews were conducted by telephone. The telephone interview format appears to work very effectively. Data collected through this interactive format has been much more useful and complete than the questionnaire-based format used by local evaluators. However, there were some limitations to this methodology. First, it typically limited the data gathering session to no more than 30 minutes. As a consequence, it was sometimes difficult to establish rapport with the informant and get a complete summary in this time frame. Second, sometimes the quality of the phone connection, background noise, and/or the heavy accent of the informant made it difficult to understand some of the highly technical information provided by the informant. The fact that interviewers did not know the informants and the technical content of the center's research necessitated multiple requests to clarify the information provided. As a consequence, we could see the benefit of having interviews done in-person and/or by

someone who was familiar with the center and the informant.

- f. Targeting “Outlier” Beneficiaries. Our strategy of targeting outlier beneficiaries rather than attempting to collect data from every potential beneficiary also seemed to pay off. Our data collection efforts targeted a relatively small percentage of the center’s members and beneficiaries; we interviewed 5 to 6 beneficiaries for each center. For the centers included in this assessment, we obtained impact data from roughly 15% of their membership. Nonetheless, we were able to obtain economic impact estimates that frequently justified many times the investment NSF IUCRC had made in that center. In one case the impact appears to justify multiple years of IUCRC program-wide investment. As a consequence, we believe that a strategy of collecting impact data for a targeted but small subset of all members is worth pursuing.
- g. Validity and Credibility of Information provided. In most cases, the informant was able to very clearly document impacts and the causal path that led from the center’s research efforts to the R&D or commercialization activity and to the economic estimate they provided us. However, making clear causal attributions to center research and valid estimates were problematic in some situations.
 - i. *Long causal paths and forecasted impacts.* A major challenge in documenting the validity of various impacts relates to the fact that it often took many years for some impacts to be realized. Since some technologies had not been deployed or were just being deployed, respondents often gave us *forecasts of future impacts* that were based on some assumptions about the technology, market size and/or the demand for the product. Obviously, these are simply estimates and must be taken with “a grain of salt”. As a consequence, we decided to keep separate records for realized economic impacts and forecasted impacts that were speculative. Under ideal circumstances, a follow up would be conducted to confirm if forecasts were accurate.
 - ii. *Long causal paths and awareness of impacts.* There is a flip-side to the problem caused by long development times – current informants may have limited or no knowledge of the connection between center research and firm activities that were in the pipeline some years before they became involved in the center. Many of the breakthroughs we followed were of fairly recent vintage. Because firm representatives have a fairly high turnover, we suspect that our informants probably were unaware of impacts that had percolated up within the firm several years ago and were now fully implemented.
 - iii. *Multiple causal factors.* When we asked informants about the center’s role in a specific technology or breakthrough they would often cite multiple factors: some attributable to the center, some to the developing firm, and some to work by outside groups. Appendix 16-*Possible paths to commercialization for IUCRC ideas and technologies* illustrates several representative causal paths that we observed. At one extreme, center research led to IP that was then licensed to a firm (See Appendix 16, 1a). At the other extreme, center research led to knowledge, that led to investment of more research by a non-member firm or investigators, that led to joint IP, that was then licensed to another non-member firm (See Appendix 16, 4). The literature documents that there is a large and continuing debate about what standard a public program should use before it claims “credit” for a technology development (Watkins & Schlie, 2006). Thus, one must be careful in how much credit one gives a center when multiple agents are involved over a long time. In all the cases we described in this report, informants indicated the center had at least a “significant” but in many cases not exclusive impact on the development.

- iv. *Impacts that cannot be quantified.* It is important to not lose sight of the fact that some impacts are arguably non-quantifiable in economic terms yet can have significant implications on a firm (for example, influences on a firm's technology roadmap, R&D staff's absorptive capacity, general competitiveness, or brand image) (Salter & Martin, 2001; Bozeman et al., 2001). We did not pursue these impacts but caution that it would be a mistake to completely ignore them in future analyses.

IV. Conclusions and Implications for Future Assessments

Objective: *Based on our findings make recommendations for a strategy for routinizing the collection of such impact data on an ongoing basis.*

A. Conclusions

Although there appears to be value to the current IUCRC evaluation strategy, those evaluation efforts have tended to document R&D impacts more than actual commercialization impacts and have infrequently provided economic estimates of the value of these impacts. Our highly targeted, interview-based pilot assessment of several mature IUCRCs and nominated beneficiary firms has produced a much higher yield of documented economic impacts. Our analyses strongly suggest that the IUCRC program and at least some individual centers are having a measurable economic impact on member companies and other external beneficiaries. Although no assessment effort will be able to quantify the economic impact of all the important impacts of the IUCRCs, our new data collection strategy appeared to work well and documented realized impacts that could be estimated in economic terms derived from a mix of R&D efficiencies, internal cost savings derived from implementing center-derived process improvements and/or new processes, product improvements and/or new products, and spillover benefits derived by firms that purchase and/or license center-derived technology. We were also able to obtain forecasts or future impacts that might be validated with subsequent follow up assessments. Since we picked centers that were judged to be "successful", we do not know how representative these findings are. However, if one takes a portfolio approach to evaluating the IUCRC program at a national level, these findings alone, based on 16 members at 3 mature centers, appear to provide sufficient justification for NSF's investment in the IUCRC program over many years. Nonetheless, given the current policy discussion about the value of government-funded STI partnership programs, there would appear to be great value to the IUCRC and individual centers to be able to document these kinds of impacts in a systematic way and on an ongoing basis.

B. Recommendations

1. Continue the existing IUCRC evaluation effort but modify the responsibilities of on-site evaluators to include collection of economic impact data.

The current evaluation protocol, based on centralized collection of output and outcome data via surveys and the work of on-site evaluators and the periodic collection of "technology breakthroughs" via a separate mechanism, appears to do a good job of providing center directors and NSF with feedback on the extent to which various program objectives are being achieved including its partnership and capacity building objectives, as well as providing early evidence that firms are benefiting from center involvement. However, we believe that the on-site evaluator is in an almost ideal position to also collect the kind of economic impact data we collected in this study. The typical evaluator has an existing rapport not only with the center director, but also with the center's members that should facilitate collection of valid and detailed estimates of impact. Since the IUCRC program decided to drop one of the evaluators responsibilities ("exit interview" data), one could simply substitute the new impact assessment responsibilities for these duties. Thus, we recommend that the evaluator's responsibilities be changed to

include expanded collection of economic impact data. The changes would focus on modification to the Process/Outcome Questionnaire and an expanded responsibility to conduct targeted beneficiary interviews. We believe these changes could be implemented by the IUCRC Evaluation Project with input from a select team of evaluators.

2. Modify the Process/Outcome Questionnaire to emphasize relatively proximate quantitative economic impacts.

Member firms tend to notice and report R&D efficiency benefits relatively quickly and to report them when they respond to the Process/Outcome Questionnaire. However, they infrequently provide quantitative economic impacts estimates of this benefit. We recommend that this oversight be remedied by adding/modifying questions that will help member respondents provide these estimates more readily.

3. Develop a standardized protocol and training system that facilitates collection of economic impact data by local evaluators.

In order for impact data to be collected efficiently and effectively by the on-site IUCRC evaluators, they will need a detailed and easy-to-follow data collection protocol including standardized correspondences to use with directors, potential beneficiaries, and others and an interview script. The IUCRC Evaluation Project should assume the responsibility for developing, disseminating and aggregating these materials and insuring that individual evaluators are well prepared to reliably collect this information. Some general principles and guidelines that should undergird these assessments include the following:

- Impact data collection should become a higher priority for evaluators at centers as they become more mature with an emphasis on Phase 2 and 3 of NSF funding.
- Assessment should emphasize data collection via personal interviews of targeted high impact beneficiaries.
- A method for logging reports of forecasted impacts will be developed so that the evaluator can conduct follow-up interviews with informants in order to validate these estimates.
- A method for documenting the causal impact of IUCRCs, particularly when other factors may be involved, should be developed.
- Since centers graduate from the IUCRC program and these mature centers are likely to be promising sources of transfer-derived economic impact, provisions must be taken to include graduated centers in this procedure.

4. Develop a simple and compelling methodology for reporting the impact data to important stakeholder groups.

The IUCRC Evaluation Project should also assume responsibility for developing a standardized set of reporting forms and reports. Some general principles and guidelines that should undergird these assessments include the following:

- An “IUCRC Outcome and Impact Dashboard” data presentation methodology should be developed to help assist in decisions about Phase 2 and 3 awards
- Impact indices should include a mix of economic indices like those used by NIST ATP (e.g., Benefit:Cost ratio, Internal Rate of Return, Net Present Value) and/or ERC program or other standard indices. Any final indices used should be vetted by NSF IIP to insure that they meet program needs
- Impact data will be reported to both the local center and to NSF in a way that protects the confidentiality of the informants
- Steps should be taken to obtain appropriate OMB and/or IRB approval for the program-level and center-level data collection activities

5. *Link the revised assessment activities with the efforts to periodically collect “technology breakthrough” cases.*

We were able to produce economic estimates of impact, to a large extent, because we provided our respondents with confidentiality. What appears to be lost through this approach are the success stories that can be very compelling to external stakeholder groups like congress and the general public. Our sense is that informants are comfortable in telling confidential economic estimates or non-confidential “success stories” with no economic estimates. Since the latter can still be very valuable, we recommend that efforts be taken to coordinate the regular and routine collection of economic impact data with the separate effort to periodically attempt to document the success stories as documented in the *Compendium of IUCRC Technology Breakthroughs* in the past.

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Appendix 1: Benefit:Cost methodology impact metric formulas

Internal Rate of Return (IRR): the value of the discount rate that equates the net present value of the stream of economic benefits created by the center to zero. The stream of benefits begins at the inception of the center and runs to a terminal point; in this case, 2010 (for year-to-date benefits) and 2015 (to include prospective benefits).

$$IRR = NPV = \left[\frac{(B_o - C_o)}{(1+i)^o} \right] + \dots + \left[\frac{(B_n - C_n)}{(1+i)^n} \right] = 0$$

Benefit : Cost ratio (B:C): the ratio of the present value (in initial-year dollars) of all measured benefits to the present value of all measured costs. A ratio larger than 1.0 indicates benefits have exceeded costs. To determine present values, a discount rate (r) of 7% is used, consistent with guidelines set by the Office of Management and Budget in Circular A-94 (1992).

$$B:C = \left[\frac{\sum_{i=0 \text{ to } t=n} B_t}{(1+r)^t} \right] / \left[\frac{\sum_{i=0 \text{ to } t=n} C_t}{(1+r)^t} \right]$$

Net Present Value (NPV): the difference between the present value (in initial-year dollars) of all measured costs subtracted from the present value of all measured benefits.

$$NPV_{initial\text{yr}} = B - C$$

NPV for the current year: An adjustment of the NPV for the initial year into current year dollars.

$$NPV_{present\text{yr}} = NPV_{initial\text{yr}} \times (1+r)^{(present\text{yr}-initial\text{yr})}$$

Appendix 2: Compendium coding scheme

code	Type: type of research output or success
1	new knowledge (e.g., properties or characteristics of materials) that could have broad implications for an industry or society
2	new research method, technique, tool, or other technology that could help accelerate technological progress and could have broad implications for an industry or society
3	[process] new or improved method, technique, tool, device, software or algorithm that works with and/or improves an existing commercial process
4	[process] entirely new process that could replace or disrupt an existing commercial process
5	[product] new subsystem or component that works with and/or improves and existing commercial product
6	[product] entirely new system or product that could replace or disrupt an existing commercial product
99	undetermined
code	Stage: degree of closeness to commercialization ²²
1	Basic principles have been observed and/or general applications speculated
2	Commercial applications or proof of concept shown under experimental conditions
3	Commercial applications or proof of concept shown under simulation or relevant environment
4	Technology or concept is currently being implemented for commercial applications
5	Technology or concept has been commercialized or applied to commercial products
99	undetermined
code	Adopter: who or what is using or intends to use the innovation
1	no adopters or potential adopters named or speculated
2	potential adopters named: general sector, industry or group of firms
3	potential adopters named: specific firm(s) or institution(s)
4	adopters named: general sector, industry or group of firms
5	adopters named: specific firm(s) or institution(s)
6	adopters named: startup or spinoff firm
99	undetermined
code	Value: tangible economic benefits are associated with the innovation
1	No attempt estimate economic benefits or value
2	Potential economic impact is speculated in general nonfinancial or societal terms
3	Potential economic impact is speculated in financial terms
4	Realized economic impact is speculated in general nonfinancial or societal terms
5	Realized economic impact is provided in specific financial terms
99	undetermined

²² Coding influenced in part by Technology Readiness Assessment Deskbook, Department of Defense, July 2009

Appendix 3: Overview of methodology

1. **Center Sample:** Data collection will target three mature IUCRC (8 years old or older) where there is persuasive anecdotal evidence that the center has produced research and/or technology that had the potential to have a significant commercial and/or economic impact. Decision on which Center to target should be based on recommendations of IUCRC key informants including: NSF program manager, center directors, recommendations and/or on success stories contained within the 2009 Compendium of Technology Breakthroughs.
2. **Center Key Informants:** Key informants at the nominated center (e.g., director, IAB reps or chair, inventing faculty member) will be asked to identify potentially high impact findings, technology and/or events (e.g., start up or spin out firm created) that have occurred based their IUCRC activities and the organizations that they believe were primary adopters and beneficiaries.
3. **Center Beneficiary Sample:** Based on nominations from various key informants, three to five center members and/or other beneficiaries (e.g., a start-up or spin out firm) will be identified for further data collection.
4. **Data collection:**
 - a. **Interviewers:** Interviews will be conducted by Drs. Denis Gray, Drew Rivers at NCSU and George Vermont, Expert within NSF IIP. Given Dr. Vermont's extensive experience conducting industry interviews, he will be the lead interviewer during the face-to-face impact interviews.
 - b. **Pre-Interview Screening:** A telephone interview will be conducted with a contact individual at the nominated beneficiary organization. The focus of this interview will be to confirm that a significant center-based technology transfer event has happened and to confirm the willingness of the organization to participate in our assessment efforts.
 - c. **Impact Interview:** A face-to-face interview will be scheduled with adopters/beneficiaries that have passed the preliminary assessment screening step. Proximity (to each other and to interviewers) will be one factors considered in deciding on firms to conduct interviews at. As needed, multiple interviews will be completed with key informants within the organization to obtain estimates about the impact of the IUCRC-related benefits.
 - d. **Interview Questions.** Interview will focus on center-triggered technology (technology based on center research but formalized within the beneficiary organization) and center-based technology (technology or IP technology created within the center). Appendix A contains a draft of the questions to be used as part of an interview guide. The focus of the interviewing will be on the impact of IUCRC based technology on the company (Appendix A, Question #2).
 - e. **Specialized data collection:** Efforts to collect data from small firms, start ups and spin outs should capitalize on methodology and questionnaires used by George Vermont for SBIR/STTR assessment.
5. **Timeline:** Data collection will begin in August, 2010 and a preliminary report based on the first case will be prepared and delivered early fall, 2010.
6. **Final Report:** A final report will be prepared by Drs. Gray, Rivers and Vermont that will provide information about the following:
 - a. Description of specific product, process, service or related breakthroughs attributable to IUCRC research.
 - b. Quantitative estimates of the economic and related impact of those inventions and activities.
 - c. Description of the challenges and problems encountered in obtaining the information we intended to collect.
 - d. Recommendation about the feasibility and desirability of extending this kind of data collection effort on a broader scale.

Appendix 4: Email to directors introducing project

[Director]

I am in the process of beginning a project with two colleagues that involves developing a methodology for evaluating the economic impact of knowledge and technology transfer from IUCRCs. At this stage we're conducting pilot study to assess the feasibility of an economic assessment in the IUCRC program.

As part of this preliminary stage we're working to identify firms or organizations that have benefitted significantly from IUCRC research and technology. We're targeting 3 IUCRCs for this stage and would like to ask each director to help us identify 3 to 5 beneficiary firms and organizations with whom we could follow up with a confidential interview about their benefits.

We think your center is a great candidate for this. Please let me know if you are willing and able to help us out. If so, I will send additional information and schedule a call with you and our team.

Look forward to hearing back.

[Project member]

Appendix 5: Guidelines for identifying beneficiary organizations

IUCRC Impact Study Guidelines for Selecting Firms/Organizations for Impact Assessment Interviews

Goals:

1. Identify firms that you believe have realized the greatest economic impact from IUCRC research and/or technology;
2. Attempt to obtain a more detailed, preferably quantitative estimate of impact

Criteria for selecting firms:

- Any firm/organization that you suspect used previous or current IUCRC research and/or technology to improve and/or create products, processes or services.
- Firm/organization could be an IUCRC member, an ex-IUCRC member, a start-up or spin-out based on IUCRC technology, or even a non-member that has acquired a license to use IUCRC technology.
- You believe firm/organization's efforts are far enough along that they have already realized some economic benefits by virtue of cost savings, sales, improved performance, etc.

Examples of Types of Impacts

Impact could be technology created within the center or research that leads to the creation of IP or commercialized products and processes within the firm. Examples include:

- the discovery of new knowledge (e.g., regarding the properties or characteristics of relevant materials) that led industry in new promising directions
- a new research method or technique that helped accelerate technological progress
- a new measurement tool, device, software, or algorithm that works with or impacted an existing commercial process (either whole or in part)
- an entirely new process that replaced an existing process
- a new subsystem or component that improved an existing product
- a whole new system or product that replaced an existing system or product
- a whole new system or product that opens a new market or industry
- other developments that might have commercial value like creation of an accepted industry standard

Sources of Information on Potential Beneficiary

A variety of sources may lead you to identify a firm/organization as a potential beneficiary

- Discussions you have had with firms/organizations
- Center PIs who are familiar with member applications of center knowledge and technology
- Examples you have documented in previous Center's annual reports
- The Center Evaluator's report, including member survey data and center structure data
- Items you have nominated for the Compendium of Technology Breakthroughs (produced by Craig Scott)
- University Technology Transfer Office (for patent licensees)

Appendix 6: Guide for first contact briefing with center director

Background: The NSF is interested in developing an evaluation method to assess the economic impacts associated with the IUCRC program. We are asking directors at several IUCRCs to help us identify 3 to 5 firms that they believe have benefited significantly from the transfer of knowledge and/or technology from the center. The center research or technology they have benefited from may have been performed at any time during the center's existence. The purpose of this handout is to give you some guidance on the type of firm that might be a good candidate for our study.

Types of Beneficiary firms. Since we're interested **quantifiable, already realized economic impacts**, we are primarily investigating knowledge and/or technology that you suspect a firm used to improve or create products, processes or services. The 'firm' could be an IUCRC member, an ex-IUCRC member, a start-up or spin-out based on IUCRC technology, or even a non-member that has acquired license to use IUCRC technology.

Criteria for Selecting Firms

The IUCRC could have economic impact on firms through various channels, including IP created within the center or research that leads to the creation of IP or commercialized products and processes within the firm. Specific examples include:

- the discovery of new knowledge (e.g., regarding the properties or characteristics of relevant materials) that points industry in new promising directions
- a new research method or technique that could help accelerate technological progress
- a new measurement tool, device, software, or algorithm that works with or impacts an existing commercial process (either whole or in part)
- an entirely new commercial process that could replace an existing process
- a new commercial subsystem or component that improves an existing product
- a whole new commercial system or product that replaces an existing system or product
- a whole new commercial system or product that opens a new market or industry

What we plan to do. We recognize that you may only have a general idea about how or if a firm may have benefited from your IUCRC work. As a consequence, we'd like to talk directly with firms that you believe are beneficiaries of IUCRC knowledge and technology. Their participation will be voluntary and we will not share information they provide us without their permission. Depending on the type of knowledge or technology, we'll ask a firm representative about specific impacts, like follow-on spending, related person-years employment, total sales, cost savings to the firm, cost savings transferred to customers, and similar economic impact questions. We realize that precise information is likely to be proprietary, too difficult to develop, or both, so rough estimates will be perfectly adequate for our purposes.

Reference sources or materials that could help identify possible impact cases include;

- The director's own knowledge and experience with the Center and its members
- Items reported in the Center's past annual report
- The Center Evaluator's report, including member survey data and center structure data
- Items included in past copies of the Compendium of Technology Breakthroughs (produced by Craig Scott)
- Center PIs who are familiar with member applications of center knowledge and technology

University Technology Transfer Office (for patent licensees)

Appendix 7: Draft guide for interview with center director

Note: Ask about each impact separately. Obtain 3-5 impact cases, if possible. At this point look for general understanding of the knowledge/technology before interviewing the firm contact. Remember to ask for any written documents or weblinks that may relate to successes.

1. Taking them one at a time, can you identify 3-5 firms that you think have realized quantifiable economic impacts from center research? Who is the beneficiary firm? How is the firm related to the Center—e.g., member, non-member, start-up?
2. How do you think the firm has benefitted?
3. Can you give a short, layperson's description of the knowledge or technology that has had quantifiable, already realized economic impacts? (If other than basic knowledge, ask:)
 - a. How does this relate similar technologies on the market—e.g., incremental improvement, whole new technology, replacement technology, etc.
 - b. What are the benefits over existing technologies on the market?
4. Can you explain the technology path or trajectory and how the Center fits in? Did the knowledge or technology originate within the Center?
 - a. When did the firm adopt the knowledge or technology?
 - b. At what stage of development did the firm adopt it?
 - c. In your opinion, would this development have happened without the center's research?
5. What do you know about the impact of the knowledge or technology on the firm—for example, impact on processes, products, services, new hires, total sales, etc.? At this point we're only looking for a general sense of the impact before we talk with the firm representative. [seek written documents and/or weblinks].
6. Who can we contact within the firm for a short interview about the realized economic benefits related to the IUCRC knowledge or technology (e.g., profits, unit sales, cost savings to customers, etc)? [Get name, email and telephone number]. We need an introduction to this individual. If I send you a generic "heads up" email can you follow up with your contact?
 - a. Do you think this firm representative will be forthcoming in sharing impact-related information, even in general, rough estimate terms?

Appendix 8: Draft email from center director to beneficiary

Dear [Beneficiary]

I am writing you to give you a heads-up and an introduction to [researchers] who will be contacting you soon concerning your involvement in [Center] and benefits you may have realized. Researchers at NC State are working on a grant from the National Science Foundation to determine the feasibility of estimating the economic impact of Industry/University Cooperative Research Centers.

[Center] has been selected as a test case. The [researchers] are interested in talking with beneficiaries of [Center] research, and would like to talk to you about participating in this effort and potentially participating in an interview.

By copy of this email, [researcher] will follow up with you. I encourage you to take part, as this study could potentially influence policy on industry-university collaboration.

Sincerely,

[Center Director]

Appendix 9: Draft email from project team to beneficiary

Dear [Beneficiary]

I wanted to follow-up on [Center Director's] email to you regarding our study of economic impacts of the National Science Foundation's (NSF) Industry-University Cooperative Research Center IUCRC program.

Our project is a pilot study intended to determine the feasibility of estimating the economic impact of IUCRCs on firm beneficiaries. The [Center] is one of three IUCRCs included in this feasibility study. [Director] identified your firm as an organization that may have benefitted from their research.

The NSF is especially interested in the measurable economic impacts of IUCRCs, but we realize that many, perhaps most, of these impacts are very long-term and difficult or impossible to measure in strictly economic terms. So, we're asking companies who have benefited from working with IUCRCs to estimate (roughly) for us the impact that Center "outputs"—ideas and technology--have had on the company and its customers. We realize that precise information is likely to be proprietary, too difficult to develop, or both, so rough estimates are perfectly adequate for our purposes.

We'd like to schedule a brief phone interview with you to discuss the nature of our study, what kinds of impacts we are looking for and see if you are willing to help us out. If you decide to participate in our study, we can conduct our interview right then or schedule it for a separate time. We will not share information specific to you or your company outside the research team without your permission.

Please let us know when would be a good time to talk or we will follow up with you by phone.

Regards,

[Researcher]

Appendix 10: Guide for pre-screening interview with beneficiary

General Information: Company Name; Center Name; Participation Years; Company Contact; Title/Position; E-Mail Address; Date of Interview; Interviewed By

Introduction. Thank for agreeing to talk with us. We're investigating the feasibility of assessing the economic impact of ideas and technologies emerging from industry-university cooperative research. [Director] at [Center] suggested that your organization may have benefitted from center research and/or possibly taken research into commercialization. The purpose of this phone call is to explain the nature of our study, to confirm that your organization has realized commercial benefits from ideas or technology that could be attributed whole or in part to the [Center] and see if you're willing to share this information with us. Also, if some of the information we ask about is contained in written documents or web-based sources, please direct us to those sources.

Nature of the study. The National Science Foundation (NSF) has contracted with researchers at North Carolina State University to assess the feasibility of evaluating the economic impact of technology emerging from the Industry-University Cooperative Research Center (IUCRC) program. This pilot study involves 3-4 IUCRCs and several organizations that might have benefitted from ideas and technologies from those IUCRCs. Our report will highlight documented quantifiable outcomes and impacts and make recommendations about the feasibility and practicality (e.g., cost) of collecting this kind of data on a larger scale on a regular basis in the future. We'd like to report specific successes to the NSF; however we will not identify you or your company without your explicit permission.

Part I: Screening Question

1. Has your firm/organization benefited from its involvement with [Center]? If so, how?
 - a. Can you describe briefly, in layperson terms? (If necessary, clarify as product, process, service, component, tool, software, method, etc.)
 - b. Have these ideas and/or technologies reached commercialization (or commercial application)? If so, how long have they been in commercialization?
 - c. Would you be able and willing to provide estimates of the economic impact (e.g., sales, personnel growth) on your firm/organization? We realize that precise information is likely to be proprietary, too difficult to develop, or both, so rough estimates are perfectly adequate for our purposes.

Research note: IF THE ANSWERS PROVIDED BY THE RESPONDENT APPEAR TO CONFIRM THAT THEY HAVE BENEFITTED IN SOME SIGNIFICANT WAY THEN ASK

- d. Thanks that is very interesting. I would be interested in including information about this development in our study. We would need some detailed information about this. Would you like us to go into our more detailed questions about this now or would you like to set up a separate time to talk?

Research Note: IF THEY WANT TO KEEP GOING, BEGIN WITH PART II OF THIS INTERVIEW

- e. Read Informed Consent
- f. Begin full interview

Research Note: IF THEY WANT TO SCHEDULE SEPARATE INTERVIEW ASK THEM TO CONFIRM A DATE AND TIME.

Appendix 11: IRB informed consent form

Informed Consent- Interview (at the start of the interview)

The National Science Foundation (NSF) would like to understand the feasibility of evaluating the economic impact of ideas and technologies emerging from the Industry-University Cooperative Research Center (I/UCRC) program. To this end, we are interviewing several organizations from 3-4 IUCRCs and collecting information on benefits they have received from those IUCRCs. No identifying information will be included in our report back to the NSF. Your name and that of your organization will remain confidential. The NSF may be interested in reading case summaries that highlight organizations that have received exceptional benefits from an IUCRC. If we think your organization would make a good case study, we will ask for your explicit permission to do so. If you agree, we will share a draft of our written summary for your review and approval, before sharing it with the NSF.

This interview will take about 45 minutes. I'd like to remind you that your participation is voluntary, and there is no penalty to you for not participating. During the course of the interview we might ask a question that involves strategic information about your business that you'd prefer not to disclose to us, or you'd prefer we keep confidential upon disclosure. Alert us to the sensitivity of this information and your responses to those questions will remain confidential; we will not share any specific information outside the research team.

While there will be no immediate and direct benefit to you from participation, knowledge may be gained that may inform public policy on industry-university collaboration, and/or may result in procedures that help organizations assess the impact of their R&D sponsorships.

If you have questions about your rights as a research participant, please contact the North Carolina State University Institutional Review Board for the use of Human Subjects in Research at 919-515-4514.

Do you agree to participate in the interview? _____ (PI initial that verbal consent obtained)

Do you prefer that we keep your name confidential, so that it will not appear in any written or verbal reports related to this study? Yes / No (PI, check Yes if confidentiality in effect)

Appendix 12: Guide for interview with beneficiary

Our project for the National Science Foundation (NSF) is a pilot study intended to determine the feasibility of estimating the economic impact of Industry/University Cooperative Research Centers (IUCRCs) on organizations and their customers.

The NSF is especially interested in the measurable economic impacts of IUCRCs, but we realize that many, perhaps most, of these impacts are very long-term and difficult or impossible to measure in strictly economic terms. So, we're asking companies who have benefited from working with IUCRCs to estimate (roughly) for us the impact that Center "outputs"--ideas, technology, and student hires--have had on (a) the company and (b) the industry. We realize that precise information is likely to be proprietary, too difficult to develop, or both, so rough estimates are perfectly adequate for our purposes.

Let's talk about the [[insert idea/technology from director or screening interview](#)].

Research Note: Depending on technology type, go to outline for:

I. Established Firms: Product or product-related technology

II. Established Firms: Process or process-related technology

III. Start-ups (with no realized sales or revenues to-date)

I. Established Firms: Product or product-related technology

1. Confirm understanding of the product/technology.
 - a. Is this a product or a component of a larger product?
 - b. What are the benefits over existing, similar products on the market?
2. How does this technology relate to the center?
 - a. Triggered by the center and developed into technology/IP outside the center
 - b. IP/technology developed by the center
 - c. Would the technology have been developed without the center?
 - i. If yes- time lag or delay without the center?
3. How much did your organization invest to get this technology ready to commercialize?
 - a. Person-years dedicated to the activity?
 - b. Total of funding/ investments (wages, supplies, facilities, equipment, etc)
 - c. How long it take to reach commercialization, from when your organization first became involved with the technology? (in years / months)
 - d. [If licensed technology] what would alternative technology have cost the organization?
4. Since first commercialization what have been the impacts on your organization?
 - a. Sales and net profits (either total, annually, or per unit)
 - b. Percent of sales / profits attributable to the center
 - c. Personnel associated with the product
5. Can you provide future or prospective estimates on market growth (percent or dollars)
 - i. Conservative estimate
 - ii. Best case scenario estimate
6. What are the impacts on downstream customers of the technology?
 - a. Cost savings over prior technologies
 - b. Qualitative benefits over prior technologies
 - c. What percent of savings/benefits are attributable to the center?

II. Established Firms: Process or process-related technology

1. Confirm understanding of the process/technology.
 - a. Is this a process or a component of a larger process?
 - b. What are the benefits over existing, similar technologies on the market?
2. How does this technology relate to the center?
 - a. Triggered by the center and developed into technology/IP outside the center
 - b. IP/technology developed by the center

- c. Would the technology have been developed without the center?
 - i. If yes- time lag or delay without the center?
- 3. How much did your organization invest to get this process technology ready to commercialize?
 - a. Person-years dedicated to the activity?
 - b. Total of funding/ investments (wages, supplies, facilities, equipment, etc)
 - c. How long it take to reach commercialization, from when your organization first became involved with the technology? (in years / months)
 - d. [If licensed technology] what would alternative technology have cost the organization?
- 4. Since first commercialization what have been the impacts on your organization?
 - a. Cost savings (either total, annually, or per unit)
 - b. Percent of savings attributable to the center
 - c. Growth or improvement in sales, net profits
 - d. Growth in personnel associated with market growth
- 5. What are the impacts on downstream customers of the technology?
 - a. Cost savings over prior technologies
 - b. Qualitative benefits over prior technologies
 - c. What percent of savings/benefits are attributable to the center?

III. Start-ups (with no realized sales or revenues to-date)

- 1. Confirm understanding of the technology and firm.
 - a. What are the benefits over existing similar technologies on the market?
 - b. How long since the start-up was established?
- 2. How does this technology relate to the center?
 - a. Triggered by the center and developed into technology/IP outside the center
 - b. IP/technology developed by the center
 - c. Would the technology have been developed without the center?
 - i. If yes- time lag or delay without the center?
- 3. How much did your organization invest to get this technology ready to commercialize?
 - a. Total spending to date (wages, supplies, facilities, equipment, etc)
 - b. Total funding received from all sources: VC, private, government grants
 - c. Jobs created person-years through life of the firm
 - d. [If licensed technology] what would alternative technology have cost the organization?
- 4. Can you provide future or prospective estimates on market size and growth
 - i. Conservative estimate (total market and firm-specific)
 - ii. Best case scenario estimate (total market and firm-specific)
- 5. What are the impacts on downstream customers of the technology?
 - a. Cost savings over prior technologies
 - b. Qualitative benefits over prior technologies
 - c. What percent of savings/benefits are attributable to the center?

Appendix 13: Sample center-level report: ERC-inspired

IUCRC ASSESSMENT

Center for Advanced Surfactant Studies, IUCS

The Center for Advanced Surfactant Studies, IUCS, has graduated from their initial IUCRC funding decade and is currently operating as a new, morphed Center incorporating Surfactants and Particulates with the University of Florida. Six companies recommended by the long-term Center Director, “Som” Somasundaran, were contacted and telephone interviewed to determine the Center contribution to their business. Obviously since the Center Director is making the recommendations, the selected Companies and Representatives have a distinct positive bias. The Center contribution was measured on three overall factors, technology transfer including product and process transfers, people issues including jobs created at the company, company hires from the Center, student training, etc. Using a page borrowed from the ERC Evaluation format, I created a scale of 1 to 5 for each of these factors where 1 means exceptional results for a factor, 3 is satisfactory accomplishments on that factor, and 5 means unsatisfactory results (see attached Table). Likewise, the average of these three factors describes the overall Center performance. Remember, this is a trial case so the details are very likely to change over the next few weeks. The other attachments show the performance criteria for the three factors and a summary of the interview data. Individual short write-ups of the 6 company interviews are available.

Factor number 1 deals with the knowledge and technology transferred to the individual companies. This is probably the most important factor and should be weighted more than the others. It includes such things as new products developed based on Center inputs, processes modified for improved performance and/or cost, environmental and /or safety improvements, etc. In the case of IUCS there have been no major new products, but one is in the pilot stages, a new “green” surfactant based on soybeans, and may produce significant new product and significant employment in 2012. One of the companies points to about \$3M in annual value attributed to changes in existing products. Since the company has only been a member for 3 years I have only “credited” one year of annual savings to the data. Based on this information I have rated their tech transfer as Grade 3, satisfactory. There is evidence of technology being utilized commercially, but no single, major breakthrough.

Factor 2 deals with people factors, e.g., job creation, student training, graduate hiring by the company, cost avoidance by using Center personnel, etc. Sixteen jobs have cumulatively been created at the six companies. This is a far distance from the 200 I expected from a superior Center aged over 10 years, but nevertheless significant. It reflects the impact single big products have on the manpower figures, i.e., one big product creates a lot of production jobs. The Center, however, exhibits very close interactions with the Members and between members and students. In fact, two of the interviews took place as member reps were preparing the visit the Center. Eight people have been hired from the Center and 6-8 people-costs have been avoided by Center use. In spite of the low jobs rating, I would give this Factor a 4 on personnel factors. The Center output is geared to process improvements which are difficult to assign a specific jobs count to.

Factor 3 deals with the general activity level between the Center and the Member companies. The activity level is another measure of how well the Center is performing its objectives. Key factors are the average length of membership, number of internships, activity of Member reps at guiding the Center, etc. In this case there is evidence of a high level of interaction as demonstrated by key inputs to the Center research activities, long average membership time (7.5 out of 12 possible years, high level of internships, generally very favorable comments by Member reps, lack of negative comments by all of the interviewees. I would rate this factor as a 4.

In my opinion, IUCS is clearly operating at a SATISFACTORY or slightly higher level, let’s say a 3.5. This mid-range assessment will provide a standard from which other Centers can be judged.

Appendix 14: Sample firm-level report: ERC-inspired

Center: Center for Advanced Surfactant Studies, IUCS

Interviewee: Confidential

Company: Confidential

Interviewer: George Vermont

Date: November, 2010

History: The Company was founded 10 years ago by leading DNA/RNA researchers, and is dedicated to green chemistry with a major current effort in safe surfactants. The Company employs 19 and reports no sales revenues. Google search indicates significant financial investments from large company like Monsanto. The Company was initially attracted to IUCS by a need for an expert surfactant consultant but are now hold full membership (joined several years ago) and have a lot of different activities with the Center.

Interaction: The main role of the Center is in evaluating "natural" surfactants that the Company discovers, largely from soybeans. They have a nice 3 way collaboration going with Iowa State who grows the crops and isolates interesting dispersants, IUCS who receives the candidates and evaluates them, and the Company who will market the products. The Company is also starting a collaboration effort with the Iowa State ERC on green chemicals from engineered microbes.

Impacts summary:

- No products on the market yet, but they are scaling up to a pilot plant for one surfactant product for anticipated commercialization in 2012. No good data on potential long term value.
- Main Center contribution is surfactant expertise and specifically evaluation capabilities.
- No people acquired and no joint patents or licenses.
- At least 8 of their employees are associated with IUCS-related activities. Interviewee estimates that at least one FTE cost is avoided by the work that the Center is doing on evaluation.

In summary, there appears to be \$150K cost avoidance and 8 people employed on Center activities. Could be a sizeable product coming along in the next 3-5 years.

Appendix 15: Sample report: ATP-inspired

Company: Confidential
Years as member: 5 (2004 – 2008)
Interviewee: Confidential
Interview: Drew Rivers
Interview Date: December 2010

Orientation to Center

The Company does not currently hold a membership in the center; however, our informant indicated a renewed membership could be forthcoming. During the company’s five consecutive years as a member we identified no quantifiable benefits aside from the hiring of an IMS student near or just after the final year of membership. Otherwise, all realized economic impacts came after the termination of membership.

Table 1: Technology Transfer Events

No.	Event/Project	Description	Stage	Impact
1	Air compressors	The company’s air compressor technology was operating at below desired efficiencies due to unexpected surges and other factors. This technology was most efficient at near-surge levels. The center’s technology helped the company to predict surges before they occurred.	Testing of a new algorithm has been completed and the new technology is currently being rolled out across the company.	Testing of the new technology indicated savings of \$50,000/year, per air compressor. The company maintains dozens of air compressors at each of 8 manufacturing plants.
2	Robot joints	The company was searching for a method to predict impending failure of robot joints in a production process. After testing various factors, a correlation was found between torque and joint health, resulting in the development of a predictive algorithm.	The new predictive algorithm is in the testing phase.	Based on initial testing results, the technology could save each manufacturing plant 400-500 hours of downtime each year, at \$7500/hour in cost savings. Implementation would take 3 years for the first plant, and 5 years for all 8 plants.

Table 2: Other impact Events

No.	Event/Project	Description	Stage	Impact
1	Student hire	BA level student hired by company.	Hired	Estimated at \$50k savings in mentoring costs.

Notable Qualitative Impacts

The company sees additional value from involvement in the center through collaborative project work and general knowledge sharing among members, as well as an increase in the Company’s capacity to search and absorb new technologies.

Quantified Impacts

For prospective benefits the informant estimated initial planned deployment of the technologies in years 1 through 3 at a single plant, then accelerating across all 8 plants in years 4 and 5. Applying a best case scenario, we assume the Company will realize full benefits across its operations within the next five years, with greater benefits realized in years 4 and 5. Table 3 below shows these prospective benefits.

Table 3: Retrospective and Prospective Economic Impacts (estimates in actual dollars)

Year	Air compressors	Robot joints	Other	Total
2004				
2005				
2006				
2007				
2008				
2009			\$50,000	\$50,000
2010	\$50,000			\$50,000
2011(est)	\$594,000	\$1,113,750		\$1,707,750
2012(est)	\$1,188,000	\$2,227,500		\$3,415,500
2013(est)	\$1,800,000	\$3,375,000		\$5,175,000
2014(est)	\$7,200,000	\$13,500,000		\$20,700,000
2015(est)	\$14,400,000	\$27,000,000		\$41,400,000

Total retrospective impacts: \$100,000

Total estimated impacts through 2015: \$72,498,250

Attribution to the Center

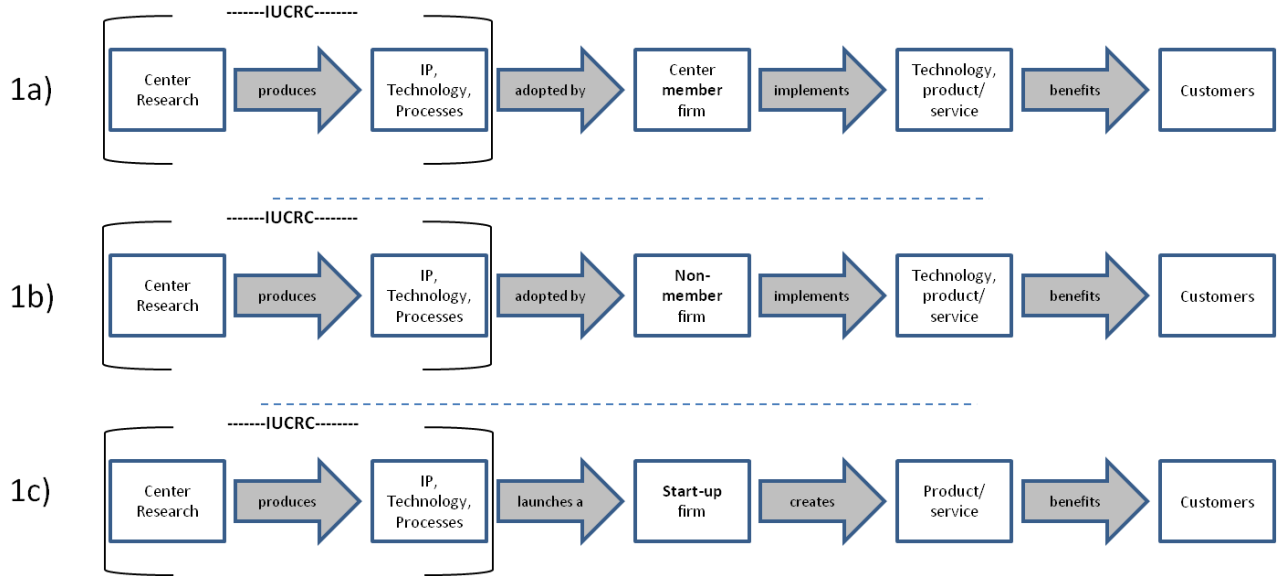
The company views the impact as a collaborative effort; the center bringing advanced skills and the company bringing knowledge of their manufacturing system. As such, both parties were necessary to achieving the outcomes. Specifically for the robot joints project, the company initially attempted to perform the work internally but later opted to involve their prognostics suppliers and the Center. The center proved a key player in the effort, with advanced skills in collecting and analyzing data. The Center played an instrumental role but was one of several actors in the development of the technology.

Summary

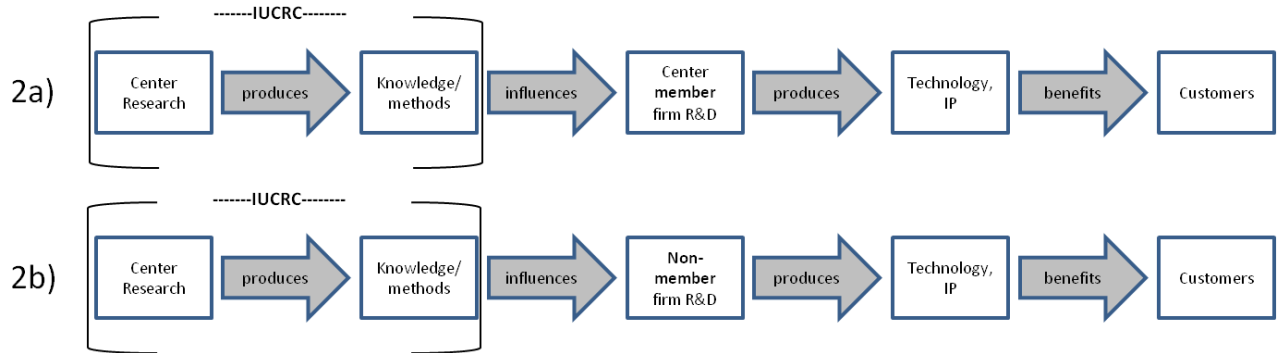
Despite clear linkages between the technology and the center, the interviewee expressed uncertainty regarding attribution; a host of actors and resources outside the Center, including the Company itself, contributed to getting the technology from early stages of development and into commercial application. Further, we assumed a best case scenario with the roll-out of these technologies across the Company's operations. Alternatively, a fully implemented evaluation might also include a conservative estimate or likelihood of complete deployment in the next five years, along with periodic follow-up by the evaluator with the Company representative to gauge progress on implementation and realized benefits from the technology.

Appendix 16: Possible paths to commercialization for IUCRC ideas and technology

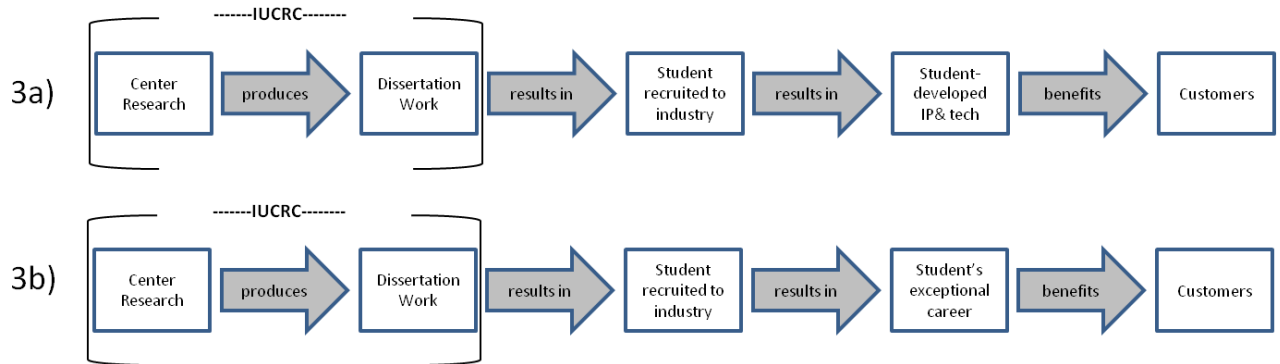
Transfer of Center IP/Technology



Transfer of Center Knowledge/ Methods



Center Student Research



Center Member Cost Savings

