Abstract

McGOWEN, LINDSEY CAIN. Predictors of Cooperative Research Center Post-Graduation Survival and Success. (Under the direction of Dr. Denis O. Gray.)

Industry/University Cooperative Research Centers (I/UCRCs) are supported by funding from NSF but, like other center programs, are expected to achieve self-sustainability after a fixed term (ten years). However, there is little evidence about the extent to which government funded programs are able to make this transition. This study attempted to identify the factors that predict Center sustainability after they have graduated from NSF funding. Archival data and qualitative interviews with Center Directors were used to explore program sustainability of I/UCRCs post graduation from initial grant support. The study examined environmental, organizational, program, and individual level constructs to predict Center status, fidelity to the I/UCRC program model, and sustainability in terms of continued infrastructure, program activities, and outcomes. Results indicated that three quarters of formerly funded I/UCRCs are sustained beyond the end of their grants and that they maintain a high level of structural fidelity while making modifications to Center assessment processes. Sustained Centers also exhibited a comparable level of continued program structures and outcomes when compared to actively funded I/URCs. Predictive analyses indicated that I/UCRC program sustainability is impacted by environmental, organizational, and program level factors. The results inform the transition process for Centers currently funded under the I/UCRC program as well add to the body of knowledge on program sustainability developed in other content areas.

Predictors of Cooperative Research Center Post-Graduation Survival and Success

by
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BIOGRAPHY

Lindsey McGowen was born in Tulsa, OK. After graduating from Bishop Kelley High School, she attended Lewis & Clark College in Portland, OR. She graduated in May of 2003 with a bachelor's degree in psychology. After working for two years, she was accepted into the Psychology in the Public Interest Program at North Carolina State University in 2005. Lindsey worked as a Teaching Assistant during the 2005-2006 academic year. In the Summer of 2006 she began working as a Research Assistant and Project Manager in the National Science Foundation Industry University Cooperative Research Center's Program Evaluation Project under the direction of Dr. Denis O. Gray. Lindsey's graduate work has cultivated a strong interest in program evaluation. She continues to work with Dr. Gray and the NSF on evaluations of the Industry University Cooperative Research Center's Program.

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INTRODUCTION

Government programs are often funded by grants that support their initial development, getting important programs up and running. However, many times, these programs are expected to become self-sufficient; independent of support from the initial granting agency. This is especially the case with many federally funded programs. These programs often take the form of demonstration projects with time-limited funding. The US federal government has 26 granting agencies, supporting over 900 grant programs that award over $400 billion dollars annually (grants.gov, 2006). One example is the National Science Foundation's cooperative research grant program. While such programs are often successful at developing new research programs and centers, little is known about how these programs are able to become self-sustaining once initial grant monies are exhausted. This paper focuses on the efforts of NSF funded Industry/University Cooperative Research Centers (I/UCRC) to become self-sustaining entities, supported by industrial members and other stakeholders.

In order to understand sustainability for I/UCRCs, the current literature on program sustainability and industry-university collaboration is summarized. Before covering this literature, a brief overview is given on the nature of industry funding to universities in the US and the types of industry-university linkages; specifically cooperative research centers. Finally, the review covers research specifically concerning program sustainability.

National Research & Development

Before addressing sustainability of the NSF I/UCRC program, it is important to understand the national research and development (R&D) context in which these Centers operate. In particular, US national policies that contribute to increased industry-university linkages, trends in industry funding to universities, and various types of industry-university linkages are discussed. One type of linkage, the industry-university cooperative research center is reviewed in detail.

Cooperative R&D Policy and Technology Transfer

Over the last three decades, national policy has facilitated greater collaboration in research between industry and academia (National Science Board, 2006). Many of these policies, especially those in the 1980s grew out of a concern over US international competitiveness. New research and development in industries such as information technology, telecommunications, and biotechnology were part of the shift to a more knowledge-based economy. The majority of the seminal research in these fields is conducted in academia. Therefore, US competitive advantage relies on developing linkages between the producers of knowledge and those who could transform it into commercializeable products and processes (Feller, 1997).

The Stevenson-Wydler Technology Innovation Act (1980) facilitated collaboration by requiring that federal laboratories transfer technology to state and local government and private industry (National Science Board, 2006). The Act resulted in the creation of several Centers for Industrial Technology, affiliated with academia and the nonprofit sector (Cohen, Florida, & Goe, 1994; Rahm, Kirkland, & Bozeman, 2000). In 1986 (Federal Technology

Transfer Act) and again in 1989 (National Competitiveness Technology Transfer Act) this act was amended to allow technology transfer to federal agencies, government-owned contractor-operated laboratories, universities, and nonprofits as well as state and local government and industry.

Industrial collaboration with universities has also been facilitated by the Bayh-Dole University and Small Business Patent Act (1980), which allows universities to retain patent rights for federally funded research results and encourages the licensing of those results to industry. This Act also deals with some of the difficulties in cross-sector collaboration by stipulating that a reasonable period of time be allowed for patent filing before research results are made publicly available. Both the Stevenson-Wydler and the Bayh-Dole Act were amended most recently by the Technology Transfer Commercialization Act (2000), which facilitates government monitoring and licensing of federally owned innovations.

The National Cooperative Research Act (1984) allows firms to collaborate on pre-competitive research and production activities, which had previously been precluded by antitrust regulations. The ability of collaborative partners to work together in the application of jointly acquired technologies was further facilitated by the National Cooperative Research and Production Act (1993). These legislative changes have contributed to an increase in collaborative research between industry and university by reducing barriers and encouraging cross-sector collaboration (Cohen, Florida, & Goe, 1994). The goal of these policy changes is to foster an environment that is conducive to lasting partnerships between industry and university. This policy landscape is complemented by grant programs and other types of funding for R&D that is conducted jointly between universities and industry.

Trends in Research & Development Funding

R&D is an important catalyst to US economic growth and its global competitive advantage. The National Science & Engineering Indicators is a major source in which trends in US R&D activity are reported. The National Science & Engineering Indicators 2006 report that national R&D spending grew to $291.9 billion in 2003, 14% of which was conducted in institutions of higher education (National Science Board, 2006). Academic institutions conducted 54% of basic research and 33% of all research (basic and applied) performed during the same period. In terms of dollars spent on R&D conducted in academia, approximately $45.8 billion were provided by federal government (63.8%), state and local government (6.4%), industry (5%), institutional sources (18.1%) and other sources (6.8%) (National Science Board, 2006).

While industry funding for university-based research has grown considerably, there have been economic factors that interrupted this trend. Industry funding for academic R&D declined in 2002 for the first time in the past thirty years. This decline was caused by industry cutbacks following the collapse of the dot-com industry. This was accompanied by a decline in the stock market and an economic slowdown in 2001 and 2002. A similar decline can be seen in overall industry spending on R&D which declined from 70% of total US R&D spending in 2000 to 64% in 2004[1]. In fact, the overall US R&D funding decline of

[1] Note the difference between industry funding of R&D and industry performance of R&D. The percentages reported here reflect industry funding. In terms of performance, industry accounted for 75% in 2000 and 70% in 2004 (National Science Foundation, 2006).

2.2% in 2002 can be attributed to retrenchment in the business sector. In 2003 this decline was reversed such that US R&D spending grew by 3.9% and it grew by a projected 4.7% in 2004 (National Science Board, 2006). The National Science Foundation's Science Resources Statistics InfoBrief also confirms a rebound in industry funding for academic R&D in 2005.

Despite the relatively small funding contribution (when compared to other sources of academic R&D funding) to academic R&D, from 1970 – 2003 industry funding has shown the greatest increase of all sources (National Science Board, 2006). As a result, academia's interest in and involvement with industry has gained increasing attention. The growth in industry support for academic R&D is part of a larger trend in industry funding for external R&D.

Increasingly, industry-funded R&D has been conducted with external partners. Collaboration in industry R&D is the result of several factors: the increasingly complex nature of R&D, a desire to reduce risks by sharing costs, to supplement internal capability, or a desire to enter new markets (National Science Board, 2006). Results from a study by Rivers (2009) indicated that these factors do contribute to firm decisions to join a university based industrial consortia. Contracted R&D grew twice as fast as internal R&D between 1993 and 2003, industrial technology alliances reached an international peak in 2003 with 695 registered alliances, and public-private partnerships have grown by 4.3% in 2003 since the previous year[2](National Science Board, 2006).

[2] Industrial technology alliances mainly involved US, European, and Japanese firms and were most prevalent in the biotechnology and information technology industries.

Types of Industry-University Linkages

These policy changes and economic trends have lead to an increase in various types of industry-funded external R&D. There are three main types of industrial collaboration in R&D: contracted out R&D, strategic industrial alliances, and public-private partnerships[3]. Still, only 1.7% of industry R&D funding flows to other sectors (National Science Board, 2006). Contracted R&D may be conducted with universities, but it does not necessarily constitute the collaborative approach that is the focus of this paper. Strategic alliances do have a collaborative approach, but generally only involve industrial partners and typically are not intended to foster long-term cooperation. Public-private partnerships however, do involve cross sector collaboration. One type of public-private research partnership is the cooperative research center.

Cooperative research centers (CRCs) partner industry and academia, and in some cases government for a collaborative approach to research. These CRCs are cross-sectorial and multidisciplinary. They are organized by research interest and have management teams, facilities, laboratories, and equipment (Gray, 2000). According to Cohen et al. (1994) there were 1,056 cooperative industry-university research centers in the US in 1990. The authors reported that during 1990, 213 American universities were conducting research with a mean of 17.6 industry members per center. These CRCs are intended to bring the producers and users of technology, knowledge, and research together in order to speed the innovation process. In bridging the gap between industry and academia, CRCs produce research that is scientifically important and industrially relevant (Gray & Walters, 1998). While CRCs

[3] These types of collaboration are also discussed in the section of National Research & Development Trends.

share the common theme of partnering industry and academia, they differ in terms of funding, research area, industry involvement, educational programs, life span, structure, and size. The NSF's Science and Technology Centers (STCs), Engineering Research Centers (ERCs) and Industry/University Cooperative Research Centers (I/UCRCs) illustrate the heterogeneity of CRCs.

National Science Foundation Cooperative Research Centers

The NSF Science and Technology Centers (STC) program was founded in 1987 and constitutes a partnership among academia, industry, government labs, and others (NSF STC, 2007). STCs are characterized as conducting long-term research, having indirect involvement from industry, emphasizing multidisciplinary education and research, and promoting diversity in science, technology, engineering and mathematics (STEM) fields. To date there are 17 active STCs throughout the nation. They receive $2-3 million per year over the course of a ten year grant (Gray, 2000). The goal of STCs is to "conduct world class research that leads to discoveries in service of society while achieving excellence in science, engineering, and math education" (NSF STC, 2007).

The Engineering Research Centers (ERC) program focuses on cross-disciplinary, systems-oriented research, education and outreach, and industrial collaboration and technology transfer (ERC website, 2007). Industrial involvement with ERCs takes an advisory format, with industrial partners providing input on strategic direction. ERC research projects constitute a public-private partnership, but also may be contracted R&D. There are currently 17 active ERC's funded by the NSF, each receiving $2.5-4 million per year over eleven years.

The I/UCRC program is differentiated from the STC and ERC programs primarily in terms of the nature of industry involvement and the scale of government investment. The program was founded in the 1980s and represents a truly collaborative approach, with industrial partners selecting research projects and sharing access to results (Gray, 2000). The goal of the I/UCRC program is to leverage government investment in R&D to improve US competitive advantage in global markets. These Centers are intended to foster long-term cooperation between industry and academia; having sustainability as an explicit program goal. There are currently 37 I/UCRCs, each receiving approximately $70,000 per year from NSF over ten years with the remainder of Centers' operating budgets being provided through university cost sharing and industrial membership fees. The comparatively small NSF investment in the I/UCRC program represents a leveraging approach to government support for industry-university cooperation in research. Despite apparent differences, STCs, ERCs, and I/UCRCs are all required to have a sustainability plan. However, little is know about what factors contribute to whether Centers remain viable once NSF funding is terminated.

The purpose of this paper is to begin to fill this gap in our understanding of I/UCRC sustainability. Further, a better understanding of the sustainability process for demonstration projects and other programs with time limited funding may be generalized from the case of I/UCRCs. In order to understand the graduation process, theoretical and empirical literature is reviewed.

LITERATURE REVIEW

Theoretical Literature

In order to understand the process by which I/UCRCs graduate from NSF support to self-sustainability, theoretical literature on sustainability and industry-university collaboration in research are reviewed and factors predictive of successful graduation are identified.

Sustainability

There is great diversity in the literature on what is meant by sustainability. This is reflected in the variety of terms used in literature: confirmation, continuation, durability, incorporation, institutionalization, level of use, maintenance, routinization, stabilization, sustainability, and sustained use (Johnson, Hays, Center, & Daley, 2004)[4]. A majority of the conceptual literature on program sustainability comes from the nonprofit sector, especially the public health field. Interestingly, much of what is written in the nonprofit and public health fields on sustainability draws on the innovation literature. The work of Tornatsky and Fleischer (1990), Kanter (1988), and Yin (1981), who have written extensively on the technology innovation process, influenced the sustainability literature, making it more applicable to I/UCRC sustainability.

Developing a Definition

The most widely cited sustainability theory was presented by Shediac-Rizkallah and Bone (1998). These authors synthesized a wide body of literature from public health,

[4] The most commonly used terms are institutionalization, sustainability, and routinization. Institutionalization places emphasis on the relationship between the program and the structures of the host organization. Sustainability focuses attention more toward continuation of program activities and benefits. And routinization emphasizes policies and practices (Johnson et al., 2004).

organizational change and innovation, and community development research. Each field defines sustainability differently. Within the public health literature reviewed, the defining feature of sustainability was "maintenance of health benefits over time" (Shediac-Rizkallah & Bone, 1998, p. 93). The public health perspective is distinguished from the organizational change and innovation perspective in which sustainability is seen as "institutionalization of a program or program components within an organization" (Shediac-Rizkallah & Bone, 1998, p. 94). Essentially, the organizational change literature views sustainability as the continuation of program activities within a given context. Finally, these authors summarized the literature on community development as it relates to sustainability. The community development perspective sees sustainability as "capacity building"(Shediac-Rizkallah & Bone, 1998, p. 95). Here the idea is that stakeholder participation and the formation of community support structures leads to investment in the program which leads to long-term sustainability. The authors concluded that sustainability can be defined as continuation of program benefits, activities, and increased capacity for continuation.

However, some authors have disagreed with Shediac-Rizkallah and Bone (1998), claiming that the third definition, capacity for continuation, is a pre-requisite for sustainability rather than a defining component of it (Johnson et al., 2004). For the purposes of this study, capacity for continuation is understood as the continuation of community and/or organizational structures (such as advisory boards, facilities, and staffing) that support a program. Including capacity for continuation as part of the definition allows one to look at sustainability in terms of program activities, structures, and outcomes.

In addition to the definition offered by Shediac-Rizkallah and Bone (1998), a fourth component of sustainability was suggested by Weiss, Coffman, and Bohan-Baker (2002): sustaining the values underlying a program. As Kanter (1988) explained, an innovative program can be sustained when it becomes "part of legitimate and ongoing practice, infused with value and supported by other aspects of the system" (p. 299). For my purposes, sustainability is defined as a program's ability to continue to provide benefits to stakeholders, conduct core program activities, and maintain structures (capacity) that support the program once initial funding has ended. Value adoption is seen a as key facilitators of sustainability, but is not included as part of the definition.

Sustainability: The Program Lifecycle Perspective

In order to understand how programs achieve sustainability, one must consider the entire program lifecycle. While sustainability is often the final outcome of an effective program, it depends on the successful execution of the preceding steps in the program innovation lifecycle. The process by which innovative programs are developed, implemented, and sustained is a complex one with each step in the process informing the next and feeding back through the cycle for further refinement[5]. Scherier (2005) identified the following overlapping stages of program design and implementation:

> *Initiation*: A program idea is conceived by innovators within an organization or by researchers wanting to test a potential new solution to a problem or felt need.

[5] This model is referred to as the linear chain-link model developed by Klien and Rosenberg (1986).

Development and adoption: The program idea is "fleshed out" with details about its components and activities, to be tested in the intended real-life context. Alternatively, a program developed in a different location is adopted by the target organization or community.

*Implementatio*n: The program ideas are put into full practice within the target organization or community; implementation often may require a year or more of work to define work roles, train staff members, acquire necessary technology or other resources, and try out delivery options, as well as to secure needed administrative and/or community support.

Sustainability (or discontinuation): The program components developed and implemented in earlier stages are (or are not) maintained after the initial funding or other impetus is removed.

Dissemination: For some programs, the funding organization expects the new program idea to be communicated to other sites and adapted or replicated to serve new beneficiaries" (Scherier, 2005, p. 322).

Scherier's (2005) discussion of the program life cycle is based on the work of Rogers (2003) diffusion of innovation model, but extends his work by including the concept of sustainability. Ideally, a collaborative model of the innovative program lifecycle allows for sustainability to flow more readily from the initiation of the program because stakeholders participate in the process[6]. Under this model, at the initiation stage program developers align

[6] Stakeholder involvement ensures buy-in, allows for access to a broader network of support, and can enhance program development because the needs of the use community and researchers' expertise is available throughout the process (Scherier, 2005; Johnson et al., 2004).

their expertise with the needs identified by the organizations that will use the program. Then the organization provides input into the development of a program that is best adapted to meet its needs. Because the use organization works closely with program developers, adoption informs core component development and refinement to fit the realities of the local context. At this point, the program is ready for full-scale implementation in the organization and administration of the program by key stakeholders. The sustainability phase involves program developers and the use organization working to develop structures, policies, and practices that incorporate the new program into the institutional routine[7]. This final phase is where the action of sustainability occurs. However, sustainability is not possible without program design characteristics, organizational features, key individuals who execute the program, and an environment that can support the program once funding stops (Johnson et al., 2004).

Sustainability Theory

It is often assumed that programs will be able to sustain themselves if they are implemented successfully (Johnson et al., 2004). While adequate implementation is important, it certainly does not guarantee long-term success. A review of the literature on sustainability suggests several barriers to and facilitators of sustainability. These factors can be categorized at the environmental, organizational, program, and individual level. It should be clear that there is some overlap between characteristics of the individual, program, organization, and environment that are associated with sustainability. Because new programs

[7] This collaborative model draw on the innovation literature and has been adapted to construct a more collaborative model of the innovation process (Kline & Rosenberg, 1986; Kline & Sorra, 1996; Mayer & Davidson, 2000; Tornatzky & Fleisher, 1990)

require cooperation throughout the life cycle, many of the factors associated with sustainability emphasize alignment across these categories.

Shediac-Rizkallah and Bone (1998) went beyond defining sustainability and also considered what factors might facilitate it. They organized these factors by three of the levels of analysis just described; environmental, organizational, and programmatic facilitators of sustainability. Environmental factors include social, economic, and political considerations and stakeholder participation. They explained that a program's long-term sustainability is influenced by whether or not the program fits with the current social climate, the availability of alternative funding sources, and the politics of the issue being addressed. Further, programs that have a great deal of stakeholder participation, both in terms of the amount of participation and the number and range of activities participated in, are more likely to be supported even after initial grant monies are exhausted.

Organizational facilitators of sustainability identified by Shediac-Rizkallah and Bone (1998) include institutional strength, integration with existing programs/services, and the presence of a program champion/leadership. The authors claimed that mature, stable organizations are better able to support new programs over the long-term. Further, programs that can easily be integrated into existing organizational structures and require fewer resources are more likely to be supported because they are compatible with organizational mission. The authors explained that vertical, stand alone programs are easier to implement in the beginning, but are less likely to become embedded in the organization once initial funding is gone. Finally, these authors discussed the role of leadership or a strong program champion in facilitating program sustainability. This person works to generate goodwill

toward the program, navigate politics both within the organization and in the larger environment, and identify resources for the program. While Shediac-Rizkallah and Bone (1998) argue that a program champion is an organizational factor contributing to sustainability, it seems as though this factor is better categorized at the individual level of analysis[8].

The final category of factors contributing to program sustainability identified by Shediac-Rizkallah and Bone (1998) are at the program level. These include the program implementation process, program effectiveness, duration, financing, and training[9]. Programs that are implemented with the participation and support of key stakeholder groups and are designed to meet their needs are more likely to retain that support throughout the life of the program. The authors also discuss the importance of both actual and perceived effectiveness; when data-based results on the effectiveness of a program are disseminated and key stakeholder groups view the program as effective, it is more likely to survive past the initial grant period. However, grants must be of sufficient length for the program to be established within the host organization. The authors cite case studies by Goodman and Steckler (1989) and Scherier (1990) that indicate programs are more likely to be sustained if the original grant was for at least 5 or 6 years, respectively. Many authors studying program sustainability have used the framework developed by Shediac-Rizkallah and Bone (1998) to influence and guide their work. The following summary of program sustainability literature

[8] Individual facilitators of program sustainability will be discussed further in that section in terms of social entrepreneurship and associated behaviors.

[9] Shediac-Rizkallah and Bone (1998) also include program type (curative or preventative) as a programmatic factor influencing sustainability. However, this is based on research in the public health field and refers to programs that either cure disease or prevent it. Since the I/UCRCs under study in this program are not public health programs, this variable was omitted.

is organized by the levels of analysis they suggested; programmatic, organizational, and environmental, with the addition of a section on individual level predictors of program sustainability.

Program Characteristics. Only those programs that effectively provide the intended benefits should move toward sustainability. As such, program effectiveness is one predictor of sustainability (Shediac-Rizkallah & Bone, 1998). Goodman and Steckler (1989) explained that not only must the program be effective on an empirical basis, it must also be perceived as such by program staff, clients, funders, and the larger community.

Perceived program effectiveness is often the result of the quality of program implementation (Johnson et al., 2004). While it is important that programs can be modified to fit local conditions, it is equally important that core components are implemented with fidelity if benefits are to be achieved (Mayer & Davidson, 2000). This is related to the concept of institutionalization or routinization in which the focus is on the structures, policies, and practices necessary to support the program. Goodman and Steckler (1989) explain that quality of implementation is a function of the extensiveness and intensiveness of the program within the host organization. Extensiveness refers to the range of organizational sectors involved in supporting the program. The degree to which a program is supported by a given sector of the organization is reflected in whether or not it has gone through passages, cycles, and niche saturation[10]. This level of support is referred to as intensiveness (Goodman & Steckler, 1989).

[10] According to Goodman and Steckler (1989) and based on the work of Yin (1981), a passage is a one-time event such as inclusion as a budget item, cycle refers to the number of routine organizational cycles through

Several authors also mention the importance of the design process for future program sustainability (Johnson et al., 2004; Shediac-Rizkallah & Bone, 1998; Williams, Labonte, Randall, & Muhajarine, 2005). In particular, they note the effect of stakeholder involvement in designing the program has on the future sustainability of that program. Williams et al. (2005) explained that "projects imposed by a funding agency may be less likely to be sustained than those which are the result of a mutually respectful negotiation process between funders and host [organizations]" (p. 98).

Much of the literature on program characteristics that influence sustainability mentions program adaptability (Goodman & Steckler, 1989; Johnson, et al., 2004; Shediac-Rizkallah & Bone, 1998). Program adaptability accommodates changes in the host organization, the community, and even changes in the nature of the problem. As briefly mentioned in the discussion of program lifecycle, identifying core program components that must be maintained with fidelity also identifies aspects that can be modified to fit local conditions while still providing benefits to stakeholders. As Kline and Rosenberg (1986) explained, "successful innovation requires a design that balances the requirements of the new [program], the [stakeholder] needs, and the need to maintain an organization that can continue to support all these activities effectively" (p. 277).

Programs designed with stakeholder involvement are also more likely to possess another facilitator of program sustainability: alignment with stakeholder needs (Johnson et al., 2004; Shediac-Rizkallah & Bone, 1998). Often, funders dictate program goals, objectives, and activities prior to involvement of stakeholders. When programs favor the

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which the program has passed, and niche saturation refers to the program's maximum possible expansion within a given sector.

needs of researchers and funders over those of the stakeholders, they run the risk of being abandoned once funding ends. Interventions that do align with stakeholder needs are more likely to gain support and buy-in; fostering a sense of ownership and encouraging investment in the future of the program (Julian & Kombarakaran, 2006). As Johnson et al. (2004) argued, a sustainable program must provide "services to targeted stakeholders that meet specific needs" (p. 144). These authors also argued that stakeholder involvement fosters positive relationships and a sense of ownership.

A final program characteristic associated with sustainability is the nature of funding (Stevens & Peikes, 2006). Shediac-Rizkallah and Bone (1998) indicated that not only must the program have adequate funding during the initial demonstration project phase, replacement alternatives should be investigated and a gradual transition from hard to soft funding may also be necessary. Programs also need to take on an entrepreneurial spirit in order to acquire the financial and non-financial resources necessary (Julian & Kombarakaran, 2006). The importance of entrepreneurship will be explored further in the section on individual factors that impact program sustainability.

Organizational Characteristics. Just as it is important for programs to align with organizational needs, it is also important that organizations choose to implement programs that fit with their mission and structure or are willing to adapt (Shediac-Rizkallah & Bone, 1998). As previously mentioned, this type of alignment is likely to occur when multiple stakeholder groups are involved in program design. Several authors emphasized the importance of staff and stakeholder ownership in fostering program sustainability (Julian & Kombarakaran, 2006; Stevens & Peikes, 2006).

Beyond alignment with organizational mission and stakeholder involvement, the other organizational factors associated with sustainability are related to capacity for sustainability and championship behavior (Kanter, 1988; Zahara & George, 2002). Organizations that are mature and have a large resource base are better suited to support programs once initial funding ends. These mature, stable organizations have the greatest capacity to sustain programs. This includes structures and formal linkages such as dedicated and trained program staff, budget allocation for the program, information technology, and human resource policies and procedures (Johnson et al., 2004).[11]

Although universities are often characterized by their silo structure in which colleges operate independently from one another and from outside institutions, that organizational structure is beginning to change. With the increasing role of industry and government funding for research in academia, universities are becoming more accountable and more connected to the practical application and the needs of outside stakeholders. This shift is embodied in what has been described as the triple helix of industry-university-government relationships (Etzkowitz et al., 2000). These authors explained that universities involved in a triple helix add development to their missions of teaching and research. They argued that entrepreneurial universities are characterized as experiencing the influence of one institutional sphere on another because they have lateral ties, formalized by tri-lateral linkage institutions that ensure cross-sector interactions are on-going (not just one-time interactions). These linkages are formalized by external funding for university research, institutional offices dedicated to managing the industry-university interface, and policy initiatives such as

[11] It should be noted that stable organizations may not have the ability to adapt to new program requirements.

the Morrill Act and the Bayh-Dole Act (Etzkowitz, Webster, Gebhardt & Terra, 2000). Universities that operate under the triple helix model are better able to sustain cooperative research centers because they have formalized the structures and linkages necessary to maintain them. The presence of cooperative research centers may in fact promote a triple helix model for the host university such that by the time their initial funding ends, the infrastructure will be in place to support the center's ongoing success.

Environmental Characteristics. Another important category of sustainability predictors is characteristics of the environment and outside stakeholders (Shediac-Rizkallah & Bone, 1998). Programs that are aligned with environmental demands and benefit from involvement of outside stakeholders are more likely to garner support and resources available. Consideration for the limitations and opportunities afforded in the environment should be present throughout the program lifecycle, from design and implementation through to the sustainability phase. Key environmental factors include the economic, social, and political considerations relevant to the program (Adelman & Taylor, 2003; Julian & Kombarakan, 2006; Shediac-Rizkallah & Bone, 1998). For cooperative research centers, this means attending to market forces, the availability of funding sources, trends and developments in their area or research, the current capacity and direction of firms in the industry, and governmental policy and legislation concerning industry-university partnerships.

Adelman and Taylor (2003) emphasize the importance of framing arguments for sustaining the program in terms of the "big-picture" efforts to strengthen communities, industries, economies. These authors also suggested including outside stakeholders in

sustainability planning. They said that "when a broad range of stakeholders are motivated and ready to work together to sustain progress, they come up with more creative and effective strategies" (Adelman & Taylor, 2003, p. 6). Outside stakeholder involvement can also allow greater awareness of and sensitivity to changes in the environment. It can also increase the community's awareness of the program and potentially their support for it. When outside stakeholders are involved in all aspects of the program lifecycle, they will have access to influence the program as well as the resources necessary to sustain the program (Goodman & Steckler, 1989).

Individual Characteristics. Shediac-Rizkallah and Bone (1998) identified environmental, organizational, and program characteristics that predict program sustainability. And while these authors did discuss the importance of program champions, they did not specifically investigate the importance of individuals and the roles they fulfill in ensuring program sustainability. Several authors emphasized the importance of a program champion and leadership (Johnson et al., 2004; Kanter, 1988; Scheirer, 2005; Shediac-Rizkallah & Bone, 1998, Stevens & Peikes, 2006, Williams et al., 2005). While program champions sell the program both within their organization and in the larger environment, leaders serve to foster integration, provide support to staff, lead program planning and implementation, develop partnerships, and expand the program's network of supporters. They do this by communicating commitment to the program, engaging others, overcoming barriers, building infrastructure, reflexivity, summarizing and communicating technical knowledge, coaching for sustainability, and building organizational capacity (Stevens & Peikes, 2006). Scheirer (2005) argued that it is important to have multiple program

champions within different sectors of the organization, in the larger environment, and in partner organizations.

The idea of program championship originally comes from the technology innovation literature. While I/UCRCs are involved in technological innovation, they are not profit driven organizations. Therefore, the concept of a program champion may not fully capture the role that Center Directors play in the program sustainability of I/UCRCs.

Much of what is important about the behavior of a program champion is reflected in the literature on social entrepreneurship. The social entrepreneurship literature looks at innovative enterprises from the individual level of analysis and can be usefully applied to the I/UCRC program to shed some light on the role of Center Directors and other advocates within the host universities, and in industry.

Dees (2001) is perhaps the most well known scholar of social entrepreneurship and one of the first to formally define it. He explained that the term combines the innovation and determination of business entrepreneurs with a social mission orientation. Dees (2001) offered the following definition of social entrepreneurship:

> Social entrepreneurs play the role of change agents in the social sector, by: 1) adopting a mission to create and sustain social value (not just private value), 2) recognizing and relentlessly pursuing new opportunities to serve that mission, 3) engaging in a process of continuous innovation, adaptation, and learning, 4) acting boldly without being limited by resources in hand, and 5) exhibiting a heightened sense of accountability to the constituencies served and for the outcomes creates (Dees, 2001, p. 4).

This definition highlights individual behaviors such as opportunity identification, innovation, adaptation, learning, risk tolerance, and accountability that may be important to program sustainability.

Craig, Hess, McGinnis, and Gray (2007) have studied leadership specific to directors of cooperative research centers. They argue that leadership requirements for cooperative research center directors differ from the requirements of leaders in more traditional organizations. Based on a qualitative study of university based cooperative research center directors, these authors identified fifteen dimensions of effective cooperative research center leadership: twelve positive and three negative dimensions. Positive dimensions include: technical expertise, ambition / work ethic, broad thinking, embracing ambiguity, balancing competing stakeholders, leveraging social capital, obtaining resources, navigating bureaucracy, granting autonomy, interpersonal skill, team building and maintenance, and task adaptability. Effective leaders demonstrate high levels of these characteristics. Negative dimensions include: abrasiveness, disorganization, and conflict avoidance. Effective leaders demonstrate low levels of these characteristics. Although the Craig et al. (2007) study did not specifically address the importance of these leadership dimensions to program sustainability for cooperative research centers, Gray and Walters (1998) argue for the importance of effective leadership for the long-terms success of industry-university cooperative research centers.

Empirical Literature

Empirical Sustainability Literature

This literature on program sustainability essentially confirms the Shediac-Rizkallah and Bone (1998) theory. However, many of the assertions made are not based on strong empirical evidence. While some studies have conducted limited case studies, others simply report the opinions of key informants about what they think contributed or detracted from program sustainability.

While the extent of empirical literature on program sustainability is quite limited, and has primarily been conducted in the public health field, Scherier (2005) did conduct a comprehensive review of empirical studies on sustainability of public health programs. A review of her article is presented below, followed by a more detailed discussion of the two most methodologically rigorous studies included in her review. Finally, the literature on program sustainability is synthesized to identify the most widely cited predictors of sustainability and most appropriate methodology for assessing those relationships.

Based on the seminal theory presented by Shediac-Rizkallah and Bone (1998) reviewed above, Scherier (2005) conducted a comprehensive review of 19 empirical studies on sustainability of public health programs. Studies included in this review collected sustainability data after initial funding had ended, were based on programs conducted in the US and Canada, and programs that addressed public health issues. Results of the studies were coded according to the levels of analysis identified by Shediac-Rizkallah and Bone (1998): environment, organization, and program.

Before considering factors predictive of sustainability, Scheirer (2005) discussed the methods of the studies reviewed. The timelines for external funding reported in the studies was between 18 months and 8 years. However, some of the studies reviewed did not report having external funding sources. It seems that findings from such programs would have limited bearing on an understanding of sustainability, defined as continued program benefits, activities, and capacity once initial grant funding is exhausted. The most common form of data collection was mail or telephone surveys, with some studies using case studies or site visits. While some of the studies reviewed collected data from only one respondent, most used multiple respondents per site. Only one study used existing programmatic records. In terms of the timing of data collection, Scheirer (2005) was not able to identify any commonly accepted period after which a program is considered to be sustained. The studies reviewed collected data between 0 and 20 years after external funding was terminated. While nearly half the studies reviewed conducted some type of statistical analysis, only two conducted any multivariate analysis, examining correlations among predictor variables and their relationship to program sustainability measures (O'Loughlin et al., 1998; Scherier, 1990). In general, Scheirer (2005) criticized these studies as methodologically weak because they did not operationally define variables, collected data from too few sources, did not consider the importance of timing of data collection, and did not conduct rigorous statistical analysis.

Despite the methodological limitations of the studies reviewed, "fourteen of seventeen relevant studies reported that 60% or more of the sites showed some sustainability"(Scheirer, 2005, p. 335). However, there were different rates of sustainability reflected in different measures. Some studies reported a high proportion of sites continuing

to conduct program activities, but a lower rate of continued benefits to stakeholders. While other studies did not differentiate what type of sustainability measure they were using: continued benefits, continued activities, or continued capacity to address the issue that was the focus of the program. The most common measure of sustainability used was continuation of program activities, with 18 of the 19 studies using this measure of sustainability (Scheirer, 2005). Scheirer (2005) operationalized the concept of capacity for continuation as whether or not the organizational structures put in place during the funding period are still in existence once initial funding is terminated (such as community coalitions and advisory boards). Scheirer (2005) reported that six studies examined whether coalitions or other program structures were still in place. Overall, continued program activities seems to be the most widely accepted measure of sustainability reflected in the literature, with continued program benefits also being used by many public health researchers. The concept of capacity for continuation seems to be less well understood as reflected in its limited use as a measure of sustainability.

Despite the variability of methods used by the studies reviewed, Scheirer (2005) was able to identify some common factors that were related to program sustainability. Again, using Shediac-Rizkallah and Bone's (1998) framework, she organizes these factors according to level of analysis: environment, organization, and program. All but three of the 19 studies reviewed identified factors related to sustainability at at least two of the three levels of analysis.

Scheirer (2005) reports that environmental factors identified include support from other organizations in terms of in-kind resources, expert fund-raising advice, political

support, and client mobilization. Another environmental factor was funding from sources other than the initial granting agency as well as the availability of multiple funding sources. However, two multivariate studies (O'Loughlin, et al., 1998; Scheirer, 1990) actually found no relationship between availability of new funds and sustainability. Rather it was the perception of program stakeholders that new funding was available that was related to program sustainability[12].

Organizational factors identified by the studies Scheirer (2005) reviewed include the presence of a program champion, organizational strength, fit with organizational mission and structure, and stakeholder support. Program champions within the organizational setting were usually in leadership positions, advocated for the program, and worked to secure resources. While Scheirer (2005) categorized program champions as organizational factors, an individual level of analysis is warranted, given that previous work on program championship has focused on characteristics and behaviors of the individual occupying that role (Howell & Boies, 2004; Howell & Shea, 2001). The concept of organizational strength showed a complex relationship to sustainability with some studies reporting that strong organizations were better able to sustain programs and others reporting no correlation to sustainability. One study reviewed even found that the "silo" structure of academic institutions had a negative impact on program sustainability (Harris et al., 2003 cited in Scherier, 2005). A more positive connection was reported between program sustainability and the programs' fit with organizational mission and structures. Programs that helped to

[12] This finding points to the importance of a program champion or leader who is able to identify sources of financial support and to convey to program stakeholders that the program is sustainable. This concept will be considered further in the section on individual level predictors of sustainability.

further the organizational mission were more likely to receive support and resources and those that could be incorporated into existing organizational practices received greater staff support and buy-in. In fact, several studies reviewed found that sustainability was more likely when program staff perceived benefits.

Programmatic factors related to sustainability in the studies reviewed by Scheirer (2005) include program adaptability, the use of volunteers/low-cost service delivery, and use of evaluation data. A majority of studies reported that programs that could be modified to fit local conditions were more likely to be sustained. However, it is unclear if modifications were made to core program components, which might impact sustainability outcomes such as program effectiveness and benefits to stakeholders. While some studies did mention the use of volunteers or low-cost service delivery, this factor was not identified by the majority of studies reviewed. Likewise, the use of evaluation data to gain support for the program was only mentioned by a few studies.

Overall, Scheirer (2005) was able to identify five factors that were reported by a majority of the studies reviewed (12 out of 19) as predictive of program sustainability once initial funding ended: program adaptability, the presence of a program champion, a fit with organizational mission/structures, perceived benefits to staff or clients, and support from stakeholders in the environment. A sixth variable mentioned by a majority of studies was funding. However many of the studies reviewed considered the acquisition of funding to be synonymous with sustainability. Therefore, it is better understood as a sustainability measure. In addition to the sustainability measures and predictor variables discussed, Scheirer (2005) also suggested some possible control variables: timing since funding ended,

whether program sites were early adopters or not, and length of the initial funding period. The author suggested that sustainability can deteriorate over time so that it would be important to account for the amount of time elapsed since funding ended. Also, she mentions Rogers' (1983) S-shaped model of adoption, which indicates that there are some difference between those that initially chose to adopt an innovation (early adopters) and those who adopted the program later. Additionally, some authors have found that there may be a minimum funding period in which programs can establish themselves and be prepared for sustainability (Goodman & Steckler, 1989; Scheirer, 1990). These authors indicated that programs funded for less than five or six years may not be prepared for sustainability. Therefore, it may be important to account for this when measuring program sustainability.

Of the articles reviewed by Scheirer (2005) two stood out as especially relevant, given their strong methodology. An article by O'Loughlin et al. (1998) looked at sustainability of community based heart health programs while Scheirer (1990) examined sustainability for a school based oral health program. Each study is reviewed below with emphasis on sustainability measures used, predictive factors identified, and methodological rigor.

O'Loughlin et al. (1998) investigate sustainability of 189 heart health promotion programs funded by a variety of agencies (particularly health departments and research institutions) and implemented in Canada. The authors defined sustainability as "the extent to which a new program becomes embedded or integrated into the 'normal' operations of an organization"(O'Loughlin et al., 1998, p. 703). This definition is reflective of the organizational development literature Shediac-Rizkallah and Bone (1998) identified in which

sustainability is viewed as the integration of a new program into an existing organization. From this perspective, sustainability is measured as the continuation of program activities. Sustainability as institutionalization is understood from the life-cycle perspective described by Scheirer (2005) and others.

This study, while drawn from the public health literature, is especially useful to developing an understanding of sustainability for I/UCRCs because of the diversity of programs included in the study. All the heart health programs included in the study sample vary in terms of the activities, clients, setting, and funding, yet all are addressing the issue of heart health promotion. Similarly, all the I/UCRCs foster industry-university cooperation, yet they are housed within a variety of university settings, investigate different areas of research, receive funding from a variety of sources, and serve different industrial stakeholders. Hopefully, the diversity of programs studies by O'Loughlin et al. (1998) will allow for greater generalizeability outside the public health field.

On the other hand, the understanding of sustainability as institutionalization may not encompass what goes on when programs lose their funding after the initial grant period. While it is possible that the heart health programs studied in this article were also dealing with the need to identify replacement funds, it may be the case that these programs never lost funding. In which case, the issue is the degree to which programs are incorporated into the host organization, not sustainability. Unfortunately, the author does not discuss how issues of funding were dealt with in terms of sample identification.[13]

[13] Scherier (1990) does discuss funding source as a predictor of sustainability. But she does not indicate whether it is replacement of initial grant monies or ongoing funding.

Data were collected from a convenience sample of key informants from hearth health promotion programs that were funded within eight years of the study and used a snow balling technique to identify additional study participants (O'Loughlin et al., 1998). Programs included in the study were those that addressed heart health and/or risk factors, developed partnerships between the funding agency/research organization and a host organization in the community, and had been implemented in a community. The key informants were typically principal investigators, senior staff, program coordinators or directors and provided data via telephone interviews.

Data collected included perceived sustainability, host organization characteristics, intervention characteristics, and sustainability predictors. Sustainability was measured using a single question: "at this point in time, how permanent [on a three point scale] do you think the (intervention) is at (provider)?"(O'Loughlin et al., 1998, p. 704). While this measure demonstrated good content validity in that it was correlated other items measuring some dimension of sustainability, the study may have been improved if this critical DV was measured in more than one way.

O'Loughlin et al. (1998) studied sustainability predictors at the organizational, program, individual and environmental levels. Local provider characteristics measured included: type of organizational setting, number of employees, employee gender, presence of an employee union, area served, number of years operating in the community, demographics of the client base, client and staff turnover, plans for sustainability, who initiated the program, modifications to intervention during implementation, previous experience in heart health promotion, and fit between the intervention and the organization. Characteristics of

the intervention measured were: type of heart health intervention, risk factor(s) targeted, first and last time the intervention was available, number of times the intervention was delivered per year, resources required to run the intervention (measure on a three point scale), number of paid staff and volunteers working on the intervention, number of participants involved in each delivery, age group targeted, staff training, intervention evaluation, difficulty in implementation, and perceived program success. The study also examined whether a program champion was present, managerial support, and perceived competence of staff to deliver the program. In terms of environmental factors, the authors examined collaboration between the local provider and external agency.

Data were analyzed using a multinomial logistic regression in which predictor variables were added to the model using a forward stepwise procedure. Results indicate that 43.6% of the interventions studied were very sustained and an additional 34.8% were moderately sustained. Programs existed in the community for an average of two years with a range of one month to eight years. Univariate analysis identified thirteen variables found to be significantly correlated with sustainability. Upon further multivariate analysis, independent variables positively correlated with sustainability were the intervention requiring no paid staff or could be integrated into the activities of existing staff, modifications to the intervention during implementation, fit between the intervention and the organization and the presence of a program champion.

While this study did a good job at taking on an empirical approach to studying program sustainability, there are several limitations in terms of methodology. First, O'Loughlin et al. (1998) only used one measure of sustainability and it did not specify what

sustainability meant. They only asked participants whether they thought the intervention was sustained and did not address the three different definitions of sustainability cited by other authors: continuation of activities, continuation of benefits, and capacity for continuation. While they did acknowledge they measured perceived sustainability, they could have easily asked respondents about continuing program activities, benefits, and capacity. Nevertheless, the authors did demonstrate some content validity of their measure. Another limitation of this study was the definition of sustainability used and the way that played out in their selection of programs and timing of data collection. O'Loughlin et al's (1998) definition of sustainability as institutionalization ignored whether or not the initial funding for the program was still in place. They seemed to only be interested in whether the program could be integrated into the host organization and not whether the program could survive once initial grant monies were exhausted. Therefore, the level of program sustainability they reported may be misleading if the programs under study were still receiving initial grant support. This conceptualization of the construct severely limits the generalizeability of study findings to the case of programs where initial grant monies are exhausted. However, the results of this study partially confirm what has been said in the literature on program sustainability and may shed some light on the sustainability process for I/UCRCs. At the very least, the O'Loughlin et al. (1998) study provides empirical support for factors to be included in the model.

The other study reviewed in the Scheirer (2005) article was also written by that author; Scheirer (1990). In this study, the author investigated the life cycle for fluoride mouth rinse programs (FMRP) implemented in US school districts. In particular, she looked at what factors predicted adoption as well as those that were related to sustainability. At the

time when this article was written, sustainability theory was not as fully developed. The author relied on the diffusion of innovation perspective in which the focus tends to be much more on adoption, implementation, and dissemination to other sites. Citing Rogers (1983), Scheirer (1990) explained that factors related to adoption were the opposite of those related to program discontinuation. Despite relatively weak application of theory, this article was included because it provides empirical evidence about the factors related to program sustainability. In particular, this study represented a longitudinal analysis of program sustainability, included data about environmental context in which programs were implemented, collected data from multiple sources for each program, and conducted multivariate statistical analysis.

Scheirer (1990) used a different theoretical framework than was used in the Scheirer (2005) review of empirical studies of sustainability of public health programs in the US and Canada. While Shediac-Rizkallah and Bone (1998) had not yet developed their theory, Scheirer (1990) used a framework that influenced it: the diffusion of innovation model developed by Rogers (1983) and adapted by Greer (1977). This model encompassed three theoretical perspectives on the diffusion of innovation: classical, organizational structure, and a political perspective. The classical approach emphasized rational decision making and considered program quality and need, and characteristics of the decision maker. The organizational perspective focused on structures and resources within and available to the organization. And the political approach examined the influence of various stakeholder groups and key players. The variables suggested by each of these perspectives are listed in Table 1 (Scheirer, 1990).

Table 1

Predictors of Sustainability Identified by Scheirer (1990)

Theoretical Perspective	Variables	Significant
Political	Expert first source, Presence of champion	Yes
	Form of initial information (*oral or written*), Stakeholder advocacy (*# of groups, # opposed, # whose approval is necessary*)	No
Organizational	Size, Type, Location, Unionization, Financial ability	No
	No paid staff	Yes
	Years using the program	Yes
Classical	Relative need (*importance of the problem, resources of beneficiaries*), Superintendent demographics (*age, level of education, relevant expertise, years experience, gender*)	No
	Attitude/favorability index (*comprehensibility, implementability, piloting, priority, cost, available funding*)	Yes

Scheirer (1990) collected data from a stratified sample of school districts that had implemented a FMRP and those that had not. From the sample of implementing districts, districts were differentiated based on whether they continued to use the program or discontinued use. The focus was on understanding the decision process and key factors used in adopting and sustaining the programs. Data were collected using semi-structured telephone interviews with superintendents, other administrators, school nurses, dental hygienists, and local officials as respondents. Each informant provided information relevant to their involvement/knowledge of the FMRP in their district. Superintendents were the first point of contact and then others were identified as needed to supplement data collected. Because data were collected in 1979 and again in 1985, the study has the potential to take a

more longitudinal view of sustainability. Unfortunately, the author reports that "because the earlier [1979] data were not predictive of 1985 outcomes, this paper reports only 1985 data"(Scherier, 1990, p. 205). No further explanation was given about what 1979 data were collected or how it was used in statistical analysis, except to say (in note 6) that data were collected on similar items. This type of information would have been especially relevant to the current study in which archival data were analyzed for any relationship to sustainability outcomes.

Political, classical, and organizational variables were entered into an exploratory multiple regression analysis using a backwards stepwise procedure. The study found that of those school districts that had adopted a FMRP, 79% had sustained it at the time of data collection (i.e. 1 - 6 years after adoption). The results indicated that sustainability was correlated with the political variables of having an expert as the first source of information about the program, having a program champion, and the perception that funding was stable. The author reports that most school districts that did not sustain the program did not engage in a formal decision process, but simply let the program "fade away." She suggested that having individuals (such as the first source of information and the champion) who are committed to the program, inhibits discontinuation. Scherier (1990) also made a point to distinguish the third significant political variable, perceived funding stability, from actual funding sustainability, which was not related to sustainability.[14]

[14] The author noted that one factor distinguishing continuers from discontinuers was obtaining budgetary funds from the school district. However, this variable did not remain significant in the final multivariate regression analysis.

Scherier (1990) found that the extent to which school districts sustained use of the FMRP was significantly affected by the number of years they had used the program. Those who adopted it earlier tended to continue using the program. Whereas late adopters who had been using the program for less time were less likely to have sustained it. In fact, sustained programs had been in operation for and average of 6.6 years while discontinued programs only made it to an average of 3.7 years. Clearly, there seems to be a critical period for programs to become established enough to be sustained over the long term.

The only other significant organizational variable was the use of school district paid staff to administer the program. Scheirer (1990) found that programs that did not require the district to pay staff, or had staff paid by another agency were more likely to be sustained. This finding is interesting because it seems to contradict the institutionalization theory. While it is clear that low or no-cost programs require fewer resources and are less taxing to the organization, they also do not require much commitment from the organization and staff. On the other hand, if staff is paid by an outside agency (such as the health department), this may indicate a strong degree of stakeholder support from groups that are highly invested in the issue of dental hygiene. The author explained that she used OLS regression rather than logistic regression (which would have been technically correct for analysis with dichotomous variables), so this result may be due to inappropriate statistical analysis.

Finally, Scherier (1990) discussed the effect of classical variables on program sustainability. The favorability index was the only variable that significantly predicted sustainability. The author explained that the index measured comprehensibility, implementability, piloting, priority, cost, and available funding. However, due to

retrospective data collection, it is possible that districts that discontinued use devalued the program after they abandoned it. This issue of retrospective data collection was important for the current analysis. While the present study relied on some retrospective data, reliability can be checked using archival data on faculty and industry member satisfaction scores for graduated Centers.

Over all, Scherier (1990) illuminates some important insights about program sustainability. While the author did not apply the same theoretical framework as others who have studied this issue, there is a significant degree of overlap in the variables found to be related to sustainability. Scherier (1990) was one of the first authors to attempt an empirical approach to studying program sustainability using pre and post measures, multiple informants, and multivariate statistical analysis. Unfortunately, she did not find any relationship between pre and post measures, used somewhat inappropriate statistical analysis, and had to rely on retrospective data alone. As previously mentioned, one of the biggest concerns with this study has to do with construct validity. Scherier (1990) seemed to be measuring institutionalization (i.e. initial funding continued) rather than sustainability (i.e. survival post-initial grant support). While the two concepts are similar and do share some of the same theoretical background and processes, institutionalization does not fully capture what happens to programs when demonstration monies end. Because the author does not specifically address funding timelines, it is not clear whether these FMRPs are being sustained or simply institutionalized.

Empirical CRC Sustainability Literature

While the literature reviewed thus far does shed some light on program sustainability, little attention has been paid to how this process plays out for I/UCRCs. The sustainability literature primarily focuses on the issues faced by traditional organizations. The cooperative research centers (CRC) that are the focus of this study face unique challenges in meeting the requirements of many stakeholders such as industry members, university administration, faculty, students, government partners, and the NSF. The existing research on CRCs in transition is primarily technical reports, intended for internal use. Hence they do not provide detailed descriptions of methodology. In fact, some of the reports reviewed caution that conclusions are based on qualitative judgment, and should be interpreted as such. Nonetheless, these reports do suggest potential variables of interest.

The majority of research on CRCs graduating from NSF funding has been conducted using data from the Engineering Research Centers (ERC) program. These centers are similar to I/UCRCs in that they emphasize cooperation with industry, but they are specifically engineering related research centers, have a stronger focus on education and diversity, and a more indirect relationship with industry. Two studies have been conducted evaluating the 16 ERCs that have graduated from NSF support; one conducted from within the ERC program (Mujumdar, 2005) and one conducted by an outside firm (Ailes, Roessner, & Coward 2000). The centers in both studies started between 1985 and 1990. These two studies are complimentary in that the Ailes et al. (2000) study collected data on centers at the end of NSF support and the Mujumdar (2005) study collected data on centers several years after the grant ended.

Ailes et al. (2000) used interviews with center leadership, including center directors, affiliated university administrators, and faculty researchers, to explore issues of sustainability and fidelity to the ERC model as they prepared for the conclusion of NSF support. Interviews were conducted the year before graduation and the year of graduation. Since centers were still working through the transition process at the time of data collection, this does not really qualify as a study on sustainability. It is more a reflection of the issues that center directors believe will be influential in whether or not their centers survive post-graduation from NSF support. The study was primarily descriptive with a small sample size (n = 16).

Ailes et al. (2000) found that ERCs varied in the degree to which they were able to continue under the program model. They suggested that some aspects of the ERC model are more durable than others. Defining survival of any piece of a center as sustainability impinges upon validity of the construct. As mentioned in previously reviewed literature, sustainability is measured in terms of continued program activities, benefits, and capacity. The degree to which these aspects are continued determines the level of sustainability achieved. In this study, the primary focus was on continued program activities.

Some of the first centers to reach the end of their grant had expected to be able to reapply for additional ERC funding, so they were less prepared to make the transition when those expectations were not met; indicating that planning for sustainability was a major factor in the degree of success that these centers achieved post-NSF funding (Ailes et al., 2000). Many of the centers lost research coherence and the multidisciplinary focus derived from ERC strategic planning (Ailes et al., 2000). This lost coherence was generally

attributed to the need to apply for other funding that did not facilitate collaborative, multidisciplinary research. However, centers that had their own physical space (i.e. a dedicated facility or building) were better able to continue in the collaborative research that center faculty had come to value.

As centers prepared for graduation, they were less likely to continue the long-term fundamental research that was considered to be the basis of ERC work. This shift was often necessary because industry members were not willing to support this type of research, which had previously been funded by NSF dollars. Graduating ERCs also were more likely to engage in more applied short-term research in an effort to cater to industry sponsors (Ailes et al., 2000). However, most Centers had not increased the actual number of industry sponsors, but the make-up of sponsorship often changed as a result of shifting research focus. Some centers even reported losing industry sponsors who had valued the more fundamental research supported by the NSF, but were unwilling to support it themselves. In fact, centers that were funded primarily by industry and lacked institutional support were less likely to engage in multidisciplinary or fundamental research and funding tended to be project specific rather than a pooling of resources. Likewise, the support of the home institutions varied from a commitment to support the center for a limited number of years to disinterest in center survival. Ailes et al. (2000) found that institutional support was one of the strongest factors believed to predict center survival under the ERC model.

The most common negative consequences of graduation from NSF support were downsizing in terms of administrative support staff, educational programs, and diversity recruitment programs and loss of the prestige associated with NSF endorsement (Ailes et al.,

2000). Apparently, the NSF "stamp of approval" was a big selling point for attracting and retaining industry members. However, an open transition planning process, involving faculty, university administration, and industry seemed to ameliorate this problem to some extent (Ailes et al., 2000). Ailes et al. (2000) state that transition planning strategies such as

> formation of a broader institute of which the center would become one component, competition for a new ERC in a different but related area, application for an I/UCRC, competition for a long-term grant from another federal agency or industry consortium, increased industry membership fees or broader membership, increased income from patents and spin-offs, increased user fees for laboratories and facilities, increased return of indirect cost recovery or direct subsidies from the university or state, and grants from NSF's Education Directorate or other sources to continue certain education functions

were often utilized by graduating centers (Ailes et al., 2000, p. 9). Based on interview findings, Ailes et al. (2000) identified several factors they believed to impact ERC sustainability:

> *Infrastructure* – Centers that have dedicated space, expensive equipment that needs to be maintained, and low core administrative costs or cost sharing will be better able to persist under the ERC model.
>
> *Transition Planning* – Centers that have a sustainability plan, do not expect to be awarded additional NSF funds, focus intensely on developing a complex transition plan, and involve their home institutions in transition planning will be

better able to make a successful transition; maintaining core ERC components post graduation.

Center Management – Centers that make positive changes in center leadership, or have a center director with an inclusive management style and a comfortable, open relationship with associated university leadership will be better able to maintain core ERC components upon graduating from NSF support.

Faculty Involvement – Centers that develop a sense of ownership in faculty and offer incentives for remaining involved in collaborative research are more likely to make a successful transition.

Institutional Factors – Centers that are provided some financial protection by their home universities, are assured of an on-going supportive attitude, are consistent with the larger university culture, are housed in universities that have developed policies that facilitate the centers' research (i.e. indirect cost recovery, release time for research, promotion/tenure criteria that place value on collaboration), and are highly prized and highly visible within the university will be better able to make a smooth transition. Centers will be able to have greater prominence in smaller universities and those with lower stature prior to the development of the ERC program.

Nature of the Research Area – Centers engaged in research that is still "hot", that lends itself to expansion, and demonstrates progress towards yielding income will be better able to attract the industry sponsorship that facilitates a successful transition.

Character of Industrial Participation – Centers who involve industrial members in transition planning, who have members that are deeply and broadly involved with the center, value access to center graduates, and do not object to increased membership fees will be better able to persist under the ERC model. The continued reduction of in-house R&D programs in industry is hypothesized to facilitate these kinds of relationships.

Educational Programs – Centers that are able to acquire alternative NSF/Federal support of their educational components, and are able to develop educational components that are valued by their home universities, have industrial members that are willing to support students, and have faculty that value student involvement with center research enough to support them despite decreases in funding will be more successful in maintaining this aspect of the ERC model post graduation (Ailes et al., 2000).

Clearly, this study provides invaluable insights into the graduation process because it specifically focused on CRCs in transition. However, there are some methodological limitations. Because data collection occurred at the time of transition, respondents were only able to speculate about what factors might impact their future sustainability. While other research on sustainability has perceptions about process, none have used speculative perceptions. In addition, no statistical analysis was conducted considering the small sample size (n = 16) so conclusions are based on inference and judgment. Finally, the applicability of these findings to the I/UCRC program is unclear given the unique character of the respective programs. Nevertheless, Ailes et al. (2000) identified some new factors to be

included in this study on I/UCRC sustainability: transition planning, prestige, the link between facilities and fidelity, changes in research scope and focus. In addition, it suggests some appropriate operationalizations of variables previously identified. For example continued capacity can be measured in terms of industrial advisory board (IAB) meetings, university cost sharing, facilities, and networking mechanisms. Continued benefits can be measured in terms of research area, technology transfer, and students. Continued activities can be measured in terms or research, industry participation, and educational programs.

In a related study conducted from within the ERC program, Mujumdar (2005) was able to collect data on eight of the 16 graduated centers. One center had closed, one referred researchers to their website, and six others did not respond. Unfortunately, no information was obtained about these centers. This would be valuable information as it might reveal factors that limited the sustainability of these centers post graduation from NSF funding. The authors could have indicated whether the non-responding centers were still in existence in some fashion, but did not. Comparisons could have been made between responders and non-responders based on data from the Ailes et al. (2000) study, but this was not possible. Also, it is not clear as to why centers did not respond. However, five of the non-responders were among the first to graduate from the ERC program and had experienced the most difficulty making the transition due, in part, to unclear NSF policies regarding self-sufficiency and reapplication for funding. It seems likely that either these centers did not survive, or they chose not to respond because they did not have positive comments to make. Clearly issues of attrition and social desirability bias are potentially affecting the internal validity of this study (Mujumdar, 2005).

Data were collected using a 22 item survey that asked questions such as is the center still operating, has the mission/focus changes since graduation, current sources of financial support, type of research, most long-lasting impact since graduation, what is missed most about not having NSF support, and suggestions to strengthen the ERC model (Mujumdar, 2005). Given that there were almost three times as many questions as respondents, statistical analysis was not appropriate. As with the previous study, all outcomes are descriptive. Also, results from the Ailes et al. (2000) study indicated the potential for other factors of interest (i.e. level of institutional support, and infrastructure, faculty satisfaction, character of industrial participation, strength of research area). Unfortunately, this information was not incorporated into the Mujumdar (2005) report. The issue of how sustainability is defined or how much fidelity an ERC must maintain is reflected in the differences between these two studies' approaches to assessing graduation outcomes. More continuity between the studies would have allowed for a greater understanding of the sustainability process for ERCs. Ailes et al. (2000) mentioned that data were collected the year before graduation and the year of graduation. Mujumdar (2005) could have served as a sort of post test had similar methodologies been used and similar variables investigated. However, since this is not the case, connections between the two studies will be drawn with caution.

All of the graduated ERCs that did respond had established alternative sources of funding post graduation from NSF funding: 100% of the graduated ERCs had funding from industry, 75% university, 63% government, and 89% of the graduated ERCs had other funding sources (Mujumdar, 2005). However, sustainability did require some of the ERCs to adapt to new stakeholder values. As predicted by Ailes et al. (2000), most of the ERCs had

developed a more industry driven mission that prioritized applied research and more broad research agendas. However, after some initial turmoil and uncertainty, all of the responding graduated centers did still report engaging in some fundamental research (Mujumdar, 2005). This seems to be a positive change from the perceptions reported in the previous study. Also, all the graduated centers had established technology transfer policies or departments, reflecting a need to cater to industrial members.

Only about half of the centers were able to continue supporting educational courses for students, and all but one ERC had developed educational outreach programs for their members (Mujumdar, 2005). Clearly, this shift reflects the shifting priorities of stakeholders in the absence of NSF influence. Unfortunately, it is not clear whether students were still routinely involved in center research projects. Since access to student with center experience is one of the main benefits valued by industry (Gray & Walters, 1998; Rivers & Gray, 2006), it is important to assess the availability of this resource once NSF funding is expired.

ERCs included in this study reported that there were both pros and cons to graduating from NSF support (Mujumdar, 2005). While they enjoyed the reduced diversity requirements, political hassles, and reporting procedures, centers stated that the loss of NSF support reduced the coherence of research focus, reduced multidisciplinary interaction at the research and administrative level, and resulted in fewer special programs (Mujumdar, 2005). Clearly, many of the changes occurring at the time of transition (Ailes et al., 2000) persisted once the centers became self-sustained.

One strength of the Mujumdar (2005) study was that it asked ERC graduate respondents to offer suggestions to improve the ERC model. Suggestions included

increasing the proportion of industry relevant research, reducing the emphasis on publishing in order to better meet industry needs, encouraging more flexibility in strategic planning of research, continued baseline support for graduated centers, fewer mandatory programs, fostering/requiring continued university support, maintaining a culture of innovation, and allowing support of foreign students (Mujumdar, 2005). It is interesting to note the more broadly focused suggestions offered in this study compared with those offered in the Ailes et al. (2000) study. At the time of transition, most of the comments were regarding the issue of whether some form of continued support from the NSF was possible. Although centers still suggested the continuation of baseline support, it seems that having some distance from the turmoil of transition allowed them to "see the big picture". As previously mentioned, there are methodological issues that limit the interpretability of these findings. However, they suggest that issues faced at the time of transition tend to stabilize in the long-term. Taken together, these studies provide an initial picture of potential factors to be considered in further research on the graduation process from NSF funded I/UCRCs.

Literature Summary

The theoretical and empirical literature on program sustainability, as well as the literature on CRCs reviewed above, provide the basis for this study. The concept of program sustainability has been defined by authors in public health, organizational development, and community development. Yet the application of the concept in research has been relatively weak. For the purpose of this study, program sustainability is defined as the continuation of core program activities, the continuation of benefits provided to program stakeholders, and the maintenance of program structures that support the capacity to continue the program once

initial funding from a time limited grant are exhausted. For I/UCRCs this means that sustained centers continue to conduct core activities such as research, collaboration with industry, and other core program components; they continue to provide benefits to faculty, the university, students and industry; and they maintain critical structures such as the IAB, university support, and membership fees that support the capacity to continue running the center beyond the 10 year grant period.

Not only do the studies reviewed provide a description of what program sustainability is, they also investigate environmental, organizational, program, and individual level variables that predict it. At the environmental level, the following variables have been suggested in the literature reviewed: availability of resources from multiple outside sources, outside stakeholder support and participation, program fit with the context, and technical assistance. In addition, the literature in CRCs includes stakeholder involvement in transition planning, the nature of the research area, the character of industrial participation, and economic trends to environmental level variables correlated with sustainability.

Organizational level variables identified in the literature on program sustainability are: institutional strength in terms of stability and maturity, integration of the program into existing organizational structures and processes, fit of the program with the organizational mission, presence of a program champion[15], a large organizational resource base, formalization of organizational infrastructure to support the program (such as dedicated staff, in-kind support, budget allocation, facilities and equipment, and formalized policies

[15] While many authors include program champion as an organizational level predictor. Research by Craig el al. (in press) on CRC leadership and by Dees (2001) on social entrepreneurship warrants discussing an individual level of analysis.

and procedures), and organizational stakeholder support. Research focused specifically on CRCs reiterated these variables and adds the perception of prestige for the organization as a result of the program and university policies that facilitate collaborative research and technology transfer to the organizational level variables associated with program sustainability for CRCs.

At the program level, the following variables were identified in the literature as being associated with program sustainability: stakeholders are involved in the design of the program, the program meets stakeholder needs and they receive benefits, fidelity to core program components is maintained, evaluation data show that the program is effective and this information is communicated to stakeholders, the program is supported by the initial grant for at least five years, the program has the necessary resources, is adaptable to local conditions, uses multiple transition strategies, and the program does not put excessive strain on the host organization in terms of resource requirements. Again, the literature on CRCs reinforces the importance of these variables to program sustainability, emphasizing, adaptation, fidelity, fit, and stakeholder benefits.

While most authors do not include an individual level of analysis in the study of program sustainability, they do mention the importance of program champions and leaders as organizational features associated with program sustainability. It may be that the presence of these roles are important organizational variables, however the behaviors and associated characteristics seem to be individual level variables. According to the literature on program sustainability, program champions sell the program both within their organization and in the larger environment, they identify resources for the program, work to garner support for it,

foster integration, provide support to staff, lead program planning and implementation, develop partnerships, expand the program's network of supporters, communicate commitment to the program, engage others, overcome barriers, build infrastructure, use reflexivity, summarize and communicate technical knowledge, plan for sustainability, and build organizational capacity. Leaders accomplish these tasks for their program by acting as social entrepreneurs: identifying opportunities, innovating, adapting, learning, tolerating risk, being accountable, using earned income strategies, partnering with other organizations, creating synergy between social and profit mission, using balanced judgment, staying focused on purpose, and being proactive. The research on CRCs specifically points out the importance of the leaders relationships with industry, university administration, and faculty. Here, a positive working relationship and active involvement are key. Research specifically on leaders of university based cooperative research centers reinforces this importance of these factors. Craig et al. (2007) identified technical expertise, ambition / work ethic, broad thinking, embracing ambiguity, balancing competing stakeholders, leveraging social capital, obtaining resources, navigating bureaucracy, granting autonomy, interpersonal skill, team building and maintenance, and task adaptability as positive dimensions of leadership and abrasiveness, disorganization, conflict avoidance as negative leadership dimensions.

Clearly there are quite a few factors that influence whether a program will achieve sustainability. But not all of these variables make sense to include in this study of program sustainability for I/UCRCs. Scherier (2005) did identify what she calls the "Big 5" of sustainability predictors: program adaptability, the presence of a program champion, a fit with organizational mission and infrastructure, perceived benefits to stakeholders, and

support from stakeholders in the environment. In addition to these, almost all the studies reviewed investigated the impact of funding on program sustainability, in terms of amount available in the environment or host organization, amount actually received, sources of funding, and in-kind support. Clearly, these issues are relevant to the sustainability of I/UCRCs and warrant further investigation. Beyond these Big 5 plus funding, there are several issues identified as specifically relevant to CRCs: infrastructure, transition planning, center management, faculty involvement, institutional factors, nature of the research area, character of industrial participation, educational programs, and leadership.

Finally, the literature review raises some methodological considerations regarding the study of program sustainability. While the literature reviewed found that between 50% and 80% of program sites were sustained, these results must be interpreted with caution given the methodological limitations of the studies reviewed. The most common measure of sustainability was continued program activities. However, research was limited by the lack of appropriate operational definitions for sustainability measures and predictors in much of the literature reviewed. The majority of studies reviewed collected data via telephone interviews or surveys with key program leaders, and a smaller number did case studies and site visits. While some studies did report collecting data from multiple sources per program, many collected data from only one source. In terms of sampling, both convenience and stratified sampling were used. While convenience sampling is clearly simpler, stratification allows one to distinguish differences between programs that were sustained and those that were not. However, no studies were able to sample all the participants (i.e. centers) in a

given program. For this study, I was able to collect data on all of graduated I/UCRCs in order to capture the diversity of outcomes and processes for these Centers.

Another methodological issue was the timing of data collection. In the studies reviewed, data were collected anywhere from 0 to 20 years after the initial funding ended and in some cases it was not clear whether funding ever ended at all. While data for this study were collected anywhere from 1 to 0 years after the end of the 10 year grant period, time since I/UCRC funding ended was controlled for by looking at the proportion of time a Center was sustained compared to the amount of time it could have been sustained. Few of the studies reviewed here controlled for the timing of data collection. In addition to controlling for time since the end of initial funding, other control variables suggested in the literature include whether program sites were early adopters or not and length of the initial funding period. As just mentioned, the issue of whether a program ever in fact lost initial funding was a concern as well. It seems that some of the authors viewed sustainability more in terms of institutionalization within a host organization, rather than as an issue of how programs grapple with transition and survival. For this study, all I/UCRCs included have reached the end of a 10 year funding cycle or dropped out prior to the end of their 10 years.[16]

Another limitation to previous literature on program sustainability is the scarcity of statistical analysis. Only two studies were identified that went beyond simple descriptive statistics. Those studies used multinomial logistic regression and exploratory multiple regression analysis to determine what factors might be correlated with sustainability

[16] It should be noted that I/UCRCs that merged with another Center at the end of their funding cycle will also be included in the sample because, while they still receive NSF support, they are using merger as a sustainability strategy and must continue to grapple with this issue of transition on an ongoing basis.

outcomes. And while O'Loughlin et al. (1998) attempted to compare pre and post data, no longitudinal studies of program sustainability exist. While the current study cannot overcome all the limitations found in previous literature, I took a longitudinal approach, used multivariate statistics, operationally defined variables, used multiple measures of sustainability, collected data from more than one respondent per Center, and controlled for variation in the timing of data collection.

METHODS

Research Questions

This study addressed the following research questions:

Descriptive Questions

1. What is the status of I/UCRCs after their grants end? Status was measured in the following ways: *graduation status* (received the full 10 year award, or exited the program prior to the 10th year of operation), *post graduation status* (operating for at least one year post-I/UCRC funding, or not operating for at least one year post-I/UCRC funding), *current status* (currently operating, not currently operating, merged with an NSF funded Center), *total years operating* (from first year of funding to last year of operation), *number of sustained* (last year of NSF funding to last year of operation).
2. How much fidelity to the standard I/UCRC model do sustained Centers exhibit? Fidelity was measured in terms of the degree to which post-NSF Centers continue to exhibit core program components (*university based, industrial support, membership fees, IAB, consortial project selection and results dissemination, multidisciplinary*

research focus, and stakeholder meetings) as well as secondary program characteristics (*using Level of Interest Feedback Eevaluation forms to evaluate research, external evaluation, and technology/knowledge transfer*) of the program model.

3. To what extent has the Center sustained itself in terms of continued program activities (*research focus, number of research projects*), structures (*number of industry members, faculty researchers, students involved, administrative staff, university overhead discount, total budget, funding sources, number of departments involved, membership fee levels*), and outcomes (*IP events, Center graduates, Center graduates hired by Center members, publications and presentations*)?

Predictive Questions

While the literature is limited, specifically with respect to cooperative research centers, it suggests that environmental, organizational, program, and individual level factors impact program outcomes post-government funding. As a consequence, I addressed the following predictive questions:

4. What environmental, organizational, program, and individual variables predict Center status as measured by *current status, post-graduation status, total years operating*, and *years sustained*?
5. What environmental, organizational, program, and individual variables predict fidelity to the IUCRC model?
6. What environmental, organizational, program, and individual variables predict Center sustainability as measured by continued activities (*number of research projects*),

structures (*number of members* and *total budget*), and outcomes (*IP events*, *graduates*, and *graduates hired by members*)?

Given the limited amount of theory and research on sustainability of centers, I examined the following exploratory question:

7. What issues do key informants think are critical for I/UCRC sustainability?

Research Design

The study design is both descriptive and predictive. In order to address questions one, two, and three data were obtained on the current status, fidelity, and sustainability of all formerly funded I/UCRCs. In order to address questions four through seven quantitative and qualitative data were collected about Center operations, support, and practices while it was funded by NSF to predict Center status, fidelity, and sustainability. Data were obtained from a variety of sources including archival records, surveys, and interviews with key Center informants.

I/UCRC Program

Program Goals & Objectives. The NSF I/UCRC program has been operating since 1979. The I/UCRC model is an industry-university linkage mechanism that takes a complex hybrid organizational form (Gray & Walters, 1998). Core components of the I/UCRC model are: university based, industrial support, membership fees, IAB, consortial project selection and results dissemination, and stakeholder meetings. Some more secondary characteristics of the I/UCRC model are: using Level of Interest Feedback Evaluation (LIFE) forms to evaluate research, external evaluation, and technology/knowledge transfer.

Centers are semi-autonomous research organizations housed within a university setting that engage in multidisciplinary collaborative research with industry member firms, in which research is directed by industrial interest. I/UCRCs are housed in at least one university, but the trend for having multiple university sites has increased over the years. Research conducted by I/UCRCs is done by faculty and student researchers in collaboration with industry partners, and projects are selected by an Industrial Advisory Board (IAB) made up of sponsoring firms. Collaboration with multiple industrial member firms means that Centers must focus on research that is precompetitive in nature and of interest to an entire industry, rather than specific member firms. Centers conduct research in the following areas: advanced electronics, advanced manufacturing, advanced materials, biotechnology, civil infrastructure systems, information, communication, and computing, energy and environment, fabrication and processing technology, health and safety, quality, reliability, and maintenance, and system design and simulation (NSF I/UCRC website, 2008).

The NSF selects proposed Centers based on a peer review process focusing on "knowledge of the I/UCRC model, scientific merit emphasizing multidisciplinary, leadership, industrial support, institutional support, marketing strategy and research strategy"(Gray & Walters, 1998). Selected I/UCRCs are awarded a five-year grant of approximately $70,000 per year. This grant can be extended for an additional five years at a reduced funding level, but does not typically exceed ten years[17]. On average, I/UCRCs are funded for 10.84 years (*SD* = 5.42). By providing a minimal amount of support (an average of less than 8% of the

[17] In the early years of the program, centers could restart their funding cycle by adding a new site or adjusting their research focus. There are still some centers that have been able to stay in the program by merging with newly formed centers under the new Center name.

annual Center budget), the NSF can reduce the risk associated with starting a Center while attracting motivated entrepreneurial faculty applicants and reinforcing a customer orientation (Rivers & Gray, 2006). As of the 2008-2009 fiscal year, NSF was leveraging its investment in Centers at a rate of eight to one (McGowen & Gray, 2009). The prestige associated with being an NSF initiated I/UCRC helps to attract industrial sponsors and garner support from host universities (Gray & Walters, 1998). In addition to support from the NSF grant, industry membership fees, and university cost sharing, the remainder of an I/UCRCs budget typically comes from other government entities, supplemental industrial support, foundation grants, and other sources. Centers receiving NSF funding must maintain $300,000 of industrial support from at least six members and have a plan for self-sufficiency from the NSF[18]. Industry members provide the largest share of financial support for Centers (approximately 30% of a Center's total budget) because the intent is to foster collaborative approaches to research with the expectation that Centers will become fully supported by industry sponsors and other non-NSF sources by the end of the grant period (Gray & McGowen, 2008).

One of the main goals of the I/UCRC program is to foster collaborative approaches to R&D that are sustainable in the long term; that is, they are able to generate support independent from the NSF. In fact, the NSF explicitly states that its "investment in the I/UCRCs is intended to seed partnered approaches to new or emerging research areas, not to sustain the Centers indefinitely. The Foundation intends for I/UCRCs to gradually become

[18] A recent change in I/UCRC program requirements now states that new Centers must have 10 industrial members, with no minimum dollar amount specified. However, all of the Centers that are the focus of this study were subject to the old rules mentioned above.

fully supported by university, industry, state, and/or other non-NSF sponsors" (National Science Foundation, 2006).

Since 1982, data have been collected on all active Centers in an effort to evaluate the degree to which I/UCRCs achieve these various goals and adhere to the collaborative process. Each Center had its own evaluator, and the evaluation effort is coordinated at the national level by the I/UCRC Evaluation Project at North Carolina State University. Data collected include, an annual qualitative Evaluator's Report detailing the progress of each Center, a Center Director Report containing financial and structural information, and Industry and Faculty Process/Outcome questionnaires assessing stakeholder outcomes. As a result, a great deal is known about the effectiveness of Centers while they are actively supported by the NSF. There are currently 37 active Centers, with 590 researchers, 998 graduate students, 206 undergraduate students, 698 industry memberships, and a combined annual budget of $62.8 million (Gray & McGowen, 2010). However, virtually nothing is known about the extent to which they survive post-graduation or what factors predict their success. While it is estimated that 80% of I/UCRCs are successful in making that transition, there is little evidence if this rate is accurate or what factors are associated with survival and sustainability (NSF I/UCRC website, 2006). The goal of this study is to further develop an understanding of the full I/UCRC lifecycle. Specifically, to understand what happens to Centers post-NSF support and how that transition is managed.

Sample

Forty-three single site Centers and 30 multi site Centers have exited the program. Centers that have exited the program conducted research on a wide range of topical areas,

including advanced electronics, advanced manufacturing, advanced materials, biotechnology, civil infrastructure systems, information, communication, and computing, energy and environment, fabrication and processing technology, health and safety, quality, reliability, and maintenance, and system design and simulation (NSF I/UCRC website, 2006). Participants in this study were former I/UCRCs. In order to participate, Centers must meet several criteria:

1. They must have received an NSF I/UCRC operating grant.
2. They are no longer funded by an NSF I/UCRC operating grant either because they reached the end of their funding cycle or exited the program prior to the end of their grant.
3. Centers whose grants ended and were subsequently funded because they merged with a newer Center were also included[19].

Centers must have also been out of the program for at least one year as of the 2005-2006 fiscal year. There is not a generally agreed upon time period after which a program can be considered sustained. However, programs that have not dealt with issues of sustainability for at least one year have not reached a point at which accurate outcome data can be obtained. The first Center was started in 1979 and as of the 2006-2007 fiscal year, there are 73 Centers that have exited the program (Gray & McGowen, 2008).[20] There are six Centers that merged with other IUCRCs to form three formerly funded I/UCRCs, bringing the total

[19] Merger with a newer Center is considered a sustainability strategy, and therefore should be captured in the analysis.

[20] There are a few more I/UCRCs that graduated from the program within the last 2 years. However, they are not included in the sample because they will not have been out of the program for long enough to truly be able to assess their sustainability. While there is no generally agreed upon time after which a program is considered sustained, surely less than one year post-NSF funding does not meet the threshold.

population to 70[21]. All 70 of these Centers were invited to participate so that the status and sustainability process for both sustained and non-sustained Centers could captured. Centers included in the study range in age from 1 to 30 years old. The first Center exited the program in 1987; six Centers exited the program by the end of the 80s, nine more exited by 1995, 20 more by 2000, and the remaining 35 left the program by 2006 (See Figure 1).

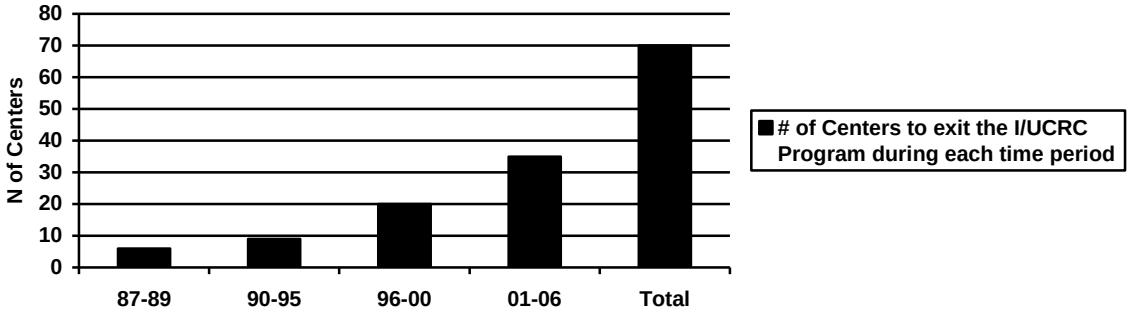

Figure 1. *Centers Exiting the I/UCRC Program by Year.*

Respondents were Center or university administrators for each Center. Because some Centers have been out of the program for as long as 22 years, it was often difficult to contact past administrators so other informants were contacted to provide information (see Key Informant Interview section for details).

Data Sources and Instruments

Data came from archival data sources as well as semi-structured interviews and surveys administered to key informants. Archival data include an annually produced Center Director Structural Information Report, managing site university records, and other national level data sources. Data have been archived since 1986. In addition to archival data, Center

[21] Graduation year data for merged centers was combined in all analyses.

administrators were asked to participate in interviews and to complete surveys in order to obtain current data on the Centers. In the case that a Center respondent could not be identified university records and online information were used to supplement interview and survey data. In the two instances that key informants declined to participate in the interview, they did provide the current status of the Center and directed the researcher to the Centers' websites for further information (participation rate = 100%).

Center Director Structural Information Database. The Center Director Structural Information database contains information about Center budgets, income by source category, membership, students graduated, and technology transfer. The reports are completed by Center Directors or other administrators and reflect Center status as of the most recently completed fiscal year. Data have been collected since 1986. However, the instrument has undergone some revisions over the past 30 years. Some variables have been disaggregated in recent years, while others have been added, with only a few being dropped entirely. Where possible, consistency was maintained throughout the data set. However, variables were selected based on availability[22].

Key Informant Interview & Survey. Data about the current status, continuing activities and fidelity of the Center were obtained from a telephone interview with key informants (See Appendix A). The goal was to collect this information from the Center's current Director. However, since Centers exited as long as 22 years ago, some are no longer in operation. Where necessary, the following hierarchy was used to select key informants: 1)

[22] A Process/Outcome Questionnaire is also administered to centers while they are funded under an I/UCRC grant. However, this data was not available prior to 1998, a 52.9% maximum response rate. Therefore, although I intended to use Process/Outcome data, those variables were dropped.

current Director; 2) recent Director; 3), Director at the time of transition, 4) secondary Site Director, 5) University official to whom the Director reported, 6) anyone else at the university who was/is involved with the Center, and/or 7) university records and information available online. Of the 70 Centers in the sample 48.6% had the current Center Director as the primary key informant, 21.4% had a past Center Director, 2.9% had Center personnel, 4.3% had a university administrator, 4.3 had online sources, and 18.6% had multiple primary key informants. If those with multiple key informants 15.7% included a current or past Center Director, while only 2.9% did not.

In addition to the interview, key informants were also asked to complete a survey to collect more specific budget, outcome, and personnel information relevant to the Center's current operation (See Appendix B). In most cases the survey was administered over the phone. However, respondents were given the option to receive the survey via email.[23]

Other Archival Data Sources. In addition to archival data collected as part of the NSF I/UCRC Evaluation Project, other national level data sources and university records were used to assess environmental and organizational level predictors of program sustainability. The national gross domestic product (GDP) was used as an environmental measure of economic strength (Shediac-Rizkallah & Bone, 1998; Officer & Williamson, 2006). The National Science Board's Science and Engineering Indicators (1987-2006) were used to measure various sources of funding for R&D in the US. In terms of organizational

[23] Some data were also collected from evaluators about transition planning and program implementation. However, response rates from evaluators was extremely low (32%) so their data were dropped from analysis. See Appendix C for the evaluator survey.

level predictors from outside archival data sources, information from the managing university as well as the Carnegie Foundation were collected (Carnegie Foundation website).

Procedures

National Science Foundation, I/UCRC evaluators, I/UCRC Center Directors, and the NC State IRB approved the project and data collection. Archival data from the Center Director Structural Information Report for Centers that have exited the I/UCRC program, were merged into a new dataset. In order to assure continuity across the data set, all old instruments were examined for similarities and differences. Items that were not collected throughout the evaluation project were dropped. Where items have been modified over time, an attempt was made to reconcile these differences by re-combining items that had been disaggregated in more recent versions of the report or drop the variable. Data are available back to 1986.

Prior to substantive data collection, the survey and interview protocol were piloted with a few Center Directors from the I/UCRC program (n = 4). Based on interviews with these respondents several items had to be dropped; either because the information was too difficult to obtain, or because respondents indicated that they had trouble providing retrospective data. Dropped items are listed in Appendix D.

In order to identify study participants, archival records were used to identify the last director of record. This information was cross-referenced by checking the website of the host university and/or Center. Persons listed as Center Director in any of these sources were contacted to determine who was the appropriate respondent according to the hierarchy established in the section on sample. After the list of potential respondents and their contact

information was developed, the NSF I/UCRC Program Director and the I/UCRC Evaluation Project Director sent out an email inviting and encouraging them to participate (Appendix E). This communication clearly associated the study with the I/UCRC program, placed some importance on participating in the interview, and served to reduce the chances that communications from the investigator were ignored.

The day after the emails from the I/UCRC Program Director and I/UCRC Evaluation Project Director were sent, the researcher sent an invitation email (Appendix F). The email referenced the previous emails, explained the purpose of the study again, invited participation, described the types of information to be discussed, ensured confidentiality of respondents, identified the expected time the interview would take, and asked to schedule an interview time. Respondents were given one week to respond to the email at which point the researcher called them/their administrative assistant to request an interview time. Follow-up contacts were made with non-responding administrators to increase the response rate. Research results will be posted on the I/UCRC Evaluation Project's website and those who participate in the study will be notified that the results are available.

Measures

Outcome Measures

Graduation Status. The I/UCRC program is designed to fund Centers for 10 years. After which point it is hoped that Centers will be able to sustain themselves with support from other sources. However, not all Centers receive the full 10 years of support either because they are not meeting grant requirements, they choose to go after larger grants, or simply choose to leave the program. Before addressing whether a Center is still operating, a

decision was made to also assess *graduation status*. This variable was assessed via archival data from the Center Director Report. Centers that received less than 10 years of I/UCRC funding were coded as not graduated. Those with 10 or more years of I/UCRC funding were coded as graduated.

Post-Graduation Status. Some older Centers may have sustained themselves for a significant period of time, but are not currently operating. As a result, participants were asked to report whether the Center operated for at least one year after the end of its I/UCRC grant (*post-graduation status)*. When respondents indicated that the Center was no longer in operation, they were asked a series of follow-up questions to assess whether the Center achieved sustainability for any period of time prior to closing down. This variable was measured via the Key Informant Interview by asking "What happened to CENTER NAME after the I/UCRC grant ended?" Respondents indicating that the Center was closed were asked "When did CENTER NAME cease operations?" Responses were coded as a year and compared with the final I/UCRC grant funding year. Since most studies in the literature considered programs that lasted as little as one-years as sustained, centers whose final I/UCRC grant funding year was at least one year prior to their final year of operation were coded as sustained. Those that reported closing the Center in the year of graduation were coded as not sustained.

Current Status. One of the most commonly used measures of sustainability is *current status* (Scheirer, 2005; Mujumdar, 2005). For Centers, this refers to whether or not a given Center exists as an industry-university cooperative research entity. This variable was assessed via the key informant interview by asking respondents: "What happened to

CENTER NAME after the I/UCRC grant ended?" This was coded as currently in operation or no longer in operation.

There are some minimum criteria against which Center status was gauged: *conducts research, receives external support, involves at least 3 PIs,* and *at least 1 student involved*. Operational definitions for these items are included in Appendix A. All sustained Centers met the minimum Center criteria.[24] Centers that reported negative scores on any of these criteria were coded as not operating.

Years Operating and Sustained. In addition to measuring the current operational status of I/UCRCs, *total years operating* was used as another measure of Center status. This outcome measure is valuable for two reasons. First, since Centers differ on how long ago they graduated, it provided a better measure of longevity than the *current status* variable. In addition, because of the ever changing nature of research and innovation, it cannot be expected that Centers sustain themselves indefinitely. Rather it may be that Centers are able to sustain themselves until their field of research begins to decline, comes to a natural conclusion, or is replaced by a more promising line of inquiry. Therefore, Centers can be said to have achieved an acceptable level of sustainability if they are able to continue operations, despite having subsequently closed. In order to measure *total years operating*, the initial funding year (as recorded in the Center Director archival database) was subtracted from the year reported by key informants as the final year of operation (for closed Centers) or the current year (for Centers still operating). The resulting number was the total number of years the Center has operated.

[24] Some centers had missing data on one or more of these items, but no sustained center indicated that they did not meet these criteria.

In addition, to reporting the actual number of years operating, a *years operating fraction* was also calculated. *Years operating fraction* controls for variation in total years funded and years since graduation by taking the proportion of time the Center has been operating divided by the total possible years that Center could have been operating (i.e. current year minus start year).

Years sustained was also used as a measure of Center status. While many Centers receive 10 years of funding, some Centers were able to re-compete and/or extend their NSF award by adding a new university site. Thus, a great deal of variation exists in both the age of Centers and in the number of years that Centers were supported by an I/UCRC grant (due to early termination or grant extensions). In order to account for these variations, the final year of I/UCRC grant support (as recorded in the Center Director archival database) was subtracted from the final year of operation (for closed Centers) or the current year (for Centers still operating). The resulting number is the total number of years the Center has been sustained.

In addition, to reporting the actual number of years sustained, a *years sustained fraction* was also calculated. *Years sustained fraction* controls for time since the I/UCRC grant ended by dividing the total years sustained by the total possible years sustained (i.e. current year minus years of graduation)

Other Outcomes

Previous studies have been criticized for not probing beyond simply asking if (or for how long) the program was continued to determine whether a program is really sustained. The continuation of program components as well as continued program activities, structures,

and outcomes were measured to assess program fidelity and sustainability. These data were collected for all Centers that were sustained for at least one year (N = 53).

Fidelity. Fidelity refers to the degree to which post-NSF Centers still operate under the I/UCRC model. A rationally created fidelity scale was created for this study based on core and secondary elements of the I/UCRC program model. Items were selected based on the I/UCRC program model and input from expert program personnel. The scale included the following core program components: *university based, industrial support, charges membership fees, has an IAB, consortial project selection, consortial results dissemination, and holds stakeholder meetings*. Secondary fidelity components include: *using LIFE forms to evaluate research, conducting external evaluation, and technology/knowledge transfer*.

Key informants were asked via interview to discuss the core and secondary program components. All items are presented in Appendix A. With the exception of *project selection* and *results dissemination* all items are dichotomous; 1 indicates that fidelity to the item while 0 indicates a lack of fidelity to the item. For *project selection,* responses were originally coded as 1) a numerical count of votes, 2) some other type of voting system; 3) members discuss and then develop consensus, 4) faculty driven project selection, 5) fee for service/contract based. For inclusion in this scale responses one through three were recoded as consortial project selection (1), and four through six were recoded as non-consortial (0). Likewise *results dissemination* responses were originally coded as 1) everyone has access to results of all projects, 2) members get access to some projects but not all, or 3) members get results of their "pet" projects (i.e. the one's they fund). For inclusion in this scale response

one and two were recoded as consortial results dissemination (1), and three was recoded non-consortial (0).

My plan was to create a fidelity scale. In the absence of a theoretical basis for assessing program fidelity, Exploratory Factor Analysis (EFA) with VARIMAX rotation was conducted using PSAW Statistics 18 (SPSS Inc.). The number of factors to retain was based on Kaiser's criterion, Catell's scree plot, and qualitative assessment of the variance explained by each factor. *Industry support, university based,* and *tech transfer* had to be dropped because there was too little variance in these items and the factor analysis would not run while they were included in the model.

Ultimately, the remaining seven items loaded onto two factors; structural fidelity and assessment fidelity. Structural fidelity was made up of *membership fees, IAB, consortial results dissemination, stakeholder meetings*, and *consortial project selection*. It explained 60.66% of the total variance. Assessment fidelity was made up of *evaluator* and *LIFE* and explained 18% of total variance (Table 2). Together these factors explain 78.66% of total variance.

Table 2

Output for Fidelity EFA

	h^2	F1: Structure	F2: Assessment
stakeholder meetings	.70	.84*	.02
membership fees	.93	.94*	.20
IAB	.89	.93*	.16
consortial results dissemination	.89	.93*	.16
consortial project selection	.63	.76*	.23
Evaluator	.71	.15	.83*
LIFE	.76	.13	.86*
Eigenvalue		4.25	1.26
% Total variance explained		60.66%	18.00%
α		.93	.66

h^2 = final communalities; * Indicates loadings above .40

Therefore, the five structural items were summed and averaged to create the structural fidelity measure and the two assessment items were summed and averaged to create the assessment fidelity measure. Since all items were coded 0 or 1, subscale scores ranged from 0 to 1 on both scales such that they can be thought of as the percentage of items to which fidelity was maintained. Reliability analysis indicated that the structural fidelity scale had very good reliability ($\alpha = .93$). However, the two-item assessment fidelity scale showed marginal reliability ($\alpha = .66$).

Sustainability

Continued Activities. The literature suggests that one way program sustainability can be measured is in terms of continued program activities (Shediac-Rizkallah & Bone, 1998). For I/UCRCs this means conducting *research projects* and continuing to pursue the same *research focus*. These variables were measured for Centers sustained at least one year. Key informants were asked to discuss the degree to which these activities are still conducted

(Appendix A). *Number of research projects* was coded as a count of the research projects conducted within the Center in the most recently completed fiscal year. *Research focus* was assessed via a five point scale: 1) no change, 2) slight change, 3) some change, 4) a great deal of change, or 5) totally different.

Continued Outcomes. While the literature suggests that measuring continued benefits to stakeholders is an important measure of program sustainability, an accurate assessment of the benefits of participation in an I/UCRC is not feasible. Because I/UCRCs are intended to provide benefits to a wide variety of stakeholders on a national level which are not realized for many years, directly measuring benefits is beyond the scope of this project. However, more proximal Center outcomes may indicate the productivity of a Center and its potential ability to provide benefits to stakeholders. These items came from the Key Informant Survey (Appendix B). Key informants were asked to quantify in the most recently completed fiscal year: inventions disclosed, licensing agreements, patent applications, patents granted, inventions producing royalties, and software copyrights. These variables were summed to create a count of intellectual property (*IP) events*. The survey also collected data on *number of Center graduates* (at the graduate level), *Center graduates hired by Center members* (at the graduate level), and a sum of *publications and presentations* acknowledging Center support during the most recently completed fiscal year.

Continued Capacity. Shediac-Rizkallah and Bone (1998) asserted that sustainability could also be measured in terms of community capacity for continuation of the program. These authors conceptualized capacity for continuation as the development of key structures and resources that could support the program once initial funding ended. In the case of

I/UCRCs, continued capacity is measured in terms of continuation of critical support structures and resources that enable Centers to sustain themselves. All items were assessed via the Key Informant Survey (Appendix B) for Centers that were sustained at least one year. Continued capacity variables are: *number of industry members, number of faculty researchers, number of students involved, number administrative, university overhead discount, total budget, funding sources, number of departments involved,* and *membership fee level*. With the exception of *university overhead discount*, *total budget*, and *membership fee level,* all variables were coded as a count. *University overhead discount* was calculated by subtracting the overhead rate charged to membership fees from the typical overhead rate charged by the university for grants and contracts. *Funding levels* are measured in $100K increments. *Membership fee level* is coded in dollars. It should be noted that *funding sources* is a count of the number of funding categories (total from member fees, additional industry support, other NSF support, other federal government, non-federal government, state support, university, and other cash funding) from which Centers reported receiving support.

Predictor Variables

Beyond measuring descriptive characteristics of I/UCRCs that have exited the program, it was also important to measure environmental, organizational, program, and individual level variables that predict these outcomes. These variables came primarily from archival and outside data sources and reflect the final year (graduation year) during which the Center was funded under the I/UCRC grant.

Contextual/Environmental Factors. The literature on program sustainability suggests that characteristics of the larger environment within which a program operates have an impact on potential for future sustainability (Shediac-Rizkallah & Bone, 1998; Scheirer, 2005). In the case of I/UCRCs, the most relevant environmental variables relate to economic trends in research and development. Environmental variables to be included are: *US gross domestic product (GDP)* (*M* = $9,696.44B, *SD* = $2,477.32B), *US R&D spending* (*M* = $520.19B, *SD* = $64.88B), *US industry outside spending on R&D* (*M* = $160.10B, *SD* = $47.51B), *and US R&D spending in academia* (*M* = $32.14B, *SD* = $10.56B). Each of these environmental indicators were measured at each Center's final I/UCRC funding year. All data were obtained from the Science and Engineering Indicators (National Science Board, 1987-2006). However, US GDP data were obtained from Officer and Williamson (2006).

Center Organizational Characteristics. Organizational level predictors refer to characteristics of the managing university site for a Center (whether single or multi-university Centers). All data reflect the final year of I/UCRC support. Variables of interest include: *graduation year overhead discount* (M = 31.73&, *SD* = 22.28%), *graduation year in-kind support in $100 thousands* (*M* = $1.23, *SD* = 2.95), *graduation year percent university funding to the Center* (*M* = 8.82%, *SD* = 12.66%), *managing university annual R&D expenditures* (*M* = $242.03M, *SD* = 188.17M), *industry support provided to the managing university during the final year of I/UCRC grant support* (*M* = 8.94%, *SD* = 7.37%), *university type* (22.9% private, 34.3% public, 42.8% land-grant), and *Carnegie classification* (2.9% Masters, 2.9% Large Masters, 2.9% Doctoral research, 32.9% High Research, 57.1% Very High Research). The first three variables listed come from the Center

Director Report archival database. *Graduation year overhead discount* is calculated by subtracting the overhead rate charged to membership fees from the rate typically charged by the managing university. Data are coded as a percentage. *Graduation year percent university funding to the Center* is coded as a percentage and calculated by dividing graduation year university funding by graduation year total budget. Data for *university annual R&D expenditures* (coded in dollars) and *industry support provided to the university during the final year of I/UCRC grant support* (coded as a percentage) come from the Science and Engineering Indicators report for the year of graduation (National Science Board, 1987-2006). *University type* data come from university records for the managing site. The *Carnegie classification* comes from the Carnegie foundation website (www.carnegiefoundation.org/). Data are coded as: 1) Masters, 2) Master's - larger programs, 3) Doctoral Universities, 4) Research Universities (high research activity), and 5) Research Universities (very high research activity).

Program Level Characteristics. Program level predictors are characteristics of the Centers themselves in their last year of the I/UCRC grant that predict current sustainability outcomes. Variables of interest include: *graduation status*(graduated/not graduated), *total funding in the final I/UCRC grant year in $100 thousands* (*M* = $10.36, *SD* = $10.98), *number of university partners in the final I/UCRC grant year* (*M* = 1.57, *SD* = .90), *number of funding categories in the final I/UCRC grant year* (*M* = 3.61, *SD* = 1.29), *number of members in the final I/UCRC grant year* (*M* = 15.22, *SD* = 23.83), *number of faculty in the final I/UCRC grant year*(*M* = 9.82, *SD* = 7.50), *number of administrative staff in the final I/UCRC grant year* (*M* = 1.97, *SD* = 1.59), *and number of students* (graduate and

undergraduate) *in the final I/UCRC grant year* (*M* = 13.44, *SD* = 11.26. All data come from the Center Director report archival database.

Individual Characteristics. Individual level predictors refer to characteristics of key individuals involved with the Center; specifically the Center Directors. These predictors were intended to measure individual level variables during the final year of I/UCRC grant support. Variables of interest include D*irector administrative time allocation* (*M* = 26.06, *SD* = 22.95) and *Director research time* (*M* = 32.46, *SD* = 18.83). Both variables were measured via the Center Director archival database and reflects the percentage of time the director reported spending on Center administration and research during the final I/UCRC grant funding year. Responses were coded as a percentage.

Exploratory Variables

Because the research on program sustainability is fairly limited and has not been applied to the case of cooperative research centers, exploratory questions were asked to probe for factors that might be unique to I/UCRC program sustainability. In particular, key informants were asked "What factors do you think were most influential in leading to the Center [sustaining] [not sustaining] itself after the end of the I/UCRC grant?" Responses were coded according to qualitative content analysis.

RESULTS

The study attempted to address seven questions. Questions one through three were descriptive in nature, questions four through six were predictive, while question seven was qualitative in nature.

Descriptive Questions

Research Question 1: What is the status of I/UCRCs post-graduation?

Center status was measured in a variety of ways. Findings are summarized in Table 3. First, the graduation status of formerly funded I/UCRCs was assessed. Of the 70 Centers included in the study, 64.3% received the full 10 years of I/UCRC grant support (N = 45) while the balance (35.7%) received less than 10 years of funding. Most but not all of this group received less than 10 years of funding because they no longer met the funding or membership requirements for continued NSF support.

Because some Centers sustain themselves for a period of time before closing down, it was necessary to develop a measure, *post-graduation status*, to capture program sustainability regardless of current status. Centers that were sustained for at least one year post-I/UCRC funding were considered to be sustained post-graduation. Over seventy-five percent of I/UCRCs are sustained at least one year post-graduation (N = 53). However, not all Centers that were sustained post-graduation are still operating today. Of the 70 formerly funded I/UCRCs 62.9% are currently operating (N = 44).

Table 3

Center Status Measures

	N	%
Graduation Status		
Graduated	45	64.3
Not graduated	25	35.7
Post-graduation status		
Sustained	53	75.7
Not sustained	17	24.3
Current status		
Operating	44	62.9
Not operating	26	37.1

Center sustainability was also assessed in terms of number of years operating and number of years sustained. Formerly funded I/UCRCs operated for an average of 16.99 years (*SD* = 7.03). They are sustained an average of 5.90 years (*SD* = 4.71). These measures of Center status are influence by variability in the time at which Centers were started, as well as the time since graduation. For example, a Center that graduated 5 years ago and is still operating would have a years sustained score of 5 years. A Center that graduated 10 years ago and was sustained for 5 years, but is now closed would also have a years sustained score of 5. But because of the age difference between the Centers, the amount of sustainability they achieved seems the same (i.e. 5 years). In other words, years operating and years sustained are affected by how old a Center is. Therefore a *years operating fraction* and a *years sustained fraction* were calculated.

Years operating fraction controls for variation in total years funded and years since graduation by taking the proportion of time the Center has been operating (end year minus start year) divided by the total possible years that Center could have been operating (current year minus start year). Scores range from 0 (did not operate) to 1 (still currently operating). Likewise, the *years sustained fraction* controls for time since the I/UCRC grant ended by dividing the total years sustained (end year minus graduation year) by the total possible years sustained (current year minus graduation year). Scores range from 0 (not sustained) to 1 (currently operating). Here the Center that graduated 5 years ago and is still operating would have a years sustained fraction of 1.00 where as the Center that graduated 10 years ago but was also sustained for 5 before closing would have a years sustained fraction of .50.

Formerly funded I/UCRCs operated an average of 82.8% of their totally possible years of operation. They were sustained an average of 70.2% of the total possible years of sustainability.

Table 4

Means and Standard Deviations of Years Operating and Sustained Measures

	M	SD
Total years operating	16.99	7.03
Years operating fraction	.82	.28
Years sustained	5.90	4.71
Years sustained fraction	.70	.43

N =70

Research Question 2: How much fidelity to the standard I/UCRC model do sustained Centers exhibit?

Fidelity data were measured for the most recently completed year of operation. For currently operating Centers, this represents how the Center operates currently. However, for Centers that were sustained for a period of time and then closed, it represents how they operated in their last year. Ten fidelity items were measured. The percentages of sustained Centers maintaining fidelity to each of these items are presented in Table 5.

Table 5

Percent of Sustained Centers Maintaining Fidelity to I/UCRC Program Components

	%
Core IUCRC Components	
industrial support	96.2
university based	94.3
stakeholder meetings	69.8
membership fees	67.9
IAB	67.9
consortial results	64.2
dissemination	
consortial project selection	50.9
Secondary I/UCRC Components	
Tech Transfer	94.3
Evaluator	17.0
LIFE	17.0

N = 53

There are some items to which almost all sustained Center maintain fidelity: *university based, industrial support,* and *technology transfer*. There is another group of items to which a smaller majority maintain fidelity: *stakeholder meetings, membership fees, IAB, consortial results dissemination,* and *consortial project selection.* However very few Centers maintain fidelity to the remaining items: *evaluator* and *LIFE*.

An EFA was conducted to determine whether these fidelity items could be combined to create a fidelity scale. Results presented in the methods section yielded a two factor solution. Structural fidelity was composed of *charges membership fees, has an IAB, consortial results dissemination, holds stakeholder meetings, and consortial project selection*. Assessment fidelity was comprised of uses LIFE forms to evaluate research and has an external evaluation. There are 53 Centers for which fidelity data were collected. On average sustained Centers maintained fidelity to three quarters of the structural fidelity items

(*M* = .75, *SD* = .38). However, fidelity on the assessment scale was quite low (*M* = .21, *SD* = .36). When looking just at Centers that are currently operating results are similar (N = 44). Currently operating Centers maintain fidelity to over three quarters of the structural fidelity items (*M* = .77, *SD* = .38). They also show very low levels of assessment fidelity (*M* = .19, *SD* = .33).

Research Question 3: To what extent has the Center sustained itself in terms of continued program activities, structures, and outcomes?

In addition to looking at whether a Center continues to operate beyond the end of its grant (Center status) and whether it is still operating in the same way (fidelity), the literature on program sustainability suggests that it is important to consider continued program activities, structures, and outcomes as indicators of sustainability (Scheirer, 2005). Sustainability data were measured for the most recently completed year of operation. For currently operating Centers, this represents the Centers' current level of sustainability. However, for Centers that were sustained for a period of time and then closed, it represents their level of sustainability in their last year. Descriptive statistics for the variables in each of the sustainability categories are listed in Table 6. In order to provides a benchmark for evaluating activities, structures and outcomes of these Centers Table 6 includes data from currently funded I/UCRCs.

Table 6

Descriptive Statistics for Continued Program Activities, Structures and Outcomes for Sustained Centers Compared to Actively Funded I/UCRCs

	Sustained Centers			Currently Funded I/UCRCs					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	*t*	*F*
Continued Activities									
Research focus change	44	1.59	1.04	--	--	--	--	--	
Research projects	36	14.92	13.30	--	--	--	--	--	
Continued Structures									1.01
N of members	45	74.20	391.37	37	18.78	15.35	80	-.86	
N of faculty	44	14.91	12.74	37	12.78	10.15	79	-.82	
N of students involved	44	29.98	32.40	37	32.54	30.44	80	.37	
N of administrative staff	41	1.73	1.90	37	1.95	1.39	76	.56	
Overhead discount %	39	35.33	22.61	37	37.72	17.78	71.58	.51	
Total budget ($Mill)	43	2.44	4.07	37	1.70	1.70	78	-1.03	
N of funding source categories[25]	43	3.23	1.84	37	3.22	1.93	78	-.04	
N of dept. involved	42	3.43	1.52	--	--	--	--	--	
Membership fee level($K)	33	41.64	14.28	37	39.54	10.93	68	-.69	
Continued Outcomes									1.88
IP	39	3.51	5.07	37	2.22	4.01	74	1.23	
N of graduate students graduating	35	11.20	15.47	37	7.89	7.99	70	1.15	
N of graduate students hired by members	30	5.27	5.87	37	2.00	4.62	65	2.55**	
Publications and presentations	38	62.97	70.89	37	50.03	37.46	56.48	-.99	

*$p < .05$, **$p < .01$, ***$p < .001$

However, Centers could not be compared on continued activity measures because those data are not routinely collected for actively funded I/UCRCs. The average sustained Center conducts nearly 15 projects annually. In general, sustained Centers tend to make changes to their research focus that are categorized between slight and some change (*M* = 1.59, *SD* = 1.04). *Research focus* was coded on a five point scale with zero indicating no

[25] It should be noted that sustained centers reported on funding received from eight categories (membership fees, additional industry funding, NSF, other federal sources, non-federal sources, state, university, and other sources). In addition to the 8 funding categories listed above, currently funded I/UCRCs also report data about I/UCRC grant funding. That category was eliminated from the counts given that sustained centers no longer funded by the I/UCRC program are categorically prevented from obtaining funding from that source.

change and four indicating a totally different research focus. No change in research focus was reported by 13.2% of sustained Centers, 26.4% reported slight change, 26.4% reported some change, 15.1% reported a great deal of change and 1.9% reported a totally different research focus (17% of sustained Centers had missing data on this variable).

In terms of continued structures and outcomes, means and standard deviations are presented in Table 6. A MANOVA indicated that formerly funded I/UCRC were not significantly different from active I/UCRCs in terms of continued structures ($F(1, 71) = 1.01$, $p < .44$, $\eta^2 = .11$) or continued outcomes ($F(1, 57) = 1.88$, $p < ..13$, $\eta^2 = .12$). In addition, independent sample t-tests were conducted to determine if sustained Centers differed from actively funded I/UCRCs on any of the items. Sustained Centers were not significantly different from actively funded I/UCRCs in any way except in terms of the number of Center graduate students hired by organizations with which the Center works ($t = 2.55$, $p < .01$). Sustained Centers have significantly more of their graduate students hired by members than do actively funded I/UCRCs. Sustained Centers and actively funded I/UCRCs could not be compared in terms of number of departments involved because those data are not routinely collected for actively funded I/UCRCs.

Descriptive Results Summary

Descriptive questions addressed what happens to formerly funded I/UCRCs in terms of Center status, fidelity, and sustainability of program activities, structures, and outcomes. Results indicated that only two thirds of Centers actually receive the full 10 years of I/UCRC grant support. However, 75% of all Centers are sustained for at least one year after their I/UCRC funding ends. Currently, 62% of formerly funded Centers are still operating. On

average Centers operate for nearly 17 years (roughly 80% of the total possible years operating) and are sustained for almost six years (or 70% of the total possible years sustained).

Sustained Centers exhibit a high level of structural fidelity; maintaining about 75% of the structural elements of the I/UCRC program. However, very few sustained Centers maintain assessment fidelity. In terms of continued program structures and outcomes, results indicate that sustained Centers continue to be very successful with respect to funding, student support and degree production, and other indicators like IP. They operate at much the same level as currently funded I/UCRCs. Sustained Centers report conducting an average of 15 projects a year with only slight to some change in the research focus since the Center graduated from NSF I/UCRC support.

Predictive Questions

Prior to running any predictive analyses, predictor and outcome variables were screened for outliers, multicollinearity, and missing data. Means, standard deviations, skewness statistics, and intercorrelations for all predictor variables (Tables G1 and G2) and outcome variables (Tables G3 and G4) are presented in Appendix G. Since skewness would violate assumptions of normality for regression analysis, an attempt was made to address the issue.

Positively skewed variables with a skewness score greater than twice the standard error of skewness were subjected to a log transformation. Negatively skewed variables with a skewness score greater than twice the standard error of skewness were subjected to a square root transformation. These transformations failed to eliminate skewness issues in the data

with variables still having a skewness score greater than twice the standard error of skewness. Therefore, transformed data were not used in subsequent analyses.

Upon visual examination of variable distributions, it became evident that many skewed variables had outliers that were more than three standard deviations away from the mean. Field (2009) suggested that if transformations do not address skewness issues in the data, either the outlying case can be dropped or it can be recoded to one unit higher than the next most extreme score. In order to preserve sample size, the recoding approach was taken. The predictive analyses that follow use the recoded data. Means, standard deviations, skewness statistics, and intercorrelations for all recoded predictor variables (Tables G5 and G6) and recoded outcome variables (Tables G7 and G8) are presented in Appendix G.

In order to evaluate problems with collinearity among predictors, all graduation year data were entered into a correlation matrix. When predictor variables correlated with each other at or above r = .80, all but one of the highly correlated variables were dropped from further analysis to eliminate problems of collinearity (Field, 2009). Appendix G provides a correlation matrix of predictor variables. Ultimately, four environmental level variables exhibited high collinearity and three were dropped: *US gross domestic product (GDP), US R&D spending, and US R&D spending in academia*. Although *US industry outside spending on R&D* was also highly correlated with these variables, it was retained because it appears to have the best conceptual relevance to my focus on industry-university parternships. Specifically, it measures the amount of funding US industry provides to other sectors for research and development, which is key to I/UCRC sustainability.

Logistic regression was used for categorical dichotomous outcome measures and linear regression was used for continuous outcome measures. Given the exploratory nature of this study, a trimming approach was used for the regression analyses (Tabachnick & Fidell, 2001). First, bivariate regressions were run to determine all significant predictors of each outcome measure. Next, significant bivariate predictors were grouped by domain and tested using multiple regression analyses. The domains included: environmental, organizational, program and individual levels. After running domain level regressions, all significant predictors for each outcome were combined for the full model multivariate analysis. A statistical significance of $p < .10$ was employed because the limited sample size limits power and increases Type II error. For the purpose of this study and analyses, standardized beta coefficients were used as effect size parameters; however, it should be noted that some authors recommend using alternative effect size (Johnson, 2000).

Research Question 4: What environmental, organizational, program, and individual variables predict Center status as measured by current status, post-graduation status, years operating fraction, and years sustained fraction?

Post-graduation status was regressed onto each predictor variable. It was associated with program and organizational level variables: graduation status, graduation year budget, and graduation year overhead discount. These variables were then entered into domain and full model logistic regressions (Table 7). Since there was only one significant predictor at the organizational level, bivariate and domain logistic regressions were the same. At the program level, graduation status was no longer significant. The full model logistic regression with graduation year budget and graduation year overhead discount was significant (Model χ^2

(2) = 9.59, $p < .01$). Collinearity diagnostics (tolerance = .86, VIF = 1.16) indicates that collinearity among the predictors did not bias the model (Field, 2009). It accounted for 21% of the variance in post graduation status. For every $100K in graduation year total budget, the odds of a Center being sustained post-graduation increases by 13%.

Table 7

Logistic Regression Predicting Post-graduation Status

	Bivariate Exp(B)	Domain Exp(B)	Full Model Exp(B)
Program Level			
Graduation status	3.62**	2.65	--
Graduation year budget ($100K)	1.14**	1.13**	1.13*
Organizational Level			
Graduation year overhead discount %	1.03**	1.03**	1.02
		Nagelkerke R^2: .21	
		Model χ^2 (2): 9.59***	

*$p < .1$, **$p < .05$

Current Status was entered into bivariate logistic regressions with each predictor variable. It was associated with individual, program, and environmental level variables: graduation year director time spent on research, graduation status, graduation year total budget, graduation year member count, graduation year administrative staff count, and graduation year US industry spending on research preformed outside the firm. These variables were then entered into domain and full model logistic regressions (Table 8a). Since there was only one significant predictor at both the individual and environmental level, bivariate and domain logistic regressions were the same. At the program level, graduation year member count was no longer significant. All other program predictors were retained. Graduation year director research time, graduation status, graduation year budget, graduation year administrative staff, and graduation year US industry support for outside research were

entered into the full model logistic regression. Collinearity among the predictors was not a problem as indicated by the tolerance and VIF reported in table 8a (Field, 2009)

The full model logistic regression was significant (Model χ^2 (5) =31.67, $p < .001$). It accounted for 54% of the variance in current status (Nagelkerke $R^2 = .54$). Only graduation status, graduation year budget, and graduation year US industry support for outside research predict current status in the full model. Graduated Centers are 3.65 times more likely to be currently sustained than are not graduated Centers. For every additional $100K a Center has at the point of graduation, their odds of being currently sustained increase by 16%. Every billion dollars spent by industry for research performed elsewhere in the year of graduation increases the odds of the Center being currently sustained by 2%.

Table 8a

Logistic Regression Predicting Current Status

	Bivariate Exp(B)	Domain Exp(B)	Full Model Exp(B)	Tolerance	VIF
Individual Level					
Graduation year director research time	.97**	.97**	.98	.92	1.09
Program Level					
Graduation status	8.50***	6.11**	3.65*	.62	1.62
Graduation year budget ($100K)	1.12***	1.13*	1.16*	.89	1.29
Graduation year member Count	1.08**	1.05	--	--	--
Graduation year admin. staff	.70**	.62*	.76	.72	1.39
Environmental Level					
Graduation year US Industry Support for Outside Research ($1Bill)	1.03***	1.03***	1.02**	.60	1.66
				Nagelkerke R^2: .53	
				Model χ^2 (5): 33.30***	

***$p < .01$. **$p < .05$. *p < .1

Centers have graduated from the I/UCRC program over the course of the last 25 years. It may be that time since graduation is associated with current status. It seems reasonable to assume that it is easier to sustain a Center for two years rather than 20 years. Therefore a secondary analysis was conducted, controlling for years since graduation.

Current status was again entered into bivariate logistic regressions with each predictor variable. It was associated with individual, program, and environmental level variables: years since graduation, graduation year director time spent on research, graduation status, graduation year total budget, graduation year member count, graduation year administrative staff count, and graduation year US industry spending on research preformed outside the

firm. These variables were then entered into domain and full model logistic regressions (Table 8b). At the individual level, graduation year director research time was no longer significant when controlling for years since graduation. At the program level, graduation year member count was the only variable retained when controlling for years since graduation. It the environmental level, graduation year US industry support for outside research was retained when controlling for years since graduation. Years since graduation, graduation year member count, and graduation year US industry support for outside research were entered into the full model logistic regression.

The full model logistic regression was significant (Model χ^2 (3) =28.35, $p < .01$). It accounted for 46% of the variance in current status (Nagelkerke R^2 = .46). In the full model, only graduation year member count and graduation year US industry support for outside research were significant, years since graduation did not account for significant variance in the full model. For each additional member in the year of graduation, the odds of being currently sustained increase by 10%. Every billion dollars spent by industry for research performed elsewhere in the year of graduation increases the odds of the Center being currently sustained by 7%.

Table 8b

Logistic Regression Predicting Current Status Controlling for Years Since Graduation

	Bivariate Exp(B)	Domain Exp(B)	Full Model Exp(B)	Tolerance	VIF
Years since graduation	.81***		1.14	.03	30.28
Individual Level					
Graduation year director research time	.97**	1.00	--	--	--
Program Level					
Graduation status	.12***	2.05	--	--	--
Graduation year budget ($100K)	1.12***	1.12	--	--	--
Graduation year member Count	1.08**	1.09*	1.10***	.98	1.02
Graduation year admin. staff	.70**	.72	--	--	--
Environmental Level					
Graduation year US Industry Support for Outside Research ($1Bill)	1.03***	1.08**	1.07*	.03	30.27
		Nagelkerke R^2: .46			
		Model χ^2 (3): 28.35***			

***$p < .01$. **$p < .05$. *p < .1

The *years operating fraction* represents the number of years actually operating over the total possible years a given Center could be operating. The resulting quotient can therefore be interpreted as a percentage. On average, formerly funded I/UCRCs operate for 83% of the total possible time (M = .83, SD = .28).

Years operating fraction was entered into a bivariate regression with each predictor variable. It was associated with program and environmental level variables: graduation status, graduation year budget, graduation year overhead discount, graduation year administrative staff, and US industry support for outside research. These variables were then entered into domain and full model regressions (Table 9). Since there was only one significant predictor at both the environmental and organizational levels, bivariate and

domain regressions were the same. At the program level, graduation year budget and administrative staff were no longer significant. Only graduation status was retained. Graduation status, graduation year overhead discount, and US industry support for outside research were entered into the full model regression. Collinearity among the predictors was not a problem as indicated by the tolerance and VIF reported in table 9 (Field, 2009)

Graduation status and US industry support for outside research were significant predictors. Graduated Centers reported significantly higher years operating fraction scores and Centers graduating in years with higher US industry spending on outside research also operated longer. The full model accounted for 34% of the variance in years operating fraction.

Table 9

Predicting Years Operating Fraction

	Bivariate		Domain		Full Model		Tolerance	VIF
	B	*B*	*B*	*β*	*B*	*β*		
Program Level								
Graduation Status	.31***	.54	.29***	.51	.16***	.29	.82	1.22
Graduation year budget ($100K)	.01**	.26	.01	.17	--	--	--	--
Graduation year admin. Staff	-.05**	-.29	-.02	-.87	--	--	--	--
Organizational Level								
Graduation year overhead discount	.01**	.28	.01**	.28	.001	.16	.94	1.06
Environmental Level								
US Industry Support for Outside Research ($1Bill)	.003***	.56	.003***	.56	.002***	.37	.86	1.17
Intercept					.32			
							F(3, 58) = 11.40***	
							R = .61	
							R^2 = .37	
							Adjusted R^2 = .34	

***p < .01. **p < .05 *p < .1

The *years sustained fraction* represents the number of years actually sustained over the total possible years a given Center could be sustained. The resulting quotient can therefore be interpreted as a percentage. Centers that are currently operating would have a sustainability fraction of one and those that closed immediately when the I/UCRC grant ended would have a sustainability fraction of zero. On average, formerly funded I/UCRCs are sustained for 70% of the total possible time (M = .70, SD = .43).

Years sustained fraction was regressed onto each predictor variable. It was associated with program, and environmental level variables: graduation status, graduation year budget, graduation year member count, and graduation year US industry support for outside research. These variables were then entered into domain and full model regressions (Table 10). Since there was only one significant predictor at the environmental level, bivariate and domain regressions for these variables are the same. At the program level, graduation year member count was no longer significant for the domain multivariate analysis. All other program level variables were retained. Graduation status, graduation year budget, and US industry support for outside research were entered into the full model regression.

All were significant predictors, accounting for 23% of the variance in years sustained fraction. Graduated Centers reported significantly higher years sustained fraction scores. Center with higher graduation year budgets and those graduating in years with higher US industry spending on outside research were also sustained longer (Table 10).

Table 10

Predicting Years Sustained Fraction

	Bivariate		Domain		Full Model		Tolerance	VIF
	B	*β*	*B*	*β*	*B*	*β*		
Program Level								
Graduation Status	.38***	.42	.31***	.35	.22**	.25	.74	1.35
Graduation year budget ($100K)	.01***	.30	.01*	.22	.01**	.24	.97	1.03
Graduation year member count	.01**	.25	.002	.06	--	--	--	--
Environmental Level								
Graduation year US Industry support for outside research ($1Bill)	.004***	.40	.004***	.40	.002*	.23	.75	1.33
Intercept					.12			
					F(3, 64) = 7.47***			
					R = .51			
					R^2 = .26			
					Adjusted R^2 = .23			

***p < .01. **p < .05 *p < .1

Research Question 5: What environmental, organizational, program, and individual variables predict fidelity to the I/UCRC model?

An EFA for fidelity indicated fidelity to the I/UCRC program model was made up of two factors: structural and assessment fidelity. Therefore analyses were run separately for each fidelity factor. Since fidelity data only apply to Centers that were sustained for at least one year, analysis is limited to those Centers (N = 53). The same trimming approach was used to identify predictors of fidelity. Predictor variables were entered into bivariate regressions. Predictors that were significant at the bivariate level were entered into domain

level regressions. Finally those predictors that were significant at the domain level were entered into a full model regression.

Assessment fidelity measures whether sustained Centers continue to conduct routine evaluations of the Center and Center research projects. This factor is made up of using LIFE forms to evaluate research (project evaluation) and having an external evaluation ($\alpha = .66$). Results from research question two indicated that sustained Centers maintained a low level of assessment fidelity ($M = .21$, $SD = .38$).

Assessment fidelity was regressed onto each predictor variable. It was only associated with program level variables: graduation year number of sites (i.e. university partners) and graduation year budget. Since both IVs are at the program level and both were significantly correlated with assessment fidelity in a bivariate regression individual, domain level regressions were not performed; just the full model regression was performed. Colinearity diagnostics (tolerance = .93, VIF = 1.07) indicated that colinearity among the variables was not a problem (Field, 2009). In the full model, only graduation year budget was significant, accounting for 11% of the variance in assessment fidelity. Those with higher graduation year budgets also reported higher assessment fidelity.

Table 11

Predicting Assessment Fidelity

	Bivariate		Full Model	
	B	*β*	*B*	*β*
Program Level				
Graduation year number of sites	.10**	.29	.08	.23
Graduation year budget ($100K)	.01**	.31	.009*	.25
Intercept			-.03	
			$F(2, 43) = 3.65$**	
			$R = .38$	
			$R^2 = .15$	
			Adjusted $R^2 = .11$	

**$p < .05$ *$p < .1$

Structural fidelity measures whether sustained Centers continue to operate according to the structural components of the I/UCRC program model. This factor is made up of charges membership fees, has an IAB, consortial results dissemination, holds stakeholder meetings, and consortial project selection ($\alpha = .93$). Results from research question two indicated that sustained Centers maintained a high level of structural fidelity ($M = .75$, $SD = .38$).

Structural fidelity was regressed onto each predictor variable. It was associated with program and organizational level variables: graduation status, graduation year budget, graduation year member count, graduation year faculty, graduation year in-kind support, graduation year overhead discount, and graduation year university funding percent. These variables were then entered into domain and full model regressions (Table 12). At the program level, graduation year member count and graduation year faculty count were no longer significant. All other program level variables were retained. At the organizational

level only graduation year in-kind support was significant and therefore retained for the full model.

In the full model regression graduation status, graduation year budget, and graduation year in-kind support significantly predicted structural fidelity, accounting for 32% of the variance. Graduated Centers had higher structural fidelity than did non-graduates. Sustained Centers with higher graduation year budgets also maintained higher structural fidelity. However, those with more in-kind support reported lower structural fidelity.

Table 12

Predicting Structural Fidelity

	Bivariate		Domain		Full Model		Tolerance	VIF
	B	*β*	*B*	*β*	*B*	*β*		
Program Level								
Graduation Status	.39***	.45	.32***	.37	.29**	.32	.96	1.04
Graduation year budget ($100K)	.01**	.36	.008***	.20	.01***	.39	.95	1.06
Graduation year member count	.01**	.35	.002	.05	--	--	--	--
Graduation year faculty	.03***	.43	.01	.24	--	--	--	--
Organizational Level								
Graduation year In-kind ($100K)	-.07**	-.34	-.07**	-.35	-.08***	-.37	.92	1.09
Graduation year overhead discount %	.005**	.32	.003	.17	--	--	--	--
Graduation year university funding %	-1.05***	-.36	-.72	-.25	--	--	--	--
Intercept					.48			
					$F(3, 35) = 6.98$***			
					$R = .61$			
					$R^2 = .37$			
					Adjusted $R^2 = .32$			

***$p < .01$. **$p < .05$ *$p < .1$

Research Question 6: What environmental, organizational, program, and individual variables predict Center sustainability as measured by continued activities (number of research projects), structures (number of members and total budget), and outcomes (IP and graduates,)?

Since continued activities, structures, and outcomes data only apply to Centers that were sustained for at least one year, analysis is limited to those Centers (N = 53). The same trimming approach was used to identify predictors. Because this question addresses multiple outcome measures, intercorrelations were examined due to the potential for Type I error (See Appendix G). Since some of the outcomes measures were correlated, a more strict p-value was used to reduce the potential for Type I error ($p < .05$).

Continued Activities. Number of research projects was entered into a bivariate correlation with each predictor variable. It was not associated with any individual, program, organizational, or environmental level predictors. Therefore, no further analyses were conducted.

Continued Structures. Number of members in the most recently completed fiscal year was regressed onto each predictor variable. Only program level predictors were significant: graduation year budget, graduation year member count, and graduation year number of graduate students. Since all three predictors are at the program level and significantly correlated with current member count in a bivariate correlation matrix, individual and domain level regressions were not performed; just the full model regression was performed. Collinearity diagnostics indicated that colinearity among the predictors was not an issue, as reported in table 13 (Field, 2009). In the full model, only graduation year member count was

significant, accounting for 54% of the variance in current member count (Table 13). Centers with more members at the time of graduation also have more members currently.

Table 13

Predicting Current Members

	Full Model		Tolerance	VIF
	B	*B*		
Program Level				
Grad year budget ($100K)	.24	.18	.57	1.75
Grad year member count	.89*	.79	.51	1.95
Grad year graduate students	-.23	-.20	.39	2.56
Intercept	3.84			
			$F(3, 40) = 17.69$*	
			$R = .76$	
			$R^2 = .57$	
			Adjusted $R^2 = .54$	

*$p < .01$

Budget in the most recently completed fiscal year was regressed onto each predictor variable. Only program level predictors were significant: graduation year budget, graduation year member count, and graduation year number of graduate students. Since all three predictors are at the program level and significantly correlated with current member count at the bivariate level, domain level regressions were not performed; just the full model regression was performed. In the full model using the simultaneous entry method, none of the predictors were significant, even though the overall model was significant and accounted for 15% of the variance in current budget.

The failure of any one of these predictors to account for unique variance in current budget is likely due to the intercorrelation between graduation year members, budget, and graduate students (See Appendix G, Table 4). However, correlation among predictors was not high enough *($r \leq .63$)* to warrant elimination of any of the predictors in the preliminary

screening process described. In addition, collinearity diagnostics did not fall within the range discussed in Field (2009) as indicating a colinearity problem among predictors (see table 14). Therefore a full model regression using the backward entry method was performed to determine if any of the predictor variables could be retained when others were removed from the analysis. In the final model only graduation year member count was retained, accounting for 15% of the variance in current budget. Centers with more members in the year of graduation have higher current budgets.

Table 14

Predicting Current Budget

	Bivariate		Full Model: Enter Method		Full Model: Backward Entry Method		Tolerance	VIF
	B	*β*	*B*	*B*	*B*	*β*		
Program Level								
Grad year budget ($100K)	.65**	.32	.34	.17	--	--	.57	1.75
Grad year member count	.80***	.40	.59	.31	.80***	.42	.51	1.95
Grad year graduate students	.68**	.37	.34	.07	--	--	.39	2.56
Intercept			4.61		7.40			
			$F(3, 38) = 3.36$**		$F(1, 40) = 8.30$***			
			$R = .46$		$R = .42$			
			$R^2 = .21$		$R^2 = .17$			
			Adjusted $R^2 = .15$		*Adjusted* $R^2 = .15$			

*$p < .1$, **$p < .05$, ***$p < .01$

Continued Outcomes. Number of IP events in the most recently completed fiscal year was entered into a bivariate correlation with each predictor variable. It was correlated with program and organizational level variables: graduation year number of funding source categories and graduation year university-wide expenditures on R&D. Since there is only one significant variable in each domain, only bivariate and full model regressions were

preformed (Table 15). In the full model using the simultaneous entry method, none of the predictors were significant, even though the overall model was significant and accounted for 12% of the variance in current IP events.

The failure of either of these predictors to account for unique variance in current IP events is likely due to the correlation between graduation year number of funding source categories and graduation year university-wide expenditures on R&D (See Appendix G, Table 4). However, correlation among predictors was not high enough (r = -.24) to warrant elimination of either of the predictors in the preliminary screening process described. In addition, collinearity diagnostics (tolerance = .86, VIF = 1.16) did not fall within the range discussed in Field (2009) as indicating a colinearity problem among predictors. Therefore a full model regression using the backward entry method was performed to determine if either predictor variable could be retained when the other was removed from the analysis. In the final model only graduation year university expenditures on R&D was retained, accounting for 11% of the variance in current IP events. Centers with more graduation year university expenditures on R&D have fewer current IP events.

Table 15

Predicting Current IP Events.

	Bivariate		Full Model: Enter Method		Full Model: Backward Entry Method	
	B	*β*	*B*	*β*	*B*	*B*
Program Level						
Graduation year number of funding source categories	1.14**	.33	.73	.21	--	--
Organizational Level						
Graduation year university expenditures on R&D	-.008**	-.37	-.007*	-.29	-.008**	-.37
Intercept			2.51		1.14	
			$F(2, 33) = 3.43$**		$F(1, 34) = 5.33$**	
			$R = .42$		$R = .37$	
			$R^2 = .17$		$R^2 = .14$	
			Adjusted $R^2 = .12$		*Adjusted* $R^2 = .11$	

***$p < .01$. **$p < .05$ *p < .1

Number of current Center graduate students graduating in the most recently completed fiscal year was regressed onto each predictor variable. Only program level predictors were significant: graduation year budget and graduation year number of graduate students. Since both predictors are at the program level and significantly correlated with graduate students graduating in bivariate regression, domain level regressions were not performed; just the full model regression was performed. Colinearity diagnostics (tolerance = .57, VIF = 1.76) indicated that colinearity among predictors was not a problem (Field, 2009). In the full model, only graduation year number of students involved was significant. The full model accounted for 37% of the variance in current graduate students graduating.

Sustained Centers with more students involved in the year of graduation have more current graduate students graduating.

Table 16

Predicting Current Graduate Students Graduating

	Bivariate		Full Model	
	B	*β*	*B*	*β*
Program Level				
Grad year budget ($100K)	.45**	.41	.05	.05
Grad year graduate students	.68***	.61	.66***	.60
Intercept			.26	
			$F(2, 31) = 10.49$***	
			$R = .64$	
			$R^2 = .40$	
			Adjusted $R^2 = .37$	

*$p < .1$, **$p < .05$, ***$p < .01$

Predictive Results Summary

Regression analyses were conducted to identify individual, organizational, program, and individual level variables that predict Center status, fidelity, and sustainability of program activities, structures, and outcomes. Post-graduation status was predicted by graduation year budget, with each additional $100K increasing the odds of being sustained by 13%. Graduation year budget also predicted current status, increasing the odds of being currently operating by 11% for every $100K. In addition, current status was predicted by US industry spending on outside research. Every billion dollars spent increases the odds of the Center being currently sustained by 3%.

Graduation status and US industry spending on outside research predicted years operating fraction. Centers that received their full 10 years of I/UCRC funding and graduated in years with higher US industry spending on outside research operated for a larger

percentage of the total possible years of operation. Years sustained fraction was predicted by graduation status, graduation year budget, and US industry spending on outside research. Graduated Centers, those with higher budgets, and those graduating in years with higher US industry spending on outside research were sustained for a larger percentage of the total possible years sustained.

In terms of fidelity to the I/UCRC model, assessment fidelity was predicted by graduation year budget. Larger budgets were associated with more assessment fidelity. Graduation status, graduation year budget, and graduation year in-kind support predicted structural fidelity. Centers receiving their full ten years of I/UCRC support maintained higher structural fidelity. Centers with higher graduation year budgets also maintained higher structural fidelity. However, those with more in-kind support reported lower structural fidelity.

Continued program activities, as measured by current number of projects, was not associated with any predictor variables. However continued structures were predicted by graduation year members. Centers with more members in the year of graduation have more current members and higher budgets. Continued program outcomes were predicted by graduation year university expenditures on R&D and graduation year number of students. More university R&D expenditures was associated with fewer IP events. Centers with more students involved at the time of graduation reported more graduate students graduating currently.

Research Question 7: What issues do key informants think are critical for I/UCRC sustainability?

In addition to describing post-funding outcomes and examining factors predictive of Center sustainability, interviews with key informants explored what issues they perceived to be critical to Center sustainability. Given that literature on program sustainability in general is limited, and no empirical studies on program sustainability for cooperative research centers exist, exploratory qualitative analysis was warranted. Key informants were asked to discuss what factors they thought were critical to I/UCRC sustainability. Transcripts of key informant interviews were subjected to qualitative content analysis using a grounded theory approach in which themes are allowed to emerge from the data (Charmaz, 2001; Ulin et al., 2005). This approach is particularly appropriate for exploratory research. Interview transcripts were coded for factors that key informants believed were critical to Center sustainability. Based on the responses, 19 themes were identified (See Table 17). A total of 191 comments were made by 48 respondents. At least 30% of respondents mentioned economic factors, pursuing new funding opportunities, close connection to member firms, meet industry needs: technical, university support, director commitment/persistence, meet industry needs: partnership format, and research quality as important factors contributing to Center sustainability.

The most commonly reported factor affecting program sustainability was economic factors, identified by 45.83% of respondents. For instance one respondent said:

> The problem was that the economy in the U.S. – not as bad as it is right now – went down and companies were laying people off, companies were going

> bankrupt and closing and it was just hard as heck to keep them interested in paying $50,000/year, that's an employee-they just didn't want to do it – so the companies we had supporting us they said hey, we love what you're doing but we just can't lay off another person so we can be a great member of your Center and that is the bottom line.

For this respondent, economic factors affecting the viability of their members and industry in general prevented the Center from being sustained.

Over 40% of respondents mentioned pursuing new funding opportunities as a critical factor in sustaining their Center (41.67%). For instance, one respondent said: "I think that's one of the key things to the Center is to really always be maintaining it and to be looking for new projects, and new partners." Another respondent advocated for making the pursuit of new funding opportunities part of the daily routine:

> It's always understandable that you can launch a proposal and wait for it to come in. But it really should be a daily and weekly practice because in order to receive money, you have to write proposals- no one is going to walk in and just hand you money. You have to keep contacts with industry, potential sponsors, keep coming up with new ideas and put them into proposals and look for agencies which will accept them.

Nearly as many (33.33%) respondents indicated that developing a close relationship with industry partners and meeting industries technical needs were both critical in sustaining a Center. In terms of maintaining a close relationship with industry partners, one respondent

explained how a close relationship increased member retention (a continued program structure):

> I probably spend 10 hours a week on the phone talking to the researchers, prospective affiliates, everything from the I/UCRC contract down to indirect cost rates, down to is the money there yet kind of questions. Everyone's so busy and we're dealing with senior people at these companies and so these guys are called upon a lot. So you have to cultivate a base of interest in the company. That's another thing if you're looking at what else can they do [to sustain the Center]. We lose members sometimes when our champion is gone. The other things is too that sometimes you just can't avoid that transition period like right now with [Company Name], they're going through really tough times. And our main contact there and his entire lab was closed down. But we have another person. Luckily we knew other people in [Company Name] and they stayed in, but that may not always happen.

Another respondent explained that a close relationship to industry was critical to Center research (a continued program activity):

> Learning how to involve industry actively in the review of your research is important and learning to listen to industry. I think a lot of Center Directors think that because they're scientists and they're knowledgeable in their field that industry will come to them for their great knowledge and they can, they spend a lot of time telling industry what they think industry needs to know. And my impression is exactly the opposite. That industry is in many ways

> way ahead of what's going on in the university; they just don't talk about it. So you really have to spend the time to go to them and sit in their office at their company and go on a tour of the plant and do all the things you think are taking time from your life. They are, but if you don't do that, you will not get it.

In terms of meeting industry's technical needs, one respondent explained that industrial support is contingent upon providing benefits to member companies (continued outcomes):

> You have to have something that Industry needs or wants, obviously – nobody pays anything unless they have benefits, the technology they need. So we have found that one of the things we can do is provide them with the tools so they can enhance their productivity and so the company becomes more competitive because of having the tools to implement new ideas so that is what we try to do.

A third of respondents (31.25%) also mentioned the importance of university support for the Center; "you have to have a dean or a VP who buys on to the concept." Another respondent elaborated:

> They were able to convince the vice chancellor for research that this was the right thing to do and he bought into it and then helped convince the chancellor and others… that if you don't have [Center Name], you're not going to bring in a lot of these industrial funds; you'll bring in some of them through, you know, regular grants office, but no way near it than if you have someone

> that's going to stay, you know, informed with companies and market us and do all this stuff.
>
> So that was the just-and, and people bought it… Every time a new dean comes in I have to justify why this, because they want, basically they come in and say "no we want that money" and the Center can't run without the overhead return and the buy-in from the university.

An equal proportion of respondents (31.25%) also mentioned the importance of Director commitment for Center sustainability. As one respondent so succinctly put it, "I would say that you have to be an insanely committed Center Director. Period." Others talked about how a lack of Director commitment impacted sustainability:

> I think [Person's Name], who was sort of the corporate advisor, was getting basically a little sick of it because the money was hard to get. So I think the decision had to be made whether we wanted to go out and aggressively look for other companies – by that time I [the Center Director] didn't really feel that I could devote the time that would have been necessary.

Meeting industry needs in terms of the partnership format was mentioned by 29.17% of respondents as important to sustainability:

> These things change – the relationship – we do work with a large number of companies, "but they vary – depending on topic, depending on company – never fixed format – in general, we try to collaborate and do something that will benefit both the company as well as the university.

Another respondent was more specific about the importance of the partnership format:

> In our industry, the companies were not willing to commit money in, for any intellectual property they had to share and the way that we overcame that was that we worked out a formula and the formula was that each company put in $75,000 a year membership but of that 25,000 was in to the pool that was, you know with shared IP and 50,000 could be designated for an exclusive study of some kind.

In terms of research quality, 29.17% of respondents mentioned that it was a factor contributing to Center sustainability:

> Well I think the quality of our research. The Center has been operating since 1984 and over that time companies know the quality of our work and I think they trust us to do good work for them. Everybody is highly respected in their professional society. I think that is what keeps it going – it's more the quality of work we do.

The remaining 11 themes were mentioned by less than 20% or respondents and accounted for just 30% of all responses (See Table 17).

Table 17

Factors Identified by Key Informants as Critical to Sustainability

	% of respondents	% of responses
economic factors	45.83%	11.52%
pursuing new funding opportunities	41.67%	10.47%
close connection to member firms	33.33%	8.38%
meet industry needs: technical	33.33%	8.38%
University support	31.25%	7.85%
director commitment/persistence	31.25%	7.85%
meet industry needs: partnership format	29.17%	7.33%
research quality	29.17%	7.33%
alignment of goals	18.75%	4.71%
quality graduate students	16.67%	4.19%
faculty technical expertise	16.67%	4.19%
faculty buy-in	14.58%	3.66%
Center as community	10.42%	2.62%
IAB reps with decision power	8.33%	2.09%
benefits to stakeholders: faculty	8.33%	2.09%
director technical expertise	8.33%	2.09%
facilities/equipment	8.33%	2.09%
Leveraging	6.25%	1.57%
focused research portfolio	6.25%	1.57%

N of respondents = 48; N of responses = 191

DISCUSSION

The goal of this study was to determine the extent to which formerly funded I/UCRCs are sustained and what factors predict their post-funding sustainability. The issue of post funding program sustainability is not unique to I/UCRCs. Government programs are often funded by grants that support their initial development, getting important programs up and running. However, many times, these programs are expected to become self-sufficient; independent of support from the initial granting agency. This is especially the case with many federally funded programs, including cooperative research centers. While such

programs are often successful at developing new research programs and centers, little research exists about how these programs are able to become self-sustaining once initial grant monies are exhausted. The goal of the I/UCRC program is to leverage government investment in R&D to improve US competitive advantage in global markets. These Centers are intended to foster long-term cooperation between industry and academia; having sustainability as an explicit program goal. This study was a first step towards beginning to fill this gap in understanding of I/UCRC sustainability. While the current study cannot overcome all the limitations found in previous literature, I took a longitudinal approach, used multivariate statistics, operationally defined variables, used multiple measures of sustainability, collected data from more than one respondent per Center, and controlled for variation in the timing of data collection. Results showed that the majority of formerly funded I/UCRCs are sustained and identified environmental, organizational, and program level variables predictive of program sustainability.

Descriptive Results

Center Status

Center status was assessed by looking at graduation status, post-graduation status, current status, years operating (total years operating and year operating as a proportion of total possible years operating), and years sustained (total years sustained and years sustained as a proportion of total possible years sustained). Results indicated that two thirds of formerly funded I/UCRCs receive the full ten year grant. Anecdotal evidence suggests that many of the Centers that do not graduate fail to meet the requirements of the grant and are dropped from the program, while a smaller number exit the program to pursue larger funding

opportunities or different partnership structures. Both Goodman and Steckler (1989) and Scherier (1990) explain that the initial grant to start a center must be of sufficient length for the program to be established within the host organization. While some Centers that exited the I/UCRC program early were sustained for at least one year post-graduation, Centers that received at least ten years of funding had higher current status sustainability (80%) than those that receive less than ten (32%; $\chi^2 = 15.86$, $p > .001$). Previous studies on program sustainability reported that between 20% and 80% of sites achieved some level of sustainability (Scheirer, 2005). Formerly funded I/UCRCs exhibit similar rates of sustainability with results indicating that I/UCRC's fall on the high end of the sustainability spectrum at 75% sustained. While current status for formerly funded I/UCRCs measures fall more squarely in the middle of the sustainability distribution identified in previous studies, given the age of the I/UCRC program, and the fact that some Centers have been operating for 30 years and sustained for as long as 20 years, it seems fair to say that a high level of sustainability has been achieved by the I/UCRC program.

In fact, results showed that formerly funded I/UCRCs operated longer than was indicated by other studies on program sustainability. Formerly funded Centers operated an average of about 17 years, and were sustained for an average of about 6 years. O'Laughlin et al. (1998), who also examined sustainability for relatively older programs (funding ended between 0 and 20 years prior to data collection) found that programs operated for an average of 6.6 years, while they were sustained for an average of 3.7 years.

Measures of years operating and years sustained tend to be affected by when a Center started. Centers that were started in the 1980s have the potential to be in operation longer

than those started more recently. Likewise, Centers that exited the I/UCRC program in the 1990s will have had a longer period to potentially be sustained than those whose funding ended more recently. In order to account for differences in the age and time since graduation a proportion was calculated for years operating and years sustained. Formerly funded I/UCRCs operate for an average of 82% of the total possible years operating and are sustained for an average of 70% of the total possible years sustained. While Scheirer (2005) reported that five studies reviewed looked at the relationship between time since graduation and current status, none have attempted to control for it. It should be noted that the years operating and sustained proportion measures are affected in the opposite direction compared to the raw scores; favoring Centers that were started more recently and graduated more recently. It is easier for a Center that was started 12 years ago and graduated two years ago to achieve 100% years operating and years sustained than it is for a Center that was started 30 years ago and graduated 20 years ago to do the same. However, by reporting raw scores and proportion scores for years sustained and operating, an attempt was made to reduce the bias associated with each.

Fidelity

Much of the literature reviewed discusses the importance of adaptability of the program model for program sustainability (Ailes et al., 2000; Goodman & Steckler, 1989; Johnson, et al., 2004; Mujumdar, 2005; Rogers, 2003; Scherier, 2005; and Shediac-Rizkallah & Bone, 1998;). This study measured fidelity in terms of core and secondary program components. Nearly all sustained Centers are still university based, receive industrial support, and transfer technology to their stakeholders. A smaller majority of sustained

Centers continue to have an IAB, charge membership fees for participation in the Center, hold regular meetings for stakeholders, select projects using a consortial model, and share results of Center projects with all members. Very few Centers continue to have an outside evaluator or use LIFE forms to evaluate research projects.

Results of an EFA showed that the first group of items mentioned were so universal among sustained Centers that there was little variability and these items were dropped. The remaining items created two factors; structural and assessment fidelity. Sustained Centers maintained fidelity to about 75% of the structural components, but only to about 20% of the assessment components. The propensity for sustained Centers to make adaptations to the program model is consistent with both the theoretical and empirical literature on program sustainability and echoes sentiments expressed by participants in previous studies on sustainability of cooperative research centers (Ailes et al., 2000: Mujumdar, 2005). Mayer and Davidson (2000) argued that while it is important that programs can be modified to fit local conditions, it is equally important to maintain fidelity to core components if continued program benefits are to be achieved. Results of this study seem to indicate that this is the case for formerly funded I/ICURCs. Qualitative evidence from key informant interviews indicates that once the grant ended and formal requirements were no longer in place, Center administrators made some changes, but in general felt that the program model worked well and only minor changes to fit the local context were necessary. As one director put it:

> I don't think it was anything where we said – we don't have to do that and now we are going to do this – I thought the operation under the NSF support was in fact rational so there was no fundamental changes that were made.

> We've made minor changes every, every couple of years so that if you look at the Center now, it's functioning more efficiently, but I think you could say that about any center. You learn and you improve. So it's evolved over the past 18 years.

Continued Activities, Structures, & Benefits

The theoretical literature on program sustainability suggests that it is not enough to simply ask whether or not a program continues to exist (Goodman & Steckler, 1989; Shediac-Rizkallah & Bone, 1998). They argued that sustainability should be measured in terms of continued program activities, structures, and outcomes. Scheirer's (2005) review of public health program sustainability found that across 17 studies reviewed, there were different rates of sustainability reflected in different measures.

In terms of program activities, the present study found that formerly funded I/UCRCs report continuing to conduct research (an average of 15 projects per year) in much the same vein as they were while funded under and I/UCRC grant. In terms of continued program structures results indicate that sustained Centers continue to be very successful with respect to membership, faculty and student involvement, administrative support, cross-departmental involvement, university support in terms of reduced overhead, and funding. Formerly funded Centers were not significantly different from actively funded I/UCRCs, on measures of continued structures. Results also showed that sustained Centers fair just as well as actively funded Centers in terms of continued program benefits. They report comparable levels of students graduating, publications and presentations, and IP events and significantly more Center trained students hired by organizations with which the Center works. However, this

finding may be an artifact of differences in Center age between the two groups. It may be that because the population of actively funded I/UCRCs includes some Centers that have only been in operation for one year, they simply haven not had time to produce students to be hired by industry, where as sustained Centers have had many years to train and graduate students who can then go on to work in industry. A non-significant MANOVA indicated that formerly funded Centers were not significantly different from actively funded Centers when all continued outcome measures were included in the analysis.

Predictive Results

The literature on program sustainability identified multiple factors at the environmental, organizational, program, and individual levels that are predictive of program sustainability. Studies on sustainability of cooperative research centers also identified variables that participants perceived to be important to their post-funding success (Ailes et al., 2000; Mujumdar, 2005). Predictive analyses were conducted to determine what factors predicted Center status, fidelity, and various measures of sustainability for formerly funded I/UCRCs.

Predicting Center Status

While post-graduation status was associated with graduation status, graduation year budget, and graduation year overhead discount in bivariate logistic regressions, only budget was significant in the full model, with each additional $100K increasing the odds of being sustained by 13%. This finding supports previous studies on program sustainability in other areas of research. Much of the literature on program sustainability either conceptualized

sustainability as synonymous with finding funding to support the program or mentioned it as a significant factor contributing to program sustainability (Scheirer, 2005).

Graduation year budget also predicted current status, increasing the odds of being currently operating by 11% for every $100K. In addition, current status was predicted by graduation status and graduation year US industry spending on outside research. Centers that received NSF support for the full time allowed under their grants were far more likely to be currently operating than those that did not. Scheirer (2005) found evidence that public health program need to be funded at least five years to be sustained beyond the end of their grants. Similarly, Yin's (1981) work suggested that program innovations become part of the within the host organization routine over time as they are integrated over time.

In addition to graduation status, the economic environment at the time of graduation also predicted current status. Every billion dollars spent increased the odds of the Center being currently sustained by 3%. This environmental measure is conceptually very important to I/UCRC success over the long term since it is a measure of how much support industry is providing to other research sectors in general. This is precisely the funding that I/UCRCs rely on for their survival. It should be noted that US industry spending on outside research was measured for the year of graduation, yet it still predicts current status. These results indicate that the point of graduation is a critical transition point for these Centers. The economic environment during that transition impacts whether or not Centers are able to successfully navigate the transition away from I/UCRC support, finding alternative sources of support to sustain them in the long term. This finding is consistent with studies reviewed by Scheirer (2005) who reported that funding from sources other than the initial granting

agency was predictive of program sustainability. It is also supported by historical data from the I/UCRC program which shows that the number of members leaving Centers exceeding the number of members joining Centers in times of US economic recessions (Gray & McGowen, 2010). Therfore, it is recommended that the NSF consider providing bridge funding to Centers scheduled to graduate during recession periods in order to protect their investment in these Centers until the economic environment rebounds enough for the Centers to survive beyond the end of their NSF grants. Based in part on preliminary findings from this study, NSF has begun to offer Centers set to graduate and those that have graduated in the last ten years Phase III support. According to their website, "Phase III award provides a third five-year award for centers that demonstrate their viability, sustainability, and which have had a significant impact on industry research as measured through annual reports, site visits, and adherence to I/UCRC requirements. Centers are expected to be fully supported by industrial, other Federal agencies, and state and local government partners after fifteen-years as an I/UCRC" (NSF website, 2010).

Predictive analyses were also conducted to predict years operating fraction and years sustained fraction. Variables included in the full models accounted for 34% and 23% of the variance in these outcomes, respectively. Years operating fraction was predicted by graduation status and US industry support for outside research. These same factors, with the addition of graduation year budget were also significant predictors of years sustained fraction. Graduated Centers operated for a significantly longer portion of the total possible operating time and were also sustained for a significantly longer proportion of time. Likewise, Centers graduating in years with higher US industry spending on outside research

also operated and were sustained for a significantly longer portion of the total possible times. While five of the studies reviewed by Scheirer (2005) examined the relationship between time operating and sustainability, this is the first study to look at years operating and sustained as continuous measures of program sustainability and to examine factors predictive of years operating and sustained.

Predicting Fidelity

Predictor variables included in the full model regression accounted for just 11% of the variance in assessment fidelity. Centers with larger budgets at the point of graduation exhibited higher assessment fidelity post-graduation. None of the other predictor variables were significantly associated with assessment fidelity in the full model. Given that fidelity to assessment items was so low (an average of 20%) and that the factor was made up of only two items ($\alpha = .66$), the ability to predict this outcome was reduced. Centers with more funding at graduation were able to keep these aspects of the program model.

Graduation status, graduation year budget, and graduation year in-kind support accounted for 32% of the variance in structural fidelity. Centers receiving their full ten years of I/UCRC support maintained higher structural fidelity. Centers with higher graduation year budgets also maintained higher structural fidelity. However, those with more in-kind support at the point of graduation reported lower structural fidelity. The relationship between graduation status and structural fidelity supports previous studies that suggested that programs need a significant amount of time to become established within the host organization. The negative association between in-kind support and structural fidelity is particularly interesting given that it contradicts previous research. Scheirer (2005) reported

that in-kind support from other organizations was positively associated with program sustainability. Given that I/UCRCs rely on other organizations for financial support, a higher level of in-kind support instead of direct cash support may indicate a lower level of commitment from sponsoring organizations. A higher proportion of in-kind support at the point of graduation seems to be a precursor to declining industrial investment. In fact program directors at NSF have recognized that actively funded Centers accepting in-kind support from industry in place of membership fees were not as viable and have placed a cap on how much in-kind support can be used to meet program requirements (NSF I/UCRC website, 2010).

Predicting Continued Activities, Structures, & Outcomes

Predictive analysis was not able to account for variation in program activities as measured by number of research projects. Ailes et al. (2000) indicated that research projects are an important measure of program sustainability for cooperative research centers. However, it may not be the number of projects conducted that is important but rather the quality or type of research (i.e. basic vs. applied). Future research on program sustainability for cooperative research centers would benefit from exploring more measures of continued program activities.

Graduation year number of members was the only variable that predicted continued program structures. It accounted for 54% of the variance in current number of members and 15% of the variance in current budget. The importance of member participation to continued program structures is not surprising given that I/UCRCs are built around fostering collaborative relationships with industry. Centers with more members at the time of

graduation have more members and higher budgets currently. This finding is also supported by the literature on program sustainability indicating that stakeholder support is key continued program success.

Predictive analyses for continued program benefits indicated that current IP events had a negative association with graduation year university expenditures on R&D. This is an unexpected finding that certainly warrants further research. Waugaman and Tornatzky (2001) found that universities that performed less research were able to achieve a high level of success as measured by IP events when controlling for university research budget. It may be that, while larger universities have more funding for research, their focus tends to be more on basic fundamental research which is not typically focused on IP. At the same time, smaller universities with less research funding may be working to catch up by pursuing applied research and economic development which is more suited to IP. Alternatively, it may be that IP events is a poor measure of continued activities for I/UCRCs as several key informants mentioned that they do not pursue IP, preferring to let their industrial partners pursue any IP. Given that the I/UCRC model emphasizes precompetitive research, this does make some sense.

Continued benefits was also measured by number of Center trained graduate students graduating. Only the number of students supported at the time of graduation was predictive, accounting for 37% of the variance. This result is intuitive for Centers that graduated from I/UCRC support recently. Those students that were being supported at the time of graduation may very well be the same students that are graduating currently. More broadly, Centers that

have a good track record of supporting and involving students in their research are more likely to continue to produce well trained Center graduates.

Exploratory Results

Since there have only been two previous studies on program sustainability for cooperative research centers and neither was empirical, factors that key informants perceived to be critical to their sustainability were investigated. At least 30% or respondents mentioned economic factors, pursuing new funding opportunities, close connection to member firms, meeting industry technical needs, university support, director commitment/persistence, meeting industry partnership format needs, and research quality as important factors. It is worth noting that the most commonly mentioned factor, economic factors, was also a significant predictor (as measured by industry support for outside research) in the predictive analyses for current status. Quantitative analyses also provide some support for qualitative findings that pursuing new funding opportunities is critical to program sustainability with budget being a significant predictor of program sustainability measures. The same is true for Center membership as a predictor. Both quantitative and qualitative findings indicate that their participation is crucial. Current findings are in line with Ailes et al. (2000) that industrial/stakeholder involvement is important for ERCs as well as I/UCRCs, indicating that this finding may be generalizable to cooperative research center sustainability in general and more broadly, to sustainability of other types of programs as indicated in the literature (Goodman & Steckler, 1989; Scheirer, 2005; Shediac-Rizkallah & Bone, 1998). The qualitative responses are also similar to other factors mentioned by directors of graduated ERCs participating in Mujumdar (2005) and Ailes et al. (2000). Both this study and the

Ailes et al. (2000) study identified the importance university cost sharing, Center Director leadership and commitment, faculty buy-in, research quality, and a close connection to industry partners as critical to Center sustainability. I/UCRC respondents also emphasized the importance of economic factors, meeting partner needs, and pursuing new funding opportunities. These new factors identified are unique to sustainability of I/UCRCs and emphasize their reliance on outside funding.

Limitations

This study had several limitations that are worth mentioning. First, the study relied in part on retrospective outcome data. In some cases respondents were asked to provide information about Centers that were long closed and/or events that happened when the Center was graduating. An attempt was made to correct for this problem by using archival data sources and by collecting data from Center evaluators.

The selection of predictor variables was limited to those that were available in archival data sources. Unfortunately, low response rate from Center Evaluators and missing Process/Outcome Survey data (which was collected on an annual basis) prevented inclusion of organizationally and psychologically interesting predictors like industry and faculty satisfaction, perceived benefits by industry, and perceived Center leadership. Similarly, the study originally proposed to investigate the transition process for Centers. However, because Centers made the transition from I/UCRC support to self-sustainability at least a year prior to data collection, piloting of the Key Informant Interview made it clear that respondents would not be able to provide reliable data.

Sample size was also a limiting factor for this study. Every effort was made to achieve the highest response rate possible. Data were collected from every formerly funded I/UCRC. However, there are only 70 formerly funded I/UCRCs. The fact that this study did not find association between sustainability measures and many of the predictor variables may be due to the reduced statistical power associated with a small sample.

This study could also have benefited from a control group of graduates of other cooperative research center programs. Such comparison would have allowed for examination of differences in both descriptive and predictive findings.

Future Directions

There are several ways in which future research can contribute to a better understanding of program sustainability. While this study originally intended to examine several variables related to stakeholder involvement, benefits, and satisfaction collected at the time that Centers made the transition from NSF support to self-sustainability, that was not possible due to missing data in archival records. Future studies on program sustainability would benefit from taking the life cycle approach to sustainability advocated by Scheirer (2005). By anticipating program sustainability as an ultimate outcome of demonstrations projects and collecting data throughout the course of the program lifecycle that may be predictive of future outcomes, a better understand of the program sustainability process can be achieved.

There is some evidence that the fidelity measures used do not fully capture the way formerly funded Centers operate now. For example, the reliability of the assessment fidelity scale was low ($\alpha = .66$). Fidelity measures were developed based on the I/UCRC program

model. Future research would benefit from more in depth assessment of current Center operations. Current operations could then be compared to how Centers operated while they were funded under an I/UCRC grant to develop better fidelity measures.

Based on preliminary results of this study, additional research into program sustainability for formerly funded I/UCRCs is already underway. While this study was exploratory in nature, it revealed that understanding program sustainability is a complex process that varies widely from Center to Center. In order to obtain a more in depth understanding of program sustainability as well as look at the impact of sustained Centers, a case study project is currently in progress.

Craig et al. (2007) developed measures of center leadership for cooperative research centers. Further work on understanding the role of leadership and program championship in making the transition from grant support to self-sustainability would greatly add to the body of knowledge on program sustainability.

Conclusion

Results of this study provided several insights about program sustainability. This study empirically showed for the first time in the I/UCRC program's history that the NSF has succeeded in its mission to foster long term relationships between industry and university. Second, it also took some important first steps toward quantifying the level of sustainability achieved by formerly funded Centers. Centers continued to produce benefits long after NSF support ended. These sustained impacts provide a very large indirect impact for the I/UCRC Program, nearly doubling NSFs investment leveraging from eight to one to fifteen to one (McGowen & Gray, 2009). The high levels of Center sustainability combined with high

fidelity demonstrate the viability of the I/UCRC program model for creating self-sustaining Centers. In addition, this study is the first to empirically assess factors associated with cooperative research center program sustainability. It was able to predict sustainability and related measures to a substantial extent, showing that program sustainability is related to funding, economic factors in the environment, completion of initial grant funding (graduation status), and stakeholder involvement. It is hoped that these results can be used by the NSF and directors of actively funded I/UCRCs to prepare for self-sustainability. In particular, Center Directors are encouraged to actively pursue funding opportunities for their Centers and to focus on developing and maintaining close relationships with industry members. This will allow them to maintain NSF support for the full time allowed under their grant and will prepare them for self-sustainability by ensuring they have the funds and stakeholder support to continue operating. Based on the results of this study, NSF is encouraged to continue to emphasize the importance of stakeholder support for Centers, both as a means of finding financial support and as strategic partners. NSF is also encouraged to consider providing bridge funding to Centers scheduled to graduate during economic recessions. Evidence suggests that losing NSF support while industry partners may be going through economic turmoil makes sustainability less likely for I/UCRCs. There is still a need for further investigation of program sustainability, both generally and for cooperative research centers. This study was a first step toward understanding program sustainability for cooperative research centers.

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APPENDICIES

Appendix A

Key Informant Interview

Center Name:
Evaluator Name:
Key Informant Name:
Graduation Status:

Hi Dr./Mr/Ms: _____
We are conducting a study to find out what happened to Centers that were funded under the NSF I/UCRC program. According to our records you were the Director for CENTER NAME while it was supported by the I/UCRC program from YEAR to YEAR. I would like to ask you a couple of questions about that center's transition from NSF support and what happened to it after the grant ended.

1. ***Do you think you are familiar enough with the center during that time period to answer these questions?***

   Code: Yes/No

IF YES, ASK Q2, IF NO ASK Q1a

1a. Could you refer me to someone whom you think might be able to answer these questions?

Code: name, contact info

Respondent Info:

2. **First off, can you please tell me your name and your position at CENTER NAME.**

   Code: Name
   Code: Current Director, Last Director, PI, Faculty, Administrator, Other

3. **How long have you been involved with CENTER NAME?**

   Code: number of years

IF LESS THAN 2 YEARS AND/OR NOT PRESENT AT TIME OF TRANSITION, ASK **Q3a**, OTHERWISE SKIP TO **Q4**

3a. Who was the previous director? Who would be able to tell me about the Center's transition?

Code: Name, Position

3a1. Can you give me that person's name and contact info?

Code: Name
Code: Contact info

4. **Have you ever started another Center?**

Code: yes/no

Center Status:

Ok great, so I want to ask you a couple of questions about what is going on with CENTER NAME now. If some of these questions seem obvious, I apologize, I'm just trying not to miss anything.

5. **What happened to CENTER NAME after the I/UCRC grant ended?**

Code: Still in operation , merged (get this information from our database), No longer in operation

IF NO LONGER IN OPERATION ASK **Q6 –Q8**. IF STILL IN OPERATION, SKIP TO **Q7**

6. **When did CENTER NAME cease operations?**

Code: year

IF DON'T KNOW, ASK **Q6a**, OTHERWISE SKIP TO **Q9**

6a. Could you tell me someone who would have that information?

Code: Name and contact info

7. **What factors, in your opinion contributed to your center eventually closing down?**

   Code: sustainability predictors – developed from literature and qualitative content analysis

8. **Did you make any significant changes in the I/UCRC model after the grant ended?**

   Code: yes/no

IF YES, ASK **Q8a & b**, IF NO SKIP TO **Q9**

8a. **What were they?**

Code: qualitative content analysis

8b. How do you think those changes affected the Center?

Code: qualitative content analysis

IF THE CENTER WAS OPERATING FOR AT LEAST ONE YEAR POST-NSF FUNDING, SAY THE FOLLOWING AND THEN RESUME WITH THE REST OF THE QUESTIONS. OTHERWISE SKIP TO THE END OF THE INTERVIEW:

Although CENTER NAME is no longer in operation, I'd still like to ask you about how the center operated after the end of the grant. So the following questions will refer to activities at CENTER NAME during the time period after the end of NSF I/UCRC support through the last year of operation. I'll refer to this period as the post-I/UCRC period. If some of these questions seem obvious, I apologize, I'm just trying not to miss anything.

9. **[Does] [Did] the Center conduct research [post-I/UCRC]?**

   Code: yes/no

IF NO, ASK **Q9a**, OTHERWISE, SKIP TO **Q10**

9a. How long after the end of the IUCRC grant did the center stop conducting research?

Code: number of years; less than one year, longer than 1 year

10. **[Does] [Did] the Center receive funding from external sources such as the industry, government, foundation support, etc?**

    Code: yes/no

IF NO, ASK **Q10a**, OTHERWISE SKIP TO Q10

10a. How long after the end of the IUCRC grant did the center stop receiving external support?

Code: number of years; less than one year, longer than 1 year

11. **How many faculty PIs [are] [were] involved with the Center's research [post I/UCRC]?**

    Code: number, meets or does not meet the minimum threshold of at least 3 PIs

IF LESS THAN 3, ASK **Q11a**, OTHERWISE SKIP TO **Q12**

11a. How long after the end of the IUCRC grant did the center drop to fewer than 3 PIs?

Code: number of years; less than one year, longer than 1 year

12. **[Are] [Were] there any graduate or undergraduate students involved with the Center's research [post-I/UCRC]?**

    Code: yes/no

IF NO, ASK **Q12a**:, OTHERWISE SKIP TO NEXT **INSTRUCTIONS**

12a. How long after the end of the IUCRC grant did the center stop working with students?

Code: number of years; less than one year, longer than 1 year

IF THE CENTER DOES NOT MEET ALL THE RESEARCH, FUNDING, PI, AND STUDENT REQUIREMENTS FOR BEING A CENTER FOR AT LEAST ONE YEAR AFTER THE END OF IUCRC FUNDING, ASK **Q13** AND THEN END THE INTERVIEW, OTHERWISE SKIP TO **Q14**

13. **Given that CENTER NAME does not conduct research/receive external support/involve faculty/involve students (which ever combo reflects responses to Q8-11), what characteristics make it a research center?**

    Code: qualitative content analysis

Fidelity:

The following questions [also refer to the post-I/UCRC time period] [refers to the time period after the end of the I/UCRC grant until the point at which the center fell below the criteria just discussed]. These questions are meant to assess the degree to which the center continues to operate under the I/UCRC model.

14. **In your view, did CENTER NAME make any significant changes in the way it operated after the end of the NSF I/UCRC grant?**

    Code: yes/no

IF YES, ASK **Q14a**, OTHERWISE SKIP TO **Q15**

14a. What changes were made?

Code: qualitative content analysis

Ok, some of the following questions may overlap with the explanation you just gave me. I'll try to skip over them but please excuse me if I ask you to repeat yourself.

15. **[Is] [Was] the Center based at UNIVERSITY NAME?**

    Code: Yes/No

IF NO, **Q15a**, OTHERWISE SKIP TO **Q16**

15a. Where is the center based?

Code: another university (name), non-university (name)

16. **[Does] [Did] CENTER NAME receive financial support from industry [post-I/UCRC]?**

    Code: yes/no

17. **What academic disciplines [do] [did] the faculty researchers come from?**

Code: discipline names, number of disciplines

18. [Does] [Did] the center hold meetings for its members and other supporters?

Code: Yes/No

IF YES, ASK **Q18a**, OTHERWISE SKIP TO **Q19**

18a. How often [are] [were] these meetings held?

Code:
___not at all
___Sporadically
___Once per year
___Twice per year
___More than twice per year

19. While CENTER NAME was funded under the NSF I/UCRC grant, it had an on-site evaluator. [Does] [Did] the center [still] have an on-site evaluator [post-I/UCRC]?

Code: yes/no

IF YES ASK **Q19a & b**. IF NO JUST ASK **Q19b**.

19a. Who [is] [was] the evaluator [post-I/UCRC]?

Code: Name

19b. Does the Center undergo any regular evaluation by other means? Please describe.

Code: yes/no, qualitative content analysis

20. [Does] [Did] the Center do any technology or knowledge transfer [post-I/UCRC]?

Code: yes/no

The following questions are meant to assess the degree to which CENTER NAME [operates] [operated] as a consortia [post-I/UCRC].

21. [Do] [Did] members pay a membership fee in order to participate in the Center?

Code: yes/no

22. How [are] [were] research projects selected [post-I/UCRC]?

Code:
___ A numerical count of votes
___ some other type of voting system
___ members discuss and then develop consensus
___ each member selects one project to be funded
___members provide feedback, but PIs/Director makes the ultimate decision
___Other – qualitative content analysis

22a. [Do] [Did] you use LIFE forms?

Code: yes/no

23. How [are] [were] results disseminated to center members?

Code:
___everyone has access to results of all projects
___members get access to some projects but not all
___members get results of their "pet" projects (i.e. the one's they fund)
___other – qualitative content analysis

Sustainability:

The following questions also refer to the post-I/CURC time period. They are meant to assess the degree to which the center was able to sustain itself after the end of the NSF I/UCRC grant.

24. How has the research focus changed since the end of the I/UCRC grant?

Code: qualitative content analysis

24a. Ok, which of the following categories would you say represents the differences you just mentioned:

Code:
___no change
___Slight change
___Some change

___A great deal of change
___Totally different

25. Do you have an IAB?

Code: yes/no

26. [Has] [Did] CENTER NAME [added or dropped] [add or drop] any university research sites post-I/UCRC?

Code: yes/no

IF YES, ASK **Q26a**, OTHERWISE,SKIP TO **Q27**

26a. Which ones?

Code: University names

The following questions refer to the university acting as the primary/managing site for the center.

27. Has the managing university changed since the end of the I/UCRC grant?

Code: yes/no

IF YES, ASK **Q27a**, OTHERWISE SKIP TO **Q28**

27a. What university [is] [was] the managing site [during the last year of operation post-I/UCRC]?

Code: University Name

28. [Has the managing university been] [Was the managing university] supportive of the Center [post-I/UCRC]? How so? How not?

Code: qualitative content analysis

28a. Ok, which of the following best describes the level of support you just described?

Code:
___university was very antagonistic to the center
___university was somewhat antagonistic to the center

___university was slightly antagonistic to the center
___university was neutral towards the center
___university was slightly supportive of the center
___university was somewhat supportive of the center
___university was very supportive of the center

28b. [Does][Did] the university provide any type of cost sharing, either by discounting overhead rates or by providing indirect support such as faculty salaries, graduate assistant support, etc [post-I/UCRC]?

Code: yes/no

Transition Planning:

Ok. The next set of questions refer to the ways in which CENTER NAME may have prepared for the end of their NSF I/UCRC grant.

29. Did the Center do any planning for the transition away from NSF I/UCRC support?

Code: yes/no

IF YES ASK **Q30-33**. IF NO, SKIP TO **Q34**.

30. How did CENTER NAME prepare for the transition?

Code: qualitative content analysis

30a. What strategies were used?

Code: qualitative content analysis

30b. In your opinion what was most effective?

Code: qualitative content analysis

31. How long before the end of the grant did planning begin?

Code: Years

32. Who was involved in developing the transition plan?

Code:
___Director
___Faculty
___Center Administration
___University Administration
___Students
___Industry Members
___Other (specify)

Open-ended questions:

The following questions are meant to assess your perspective on the transition from NSF support to self sustainability.

33. What were the primary challenges your Center faced transitioning from I/UCRC grant support?

Possible Prompts:

Implementation Quality
Perceived effectiveness
Alignment with stakeholder needs
Length of initial grant support
Funding
Stakeholder involvement
Training component
Adaptation
Fit with social climate
Economic
Political
Outside stakeholder participation
University support
Institutional strength
Integration with existing structures
Fit with organizational mission
Program champion

Code: qualitative content analysis

34. Did the IAB or any specific members do anything to facilitate or hinder your transition?

Code: yes/no

IF YES ASK **Q34a**, OTHERWISE SKIP TO **Q35**

34a. What did they do?

Code: developed through qualitative content analysis

35. Do you have any advice to offer other Center Directors making the same transition?

Code: developed through qualitative content analysis

36. What advice would you give NSF to help prepare Centers for the transition?

Code: developed through qualitative content analysis

IF THE CENTER DID NOT GRADUATE, ASK **Q37 – Q39**, OTHERWISE SKIP TO **Q40**

According to our records CENTER NAME did not receive the full 10 years of I/UCRC grand support. I'd like to ask you just a couple of questions about why the center left the I/UCRC program.

37. What factors do you think contributed to the fact that your center did not receive the full 10 years of NSF I/UCRC support?

Code: qualitative content analysis

38. What effect did loss of the I/UCRC grant have on the Center?

Code: qualitative content analysis

39. What could NSF do to help other centers to receive the full 10 years of support?

Code: qualitative content analysis

Ok, that's pretty much it for the interview.

40. Do you have anything else you'd like to add?

Code: qualitative content analysis

Ok, great. I do have a few questions about budget numbers, membership numbers, and a couple of other center outcomes. If you have that information handy, we can run through that quickly. Otherwise I can email you something to fill out when you have your records in front of you.

Code: ask survey questions or get email address to send survey

Thank you for taking the time to help with this study. Your responses will be kept confidential and will only be reported in aggregate. Results will be made available on the I/UCRC evaluators' webpage upon completion and you will be notified when they are available. Again, thanks for your help!

Appendix B
Key Informant Survey

Center Name: _____
Respondent Name: _____

Dear Center Director and Staff:

This form asks for information about _____ , a former NSF funded I/UCRC. Please answer the following questions in terms of the most recently completed fiscal year. If your center is no longer operating, please answer the following questions in terms of the last year of operation. Please provide a best estimate if necessary.

The following information is requested from your Center:

1. Income Information
2. Outcome & Personnel Information
3. Membership Information

Additional instructions precede each of these sections on the following pages. If you have any questions about completing this form, please contact:

Lindsey McGowen
919.515.3237
iucrc@ncsu.edu

Please return the completed form to Ms. McGowen at the above listed email address. Thank you for your assistance in this study of graduated I/UCRCs

Please answer the following questions in terms of the most recently completed fiscal year. If your center is no longer operating, please answer the following questions in terms of the last year of operation. Provide a best estimate if necessary.

INCOME INFORMATION

Please provide information on types and sources of support specific to your Center, including annual fees, capital support and contributions, cash support, and rate information. Please provide a best estimate if necessary. Information provided should reflect the most recently completed fiscal year, or the last year of operation.

Cash Support	Dollars	
Total from Member Fees (See Note 3):	$	1
Additional Industry Support (See Note 4):	$	2
Other NSF Support (See Note 5):	$	3

Other Federal Government (See Note 6):	$	4
Non-Federal Government (See Note 7):	$	5
State Support (See Note 8):	$	6
University (See Note 9):	$	7
Other Cash Funding (See Note 10):	$	8
Capital Support and In-Kind Contributions (See Note 2):	**Yes/No**	
Contributed Equipment:		9
Contributed Facilities:		10
Contributed Personnel:		11
Contributed Software:		12
Other In-Kind Support:		13
University Cost Sharing	**Percent**	
% Overhead Rate Charged to Membership Fees (See Note 11):	%	14
% Typical Overhead Rate (See Note 12):	%	15

FOOTNOTES:

1. Fees charged to Industry for membership in center, broken down into primary, secondary, and tertiary (not all centers offer the latter two categories).
2. Capital support refers to items of value over $25,000 and includes equipment and facilities. In-kind contributions include non-cash donations of equipment, facilities (occupied buildings), personnel, and software
3. The total cash collected by a center from industry membership fees.
4. Refers to additional industry cash funding for operations or research provided by industrial members (e.g., enhancements, donations, etc.) which is applied to the Center as a whole (e.g., income that results in outcomes shared equally by all Center members).
5. Any NSF awards granted to Center that are provided by other NSF groups or divisions (in addition to IUCRC Award & Supplement). This category does not include money transferred through NSF from other Federal Agencies (MIPRs).
6. Refers to cash support for Center operations provided by other Federal funding sources, but does NOT include funding from NSF.
7. Refers to cash support for Center operations provided by other non-Federal funding sources, foundations, etc.
8. Refers to the support provided by state government and/or an agency or program funded by state government.
9. Refers to the support for the Center operating costs including salary, travel, and overhead returned to the Center. It does NOT include items such as utilities and space.
10. Refers to any other cash support, such as contracts, received by Center researchers that would not have been received if the Center did not exist. The funding would not result in outcomes shared equally by Center members.
11. Refers to the overhead rate charged to membership fees.
12. Refers to the typical overhead rate the managing university typically charges to grants.
13. Refers to the estimated percentage of the Centers direct operating budget allocated to administration (e.g., administrative salaries, travel, telephone).

OUTCOMES & PERSONNEL

Please enter your Center's data as numerical counts, not percentages. In the publications section you should only enter actual publications (not works "in press"). Information provided should reflect the most recently completed fiscal year, or the last year of operation. Please provide a best estimate if necessary.

Intellectual Property	**Counts**	
Inventions Disclosed:		17
Licensing Agreements:		18

Patent Applications:		19
Patents Granted:		20
Inventions Producing Royalties:		21
Software Copyrights:		22
Center Graduates		
Graduate Degrees (Masters & Doctoral) (See Note 1):		24
Center Graduates Hired by Center Members		
Graduate Students (Masters & Doctoral) (See Note 2):		26
Publications Acknowledging Center Support		
Number of presentations made (See Note 3):		27
Number of Publications in the Open Literature (See Note 4):		28
Projects		
Number Projects Completed (See Note 6):		30
Personnel		
Number Directors & Co-Directors (See Note 7):		31
Number Faculty (See Note 8):		32
Number Professional Administrative (See Note 9):		33
Number Research Staff (See Note 10):		34
Number Postdocs (See Note 11):		35
Number Graduate Students (See Note 12):		36
Number Undergraduate Students (See Note 13):		37

FOOTNOTES

1. Refers to the number of Ph.D.s, M.S.s, that received a degree during the reporting period.
2. Refers to the number of Ph.D.s, M.S.s, that were hired by member companies during the reporting period.
3. Number of presentations produced or based on Center Research.
4. Total number of the publications in the open literature the Center researchers produced based on Center research.
5. Number of research reports produced for internal use or not published in the open literature.
6. Number of research projects funded by the center that were completed during the reporting period.
7. Number of Directors at all university research sites associated with the Center.
8. Number of faculty researchers at all university research sites associated with the Center.
9. Number of professional administrative staff whose work primarily supports the administration of the Center at all associated university sites.
10. Number of non-faculty, student, or postdoc researchers working on Center research.
11. Number of postdocs working on Center research.
12. Number of Masters and Doctoral students working on Center research.
13. Number of B.S./B.A. students working on Center research.

MEMBERSHIP INFORMATION

Please provide information about the different organizations and institutions that work with or support the work of your Center. Information provided should reflect the most recently completed fiscal year, or the last year of operation. Please provide a best estimate if necessary.

Members	Counts

Number Current Members:		38
Membership Fees	**Dollars**	
Primary Membership Fee:	$	41
Secondary Membership Fee:	$	42
Tertiary Membership Fee:	$	43

Appendix C
Evaluator Survey

Graduated I/UCRC Evaluator Questionnaire

We are conducting a study to find out what happened to Centers that were funded under the NSF I/UCRC program. We have already conducted interviews with the Center's director and would like to get input from the evaluator. We would like to ask you a few questions about the Center's status while it was still funded by NSF and its transition from NSF support. Please remember your participation is voluntary and the information you provide will be kept confidential.

*****PLEASE INDICATE YOUR CENTER***:**

Select Center Name

How long were you involved with the Center: _____ (years)

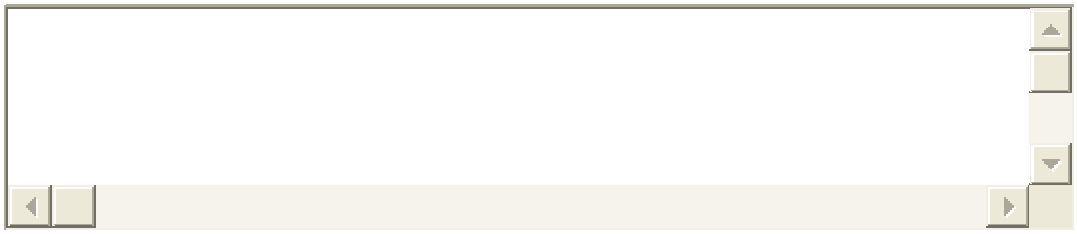
A. Center Operations -- Fidelity to the I/UCRC Model

The following questions are meant to assess how closely your Center adhered to the I/UCRC model while it was funded under an I/UCRC grant. Program implementation is thought to contribute to program sustainability, so we are interested in how the Center operated during the life to the grant.

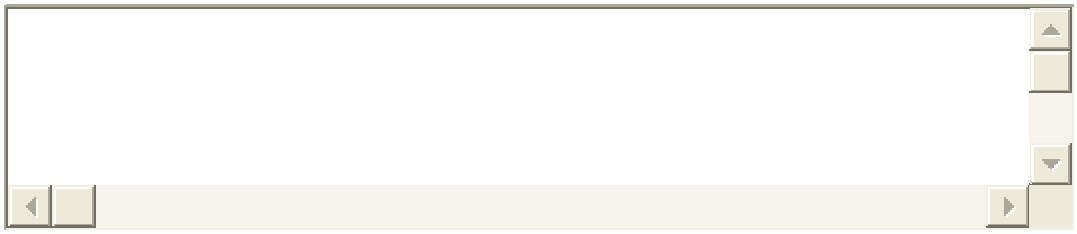
1a) Some Centers make modifications to the I/UCRC model to fit necessities of the local conditions. In your opinion, did the Center make any significant changes to the I/UCRC model (university based, industrially supported, multidisciplinary research, semi-annual IAB meetings, technology transfer, shared IP, consortial format) while it was funded?

Yes	No
○	○

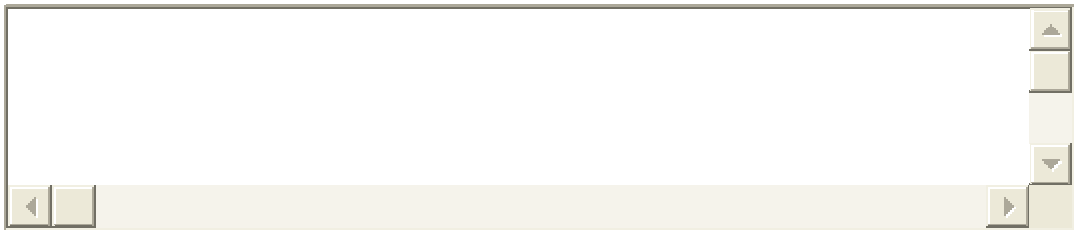
1b) What changes were made?



1c) What do you think was the impact of these changes on the Center's long-term success?



2a) While the Center operated under and I/UCRC grant, how were research projects selected?



2b) Based on your description, please indicate how research projects were selected for funding within the Center. Check all that apply.

A numerical count of votes or points	Some other type of voting system	Members discuss and then develop consensus	Each member selects one project to be funded	Members provide feedback on projects, but PIs/Director makes the ultimate decision	Other
☐	☐	☐	☐	☐	☐

2c) Which one of these project selection methods was most important to the final decision to fund a project?

A numerical count of votes or points	Some other type of voting system	Members discuss and then develop consensus	Each member selects one project to be funded	Members provide feedback on projects, but PIs/Director makes the ultimate decision	Other
○	○	○	○	○	○

3) Did you use LIFE (Level of Interest Feedback Evaluation) forms when projects were being evaluated for funding?

Yes	No
○	○

4) How were results disseminated to Center members?

Everyone has access to results of all projects	Members get access to some but not all projects	Members get results of their "pet" projects (i.e. the one's they fund)	Other (Please describe)
○	○	○	○

Other:

B. Transition Planning.

The next set of questions refer to the ways in which your Center may have prepared for continuing the program after the end of their NSF I/UCRC grant.

5a) Did the Center do any transition planning (e.g. formally consider what would happen after NSF funding ended and evaluate different courses of action to take, such as consider alternative funding sources, revise membership agreements, change research focus, consider new/different university partners, change Center operating model?

Yes	No
○	○

IF YOU ANSWERED "NO" TO THE ABOVE QUESTION, PLEASE SKIP TO ***QUESTION 6***.

5b) How long before the end of the grant did planning begin?

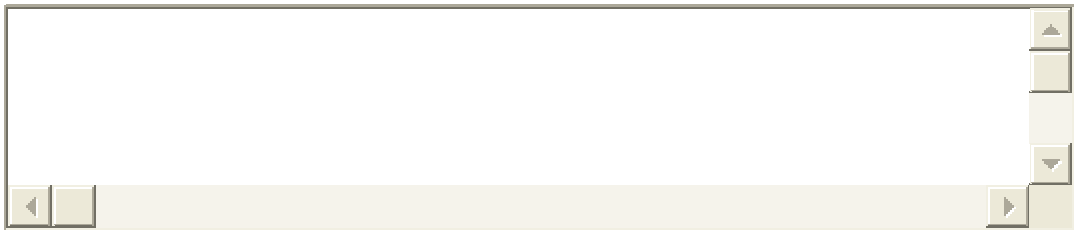
At the beginning of the grant	2+ years prior to the grant's end	1 year prior to the grant's end	6 months prior to the grant's end	Concurrent with the grant's end	After the grant ended
○	○	○	○	○	○

5c) Who was involved in developing and executing the transition plan? Check all that apply.

Center Director(s)	Center Faculty	Center Administration	University Administration	Students	Industry Members	Others
☐	☐	☐	☐	☐	☐	☐

5d) How did your Center prepare for the transition? What strategies were used?

5e) In your opinion what impact if any did these transition activities have on the Center's post-NSF success?



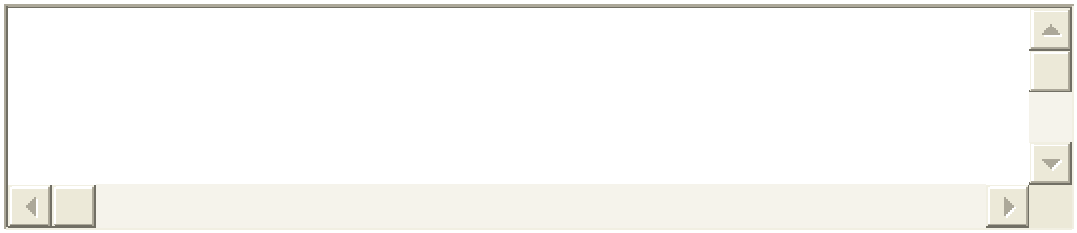
C. Post-I/UCRC funding Evaluator involvement.

The following set of questions are meant to assess your involvement (if any) with your Center after the I/UCRC grant ended.

6) To what extent have you been involved with the Center since the I/UCRC grant ended?

Not at all	Maintained involvement for 1-2 years	Maintained involvement for 3+ years	Still involved

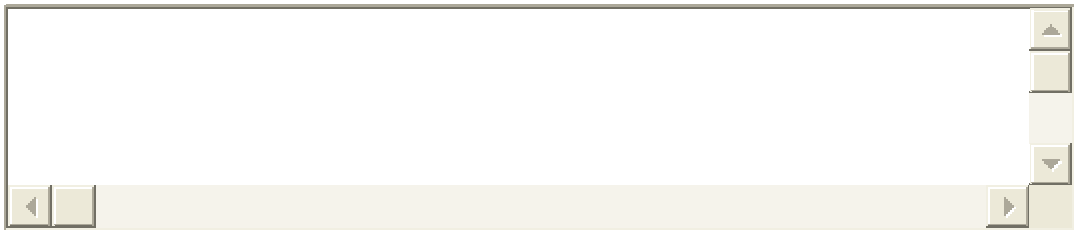
7) What was your role with the Center after the grant ended? How were you involved?



D. Program Sustainability.

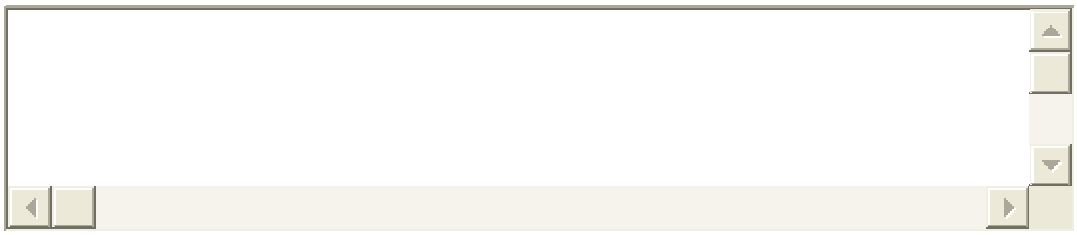
This next question is regarding your general impressions about your Center's success in making the transition.

8) What factors do you think were most influential in leading to the Center sustaining (or not sustaining) itself after the end of the I/UCRC grant?

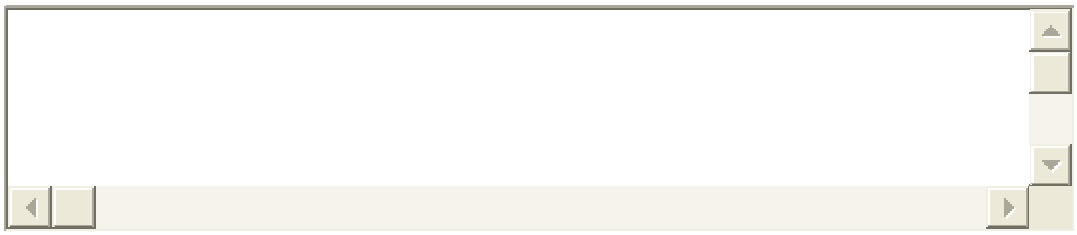


THE FOLLOWING QUESTION IS FOR CENTERS THAT RECIEVED LESS THAN 10 YEARS OF NSF I/UCRC FUNDING. IF YOUR CENTER WAS UNDER AN I/UCRC GRANT FOR 10+ YEARS, SKIP TO ***QUESTION 10.***

9) What factors do you think were most influential in your Center not receiving the full 10 years of NSF I/UCRC support?



10) Is there anything else you think it is important for me to know regarding your Center's post-I/UCRC outcomes?



Submit

Thank you!

Questions/Concerns about the questionnaire, please contact iucrc@ncsu.edu

Appendix D

Dropped Instruments

Evaluators' Interview. Evaluators have been involved with centers since they began operation up until and sometime after they exit the program. They have been key participant observers during the center's entire NSF I/UCRC-funding. An online survey was conducted to collect both objective and subjective data from the evaluators (Appendix C). The questionnaire focused on the following issues: transition planning, program implementation quality, and leadership. However the survey had to be dropped due to low response rate. Responses were received from 13 evaluators for 22 centers.

Process/Outcome Questionnaire Database. The Process/Outcome questionnaire is administered annually by the on-site evaluator for each funded center. Data are provided by both center faculty and industry members on an annual basis. There are two versions of the industry questionnaire; a longer version for years 1-5 or operation and a shorter version for years 6-10 of operation. The long industry questionnaire has 45 items categorized into six sections: research program, technical benefits, other benefits, administrations & operations, general evaluation, and member information. The short version of the industry questionnaire has 29 items categorized into five sections: research program, benefits, administrations & operations, general evaluation, and member information. Key variables include research interest (Q1), satisfaction with breadth (Q4b) and focus (Q4c) of research, general satisfaction (SQ13, Q14), intention to renew membership (Q15), research and development benefits (SQ8a, Q7a-d), commercialization benefits (SQ8b, Q7e-f), professional networking benefits (SQ8c, Q10a-c), dollar value of center stimulated in-house research, (Q6b),

satisfaction with administrative operations (SQ11, Q12a-h), member industrial affiliation (Q18), length of membership (Q19), type of member organizations (Q20), and member financial stability (Q22).

The faculty version of the questionnaire has 29 items that assess satisfaction and commitment to the center, productivity, and some demographic variables. Key variables include type (Q1a), scope (Q1b), and timeframe (Q1c) of center research, benefits (Q5a-f), satisfaction (Q6a-f), years of involvement (Q9), and academic rank (Q10). Also, because the literature on program sustainability emphasizes alignment of stakeholder needs, a difference score could be calculated for the amount of time that industry and faculty think it should take to complete projects (industry Q3, faculty Q2).

Unfortunately, data archives for this measure were incomplete. While Process/Outcome data collection has been on-going since the mid 80s, storage of this data has not been consistent. Information from old floppy disks and zip drives was not accessible. Current systems were not able to read the discs and the North Carolina State IT support staff were not able to extract any data. The archive that was available only dated back to 1998. Therefore all Process/Outcome items were dropped from the study. Items propsed are listed below:

Final I/UCRC industry satisfaction: This variable will be measured via the Process/Outcome archival database. It reflects likert scale ratings of satisfaction with breadth (Q4b) and focus (Q4c) of research, satisfaction with administrative operations (SQ11, Q12a-h), and general satisfaction (SQ13, Q14) during the final reporting year while the Center was funded under the I/UCRC grant.

Final I/UCRC industry benefits: This variable will be measured via the Process/Outcome archival database. It reflects likert scale ratings of research and development benefits (SQ8a, Q7a-d), commercialization benefits (SQ8b, Q7e-f), and professional networking benefits

(SQ8c, Q10a-c) during the final reporting year while the Center was funded under the I/UCRC grant. In addition to these benefit ratings, the dollar value of center stimulated in-house research, (Q6b) will be used as a more quantitative measure of industry benefits. Responses will be coded in continuous dollars and will be converted to 2000 constant dollars using the calculator available at http://woodrow.mpls.frb.fed.us/research/data/us/calc/.

Final I/UCRC Faculty Satisfaction: This variable will be measured via the process/outcome archival database. It reflects faculty likert ratings of satisfaction with quality of the research program, relevance of the research program to my needs, center administration and operations, amount of funding I receive for conducting research, amount of autonomy I have in conducting research, interactions with industry members, the facilities and equipment, how supportive the center is in helping me achieve my research goals, and the quality of industrial research during the final year of I/UCRC grant support (Q6a-f).

Final I/UCRC Faculty benefits: This variable will be measured via the process/outcome database. It reflects faculty likert ratings of the following benefits during the final year of I/UCRC grant support: the feeling of accomplishment I get from the work I do, opportunities for consulting, the feeling of satisfaction I get from knowing I am making a contribution to technological development, opportunities for research contracts/grants, chances for promotion, tenure, and/or salary increases, the recognition I receive for the work I do, the level of challenge posed by conducting center research, access to useful equipment, and ability to support graduate students (Q5a-f).

Final I/UCRC Faculty control variables: In order to control for differences in satisfaction and benefit ratings that are a function of familiarity with the center or academic research in general, the years of involvement (Q9), and academic rank (Q10) will also be measured via the process/outcome archival database. Years of involvement will be coded as a continuous count variable and academic rank will be ordinal.

Final I/UCRC Timing alignment: This variable is intended to measure alignment between industry and faculty in terms of expectations about the timing of research results. It will be measured via the process/outcome archival database and reflects the difference score for the amount of time that industry and faculty think it should take to complete projects (industry Q3, faculty Q2). Responses will be coded in number of months.

Key Informant Interview & Survey.

Prior to substantive data collection, the survey and interview protocol were piloted with a few Center Directors from the I/UCRC program. Based on interviews with these respondents several items had to be dropped; either because the information was too difficult

to obtain, or because respondents indicated that they had trouble providing retrospective data.

Dropped items are listed below:

General Fidelity: In addition to measuring specific aspects of fidelity, respondents will also be asked to discuss any other changes they made to the I/UCRC program model after the end of the I/UCRC grant. General issues of fidelity will be investigated by asking "In your view, did CENTER NAME make any significant changes in the way it operated after the end of the NSF I/UCRC grant?" Responses will be coded yes/no and participants that indicate changes were made will be asked "What changes were made?" Responses will be assessed via qualitative content analysis.

In-kind support: This variable will be measured via the key informant survey by asking respondents to indicate whether the center receives any equipment, facilities, personnel, software or other support. Responses will be coded as yes/no and they number of categories for which support was received will be coded as a count variable.

University support: This variable refers to whether or not there is a supportive environment for the Center. It will be measured via the key informant interview by asking "[Has the managing university been] [Was the managing university] supportive of the Center [post-I/UCRC]? How so? How not?" Responses will be coded according to qualitative content analysis. In order to assess this variable more quantitatively, respondents will be asked "Which of the following best describes the level of support you just described?" Responses will be coded as 1) university was very antagonistic to the center, 2) university was somewhat antagonistic to the center, 3) university was slightly antagonistic to the center, 4) university was neutral towards the center, 5) university was slightly supportive of the center, 6) university was somewhat supportive of the center, or 7) university was very supportive of the center.

Director Leadership Dimensions: A number of scholars have commented on the importance of leadership to center success. While empirical research on this issue is limited, Coberly (2004) demonstrated that leadership was a significant predictor of center faculty satisfaction and indirectly organizational commitment. More recently Craig (2008) has attempted to develop an assessment that identifies key center direct leadership dimensions. For the purposes of this study, I will ask evaluators to rate directors on several of these dimensions. A single likert item ranging from +3 indicates that they do too much of it, and 0 indicates that they do the perfect amount to -3 does not do enough will be used. The dimensions that may be examined include the following: technical expertise, ambition / work ethic, broad thinking, embracing ambiguity, balancing competing stakeholders, leveraging social capital, obtaining resources, navigating bureaucracy, granting autonomy, interpersonal skill, team building and maintenance, task adaptability, abrasiveness, disorganization, conflict avoidance.

Transition management: This variable will be measured via the key informant and evaluator interviews by asking "How did CENTER NAME prepare for the transition?" Responses will be coded according to qualitative content analysis.

Transition strategies: This variable will be measured via the key informant and evaluator interviews by asking "What strategies were used?" Responses will be coded according to qualitative content analysis.

Years of planning: This variable will be measured via the key informant and evaluator interviews by asking "How long before the end of the grant did planning begin?" Responses will be coded as the number of years.

Stakeholders planning: This variable will be measured via the key informant and evaluator interviews by asking "Who was involved in developing and executing the transition plan?" Responses will be coded into one of the following stakeholder categories: director, faculty, center administration, university administration, students, industry members, other (specify). This variable will be used as a categorical measure and as a count of the number of stakeholder groups involved in transition planning.

Planning effectiveness: This variable will be a subjective measure of evaluators' and key informants' perceptions of the most effective transition strategies. It will be measured via the key informant and evaluator interviews by asking "In your opinion what impact if any did these transition activities have on the Center's post-NSF success?" Responses will be coded according to qualitative content analysis.

Appendix E

Email from I/UCRC Program Director to Key Informants

Dear [Key Informant]:

As you know, one of the goals of the NSF IUCRC program is to create centers that are self-sustaining. Over the years I have had the opportunity to maintain contact with directors and faculty associated with some of our "graduated centers". However, although there has always been considerable interest within the Foundation in how these centers are doing, we have never had the opportunity to do a systematic follow up assessment.

We are about to remedy that situation with the initiation of the Graduated IUCRC Follow up Project. Dr. Denis Gray and Ms. Lindsey McGowen from North Carolina State University will be conducting the first systematic follow up with all of the IUCRCs NSF has funded since the program began in 1980. I think this is an important effort and one that will benefit IUCRCs past, present and future. Dr Gray or Ms. McGowen will be contacting you shortly about this project and I would appreciate it if you could provide them with your cooperation.

Since you were listed as the last known director of your center, they will be contacting you. We realize that a lot of time has passed since some of our centers have graduated and someone else may be directing the center, it might not still be in operation or may have evolved into something new. If you think the research team should contact someone else about the center's current status or most recent operation, please send a note to the Graduated IUCRC Follow up Study project manager, Ms. Lindsey McGowen (iucrc@ncsu.edu).

Thanks in advance for your help.

[Alex Signature]

Appendix F

Email Invitation to Key Informants

Dear [Key Informant]:

You are being contacted to participate in a research study of Centers that were funded by the National Science Foundation as part of the Industry/University Cooperative Research Center (I/UCRC) program. We are contacting current and former directors of all Centers that have exited the I/UCRC program to participate in a study on post-NSF outcomes.

Many NSF programs receive time-limited grants that seed new and innovative research. The hope is that these Centers are able to continue operating after I/UCRC funding comes to an end. The goal of this study is to follow-up with Centers that have exited the I/UCRC program and to find out how they are doing now, and to learn more about the transition from NSF funding support. Results of this study should help currently funded centers approaching the end of their I/UCRC grant to successfully navigate the transition from grant support to self-sustainability. However, achieving this goal depends on your input.

We are asking that you participate in a telephone interview to discuss your Center's current status and transition process. The interview will take approximately 20 minutes to complete.

There should be no risk to you from the interview. Your participation in this study is voluntary. While your identity and opinions expressed will remain confidential, data on the status of your center and current operations will be shared with NSF. We may wish to use your Center's name in case studies about our findings. If we wish to do this, we will obtain permission to use the Center's name.
If your center name is used, you may be indirectly identified as the Center Director.

You will receive a phone call from the research team shortly ask for your participation in this study and to schedule an interview time.

As a thank you for your participation we're offering a report of descriptive statistics of items in the interview. This summary report will be made available within 2 weeks of the close out date of the study. Instructions for receiving the report are provided at the end of the survey.

If you have any questions regarding this research, please contact Lindsey McGowen (lcmcgowe@ncsu.edu or 919-515-3237) or Dr. Denis Gray (denis_gray@ncsu.edu or 919-515-1721).

Thank you for your consideration,

Denis Gray

Program Director
I/UCRC Evaluation Project
North Carolina State University

Lindsey McGowen
Project Manager
I/UCRC Evaluation Project
M.S. Candidate, Psychology
North Carolina State University

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NCSU IRB for the Use of Human Subjects in Research Committee at either 919-515-7515 or 919-515-4514

Appendix G

Descriptive Statistics and Intercorrelations for Raw and Recoded Predictor and Outcome Variables

Table G1

Descriptive Statistics for Raw Predictor Variables

	N	*M*	*SD*	*Skewness* *Statistic*	*SE*
Individual Level					
GradDirectorResearchTime%	68	32.46	18.83	.00	.29
GradDirrectorTimeCenterAdmin%	68	26.06	22.95	1.92*	.29
Program Level					
GradNumberSites	68	1.57	.90	1.84*	.29
GradNumFundingCategories	69	3.61	1.29	.22	.29
GradBudget($100K)	69	$10.36	$10.98	2.46*	.29
GradMemCount	69	15.22	23.83	6.22*	.29
GradFaculty	68	9.82	7.50	1.61*	.29
GradAdmin	63	1.97	1.59	1.03*	.30
GradStudents	68	13.44	11.26	1.32*	.29
GradUnderGrad	64	3.91	6.26	3.64*	.30
Organizational Level					
GradUnivRDExpend($Mill)	58	$242.03	$188.17	.82*	.31
GradUnivType	70	2.09	.88	-.17	.29
CurResearchClass	69	4.41	.91	-2.10*	.29
GradInkind($100K)	58	$1.23	$2.95	3.92*	.31
GradOverheadDiscount%	63	31.73	22.28	-.57	.30
GradIndSupt%	58	8.94	7.37	2.17*	.31
GradUnivFunding%	69	8.82	12.66	1.60*	.29
Environmental Level					
GradUSGDP ($Bill)	70	$9,698.44	$2,472.32	-.27	.29
GradUSRDAcad$ ($Bill)	70	$32.14	$10.56	-.08	.29
GradUSRD$ ($Bill)	70	$250.19	$64.88	-.30	.29
GradUSIndOut ($Bill)	70	$160.10	$47.51	-.54	.29

* Skewness statistic is more than twice the standard error of skewness.

Table G2

Intercorrelations Among Raw Predictor Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Individual Level Predictors																							
1	GradDirectorResearchTime%	--																					
2	GradDirrectorTimeCenterAdmin%	-.50**	--																				
Program Level Predictors																							
3	GradStatus	-.18	.08	--																			
4	GradNumberSites	-.09	.08	.10	--																		
5	GradNumFundingCategories	-.18	.12	-.15	-.01	--																	
6	GradBudget($100K)	-.21	.09	.18	.21	.42**	--																
7	GradMemCount	-.16	.09	.19	.03	-.07	.15	--															
8	GradFaculty	-.19	.22	.09	.38**	.29*	.45**	.16	--														
9	GradAdmin	-.01	.11	-.40**	-.15	.43**	.11	.09	.10	--													
10	GradStudents	-.19	.07	.26*	.30*	.29*	.48**	.42**	.41**	.06	--												
11	GradUnderGrad	-.03	-.07	.13	-.16	.36**	.60**	.03	.13	.17	.36**	--											
Organizational Level Predictors																							
12	GradUnivRDExpend($Mill)	.08	.04	.14	.08	-.30*	-.09	.00	.01	-.04	.04	-.02	--										
13	GradUnivType	-.18	.21	-.06	-.18	.10	.04	.19	.11	.29*	.19	.19	016	--									
14	ResearchClass	-.10	-.06	.11	.19	-.06	.04	.14	.09	-.01	.23	.01	.581*	.28*	--								
15	GradInkind($100K)	.09	-.13	-.02	.13	-.01	.06	-.07	.04	.14	.02	-.02	001	-.17	.07	--							
16	GradOverheadDiscount%	.07	-.15	.23	.05	.08	.36**	.16	.22	-.03	.32*	.26*	008	.02	.16	-.05	--						
17	GradIndSupt%	.10	-.08	-.03	.02	.11	-.11	-.02	-.09	.00	-.09	-.01	-022	-.17	-.36**	-.13	-.11	--					
18	GradUnivFunding%	.03	.05	-.16	-.13	.27*	.05	-.17	-.09	.13	-.11	.00	-026	-.02	-.26*	-.06	-.24	.04	--				
Environmental Level Predictors																							
19	**GradUSGDP($Bill)**	-.15	-.06	.46**	.382**	-.27*	.05	-.15	0.10	-.42**	.12	-.04	.45**	-.15	.12	.25	.09	.02	-.22	--			
20	**GradUSRDAcad($Bill)**	-.12	-.08	.42**	.403**	-.30*	.00	-.15	.08	-.42**	.11	-.09	.46**	-.13	.12	.24	.08	.02	-.20	.99**	--		
21	**GradUSRD($Bill)**	-.14	-.07	.49**	.353**	-.26*	.07	-.14	.10	-.43**	.12	-.02	.45**	-.15	.11	.23	.11	.04	-.22	.99**	.98**	--	
22	GradUSIndOut($Bill)	-.15	-.07	.52**	.314**	-.24*	.10	-.15	.11	-.45**	.11	.01	.42**	-.16	.09	.22	.11	.05	-.22	.98**	.96**	.99**	--

*$p < .05$, **$p < .01$

Note: Dropped variables are in bold font.

Table G3

Descriptive Statistics for Raw Outcome Variables

				Skewness	
	N	*Mean*	*SD*	*Statistic*	*SE*
CurProjects	36	14.92	13.30	1.46*	.39
CurMembers	45	74.20	391.37	6.70*	.35
CurrentOrLastBudget($100k)	43	24.37	40.72	4.61*	.36
CurGradGrad	35	11.20	15.47	3.16*	.40
CurIP	39	3.51	5.07	2.01*	.38

* Skewness statistic is more than twice the standard error of skewness.

Table G4

Intercorrelations Among Raw Outcome Variables

		1	2	3	4	5
1	CurProjects	--				
2	CurMembers	.450**	--			
3	CurrentOrLastBudget($100K)	.43**	.89**	--		
4	CurGradGrad	.23	.16	.59**	--	
5	CurIP	.24	.01	.36*	.56**	--

*$p < .05$, **$p < .01$

Table G5

Descriptive Statistics for Recoded Outcome Variables

				Skewness	
	N	*M*	*SD*	*Statistic*	*SE*
CurProjects	36	14.92	13.30	1.46	.39
CurMembers	45	16.56	12.94	.99	.35
CurrentOrLastBudget($100K)	43	20.22	20.85	1.37	.36
CurGradGrad	35	10.40	12.18	2.23	.40
CurIP	39	3.28	4.43	1.66	.38

Table G6

Intercorrelations Among Recoded Outcome Variables

		1	2	3	4	5
1	CurProjects	--				
2	CurMembers	.45**	--			
3	CurrentOrLastBudget($100K)	.43**	.51**	--		
4	CurGradGrad	.21	.22	.58**	--	
5	CurIP	.25	.03	.33*	.43**	--

*$p < .05$, **$p < .01$

Table G7

Descriptive Statistics for Recoded Predictor Variables

	N	*M*	*SD*	*Skewness* *Statistic*	*SE*
Individual Level					
GradDirectorResearchTime%	68	32.46	18.83	.001	.291
GradDirrectorTimeCenterAdmin%	68	26.28	22.86	1.914	.291
Program Level					
GradNumberSites	68	1.57	0.90	1.841	.291
GradNumFundingCategories	69	3.61	1.29	.222	.289
GradBudget($100K)	69	10.01	9.54	1.620	.289
GradMemCount	69	13.04	10.68	1.254	.289
GradFaculty	68	9.59	6.65	.771	.291
GradAdmin	63	1.97	1.59	1.031	.302
GradStudents	68	13.44	11.26	1.322	.291
GradUnderGrad	64	3.72	5.30	2.718	.299
Organizational Level					
GradUnivRDExpend($Mill)	58	$242.03	$188.17	.820	.314
GradUnivType	70	2.09	.880	-.170	.287
CurResearchClass	69	4.41	.913	-2.103	.289
GradInkind($100K)	58	$.96	$1.77	2.520	.314
GradOverheadDiscount%	63	31.73	22.28	-.572	.302
GradIndSupt%	58	8.73	6.542	1.492	.314
GradUnivFunding%	69	8.36	11.87	1.639	.289
Environmental Level					
GradUSGDP ($Bill)	70	$9,698.44	$2,472.32	-.275	.287
GradUSRDAcad$ ($Bill)	70	$32.14	$10.56	-.085	.287
GradUSRD$ ($Bill)	70	$250.19	$64.88	-.297	.287
GradUSIndOut ($Bill)	70	$160.10	$47.51	-.540	.287

Table G8

Intercorrelations Among Recoded Predictor Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Individual Level Predictors																							
1	GradDirectorResearchTime%	--																					
2	GradDirrectorTimeCenterAdmin%	-.51**	--																				
Program Level Predictors																							
3	GradStatus	-.18	.09	--																			
4	GradNumberSites	-.09	.08	.10	--																		
5	GradNumFundingCategories	-.18	.12	-.15	-.01	--																	
6	GradBudget($100K)	-.23	.10	.19	.26*	.44**	--																
7	GradMemCount	-.22	.35**	.27*	.20	.11	.46**	--															
8	GradFaculty	-.17	.22	.16	.45**	.26*	.54**	.40**	--														
9	GradAdmin	-.01	.11	-.40**	-.15	.43**	.12	.19	.04	--													
10	GradStudents	-.19	.06	.26*	.30*	.29*	.55**	.63**	.47**	.06	--												
11	GradUnderGrad	-.02	-.09	.13	-.17	.38**	.53**	.25*	.13	.19	.42**	--											
Organizational Level Predictors																							
12	GradUnivRDExpend($Mill)	.08	.03	.14	.08	-.30*	-.09	.06	.04	-.04	.04	-.02	--										
13	GradUnivType	-.18	.20	-.06	-.18	.10	.01	.20	.08	.29*	.19	.19	.16	--									
14	ResearchClass	-.10	-.06	.11	.19	-.06	.06	.18	.08	-.01	.23	.02	.58**	.28*	--								
15	GradInkind($100K)	.07	-.13	-.12	.16	.05	.16	.03	.08	.20	.12	.04	.10	-.10	.12	--							
16	GradOverheadDiscount%	.07	-.17	.23	.05	.08	.37**	.23	.23	-.03	.32*	.27*	.08	.02	.16	-.02	--						
17	GradIndSupt%	.14	-.07	.02	.01	.06	-.13	-.01	-.10	-.01	-.10	-.01	-.21	-.15	-.37**	-.13	-.11	--					
18	GradUnivFunding%	.05	.08	-.20	-.19	.27*	-.04	-.25*	-.12	.17	-.15	-.03	-.28*	-.02	-.30*	-.08	-.30*	.06	--				
Environmental Level Predictors																							
19	**GradUSGDP($Bill)**	-.15	-.06	.46**	.38**	-.27*	.07	-.01	.13	-.42**	.12	-.03	.45**	-.15	.12	.24	.09	.01	-.26*	--			
20	**GradUSRDAcad($Bill)**	-.12	-.07	.42**	.40**	-.30*	.02	-.02	.11	-.42**	.11	-.08	.46**	-.13	.12	.22	.08	-.01	-.24*	.99**	--		
21	**GradUSRD($Bill)**	-.14	-.07	.49**	.35**	-.26*	.09	.01	.13	-.43**	.12	-.01	.45**	-.15	.11	.23	.11	.03	-.25*	.99**	.98**	--	
22	GradUSIndOut($Bill)	-.15	-.06	.52**	.31**	-.24*	.12	.01	.14	-.45**	.11	.03	.42**	-.16	.09	.22	.11	.04	-.25*	.98**	.96**	.99**	--

*$p < .05$, **$p < .01$

Note: Dropped variables are in bold font