# Research Center Sustainability and Survival: Case Studies of Fidelity, Reinvention and Leadership of Industry/University Cooperative Research Centers

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# Abstract

The Industry/University Cooperative Research Center (I/UCRC) program was designed to enhance the US's research, education and technology transfer infrastructure by promoting stronger technical and organizational ties between university and industry. Evaluation efforts undertaken during the I/UCRCs thirty-plus years of operation have provided persuasive and methodologically robust evidence that it has been achieving these objectives. However, like other federal S&T programs, little has been known about the extent to which the I/UCRC program achieved another important program objective – the establishment of long-term partnerships that were self-sustaining.

Based on a companion study (McGowen, 2010), we were able to demonstrate that that roughly two-thirds of all the I/UCRCs that were launched over the past thirty years were still operating. By almost any metric, this is an enviable record of success. Importantly, although these Centers are no longer supported by NSF they continue to have a large *indirect* effect on achieving program objectives including leveraging of government funding, student training, scientific achievement, technology transfer and commercialization. However, this primarily quantitative study, failed to shed much light on the factors that contributed to the long-term survival or failure of these Centers. Given this background, the overarching objective of the current study was to gain a better understanding of *why and how some Centers achieve sustainability while others do not.*

Building on archival data collected as part of the ongoing I/UCRC evaluation effort and new interviews with key informants involved in the transition from a government-funded program to self-sustainability, we developed a collection of case studies that attempted to highlight both the factors that influenced survival and the different post-NSF paths to Center sustainability that different Centers could take.

An ad hoc multiple case analysis of four I/UCRCs that failed either early or later in their program history (Chapter 2) highlighted several factors that contributed to a Center "unraveling" including: absence of key I/UCRC ingredients (e.g., doctoral level programs); poor or no transition planning; withdrawal of institutional support; problems of leadership aggravated by poor succession planning; and cascading effects of several of these factors.

Four case studies highlight how, with effective leadership, Centers can not only navigate these and other challenges to sustainability but in some cases reinvent the I/UCRC model so it was better suited to unique local needs and circumstances. Chapter 3, *Reinventing the I/UCRC Model*, tells the story of the Center for University of Massachusetts/Industry Research on Polymers (CUMIRP) and how it developed a hybrid center model. Chapter 4, *Success Through Fidelity to the I/UCRC Model*, tells the story of how the Advanced Steel Processing & Products Research Center (ASPPRC) at Colorado School of Mines used the core I/UCRC model to meet the challenges of an industrial sector that was both globalizing and shrinking. Chapter 5, *Transformation of a Small University I/UCRC*, tells the story of how the Center for Advanced Communication at Villanova University (CAC) reinvigorated a declining Center and helped build a strong graduate program by moving to a more contract research mode of operation. Finally, Chapter 6, *I/UCRC as Capacity Building Strategy for*

*State-based Economic Development*, tells the story of Ohio State's Center for Welding Research and how very early in its development it morphed into the not-for-profit Edison Welding Institute (EWI), one of the world's largest and most respected manufacturing-focused research institutes.

Taken together we hope these cases and the lessons that they convey will help both policy makers and local center leaders navigate a successful path to partnership-based program sustainability.

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# About the I/UCRC Program

The Industry University Cooperative Research Center (I/UCRC) program began as an experimental program in the early 1970s and was formally launched during 1979-80. It is one of several partnership-based programs supported by the Industrial Innovation and Partnerships (IIP) Program in NSF's Engineering Directorate.[1] I/UCRCs are university-based industrial consortia; member firms provide financial support, help steer the research agenda and share all results. The program has initiated more than 140 Centers. I/UCRCs were designed to serve as institutional structures to promote and sustain scientific cooperation between industry and universities. It has been notably successful in achieving this objective for more than three decades and is believed to be the longest operating partnership-based program sponsored by NSF. Also notable is the extent to which this 30-year history has been marked by the ongoing collection of process and outcome data from the program participants, university and industry. No other federal R&D program has been so guided by data and feedback. More detailed description of program goals and objectives can be found in its current announcement[2] and recent DVD.[3] A management guide is also available.[4]

## *Current Status*

For FY 2010-11 the I/UCRC program had a budget of approximately $15 million (with about two-thirds of funding coming from the Engineering Directorate and the balance from the Computer and Information Science and Engineering Directorate within NSF). This funding is allocated to 56 Centers with sites at over 160 universities. The disparity between Centers and sites is a function of the fact that most I/UCRCS have participation by several universities. I/UCRCs have been launched in virtually every state in the country. Centers receive 5-year awards that can be renewed for a second five year period.[5] The average multi-site I/UCRC receives approximately $220,000/year from NSF; the average university site within an I/UCRC receives approximately $75,000/year. Centers address a variety of topics, including alternative energy (e.g., biofuels and photovoltaics), advanced materials and manufacturing, energy and environment, advanced electronics, homeland security (identification technology) and many others. A complete list of I/UCRCs by technological thrust can be found at http://www.nsf.gov/eng/iip/iucrc/directory/index.jsp.

Firms (large and small), government agencies and non-profit entities support I/UCRCs by paying an annual membership fee to support Center research and operation. Approximately 700 organizations hold 1000 memberships (a significant number of organizations are members of multiple I/UCRCs). Large firms hold roughly half of all memberships. The percentage of memberships held by small firms has doubled over the past

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[1] Program website found at: http://www.nsf.gov/eng/iip/iucrc/

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

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

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

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

four years and stands at 28 percent. Government agencies (including many defense labs) and non-profit organizations hold the balance of the memberships. Most I/UCRC funding provides support for faculty and students to conduct Center research. For the most recent fiscal year, I/UCRCs supported about 900 faculty, 1500 graduate students, and 350 undergraduates.

## *Program Evaluation*

The evaluation strategy has been multi-faceted and includes a strong "improvement-oriented" focus designed to assist local Center managers.[6] Formal program evaluation has been built into Center operations since the program was launched by providing support for on-site evaluators who follow a standardized evaluation protocol.[7] In addition to traditional monitoring data on issues like personnel and budgets, data on program processes, outcomes and impacts are obtained on an annual basis via direct observation and industry and faculty questionnaires. The I/UCRC Evaluation Team based at North Carolina State University, is responsible for supporting this activity and providing NSF with program-wide analyses and summaries. In addition, periodic targeted studies address specific evaluation issues in more detail.

This report summarizes the findings of one of the evaluation project's targeted studies: an attempt to assess the extent to which I/UCRCs achieve one of their explicitly stated objectives -- sustaining themselves after their NSF I/UCRC funding ends. The project had two main objectives: *to assess the extent to which I/UCRCs achieve sustainability (in terms of structures, activities and outcomes); and to assess why and how some Centers achieve sustainability and others do not.*

[6]Gray, D.O. (2008). Making team science better: Applying improvement-oriented evaluation principles to the evaluation of cooperative research centers. New Directions for Evaluation, 118, 73-87.
[7] The I/UCRC Evaluation Project website can be found at: http://www.ncsu.edu/iucrc/

# Acknowledgement

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# Chapter 1: I/UCRC Program and the Path to Self-Sufficiency

**Denis Gray, Lindsey McGowen, and Louis Tornatzky**

## Introduction

The Industry/University Cooperative Research (I/UCRC) program was designed to enhance the US's research, education and technology transfer infrastructure by promoting stronger technical and organizational ties between university and industry. These strengthened ties are supposed to result in improved research, technology transfer/commercialization and strengthened human capital – particularly in the form of better trained students. It is also supposed to result in *long term* partnerships between industry and universities that are *self-sufficient*. Evaluation efforts undertaken during the I/UCRCs thirty plus years of operation have provided persuasive and methodologically robust evidence that it has been achieving its direct research, enhanced research, education and technology transfer objectives. However, little was known about: (1) the extent to which I/UCRCs result in long term and sustained partnerships between university and industry participants: and (2) what factors contribute to this outcome.

In a previous report, we summarized our findings related to the sustainability of I/UCRCs (McGowen, 2010). Based on this research, McGowen (2010) discovered that roughly two-thirds of all the I/UCRCs that were launched over the past thirty years were still operating. By almost any metric, this is an enviable record of success. Importantly, although these Centers are no longer supported by NSF they continue to have a large *indirect* effect on achieving program objectives including leveraging of government funding, student training, scientific achievement, technology transfer and commercialization.

However, McGowen's (2010) primarily quantitative analyses were less instructive about why some Centers continue to operate thirty years after they were launched and twenty years after NSF support ceased, while other Centers never complete their original award or cease operations shortly after NSF support ends. Given this background, the overarching objective of the current study was to help gain a better understanding of the path to center sustainability. We attempted to achieve this goal by conducting and analyzing a series of case studies on I/UCRCs that either ceased or continued their activities after NSF I/UCRC funding was concluded.

## I/UCRC Program Background and the Imperative for Self-Sustainability

I/UCRCs are university-based, government-supported, industrial research consortia. The research performed in these Centers tends to be strategic or pre-proprietary fundamental research and is carried out primarily by faculty and graduate students. I/UCRCs follow a relatively standardized set of policies and procedures, including: members pay an annual fee (usually between $30 to 50K/year); members get equal access to and ownership of all research and intellectual property; findings, know-how and technology are transmitted through a variety of means including periodic reports and semi-annual meetings; and members get one vote on the Center's Industrial Advisory Board (IAB).

The present day I/UCRC program is an elaboration of a model initially developed as part of the Experimental R&D Incentives Program (ERDIP) initiated in 1972 at the request of President Nixon. It is the only surviving element of that program (Colton, 1982). From a programmatic standpoint the I/UCRC program can be considered to have evolved over three primary stages: an experimental stage, an implementation stage, and an operational stage.

During its *experimental stage* from 1972 to 1977, NSF funded and evaluated three different models of cooperative research: an R&D extension service to the furniture industry with an emphasis on relatively low technology operational problems; a third party brokerage role between industries and universities; and the precursor to the I/UCRC model, a university-based industrial consortium, the Polymer Processing Center (PPC) at the Massachusetts Institute of Technology (MIT) (National Science Foundation, 1982; Prager and Omenn, 1980). Based on an independent evaluation, only the MIT project demonstrated the ability to attract sustained industrial support and proved to be a profitable approach both scientifically and administratively (Burger, 1979; Burger, 1982). It became the prototype for future NSF industry-university centers.

In spite of the success of the original MIT-based Center, there was no assurance that this organizational prototype could be replicated. As Baer (1980) indicated, "A principal question is estimating how many successful university-based centers can be created on the MIT model. Professor Suh's success at MIT may be so unique that few individuals and institutions can emulate it without descending into research mediocrity and administrative nightmares" (pg.19-20).

Baer’s concerns about the ability to replicate the “MIT model” were quickly addressed during the I/UCRC’s *implementation stage*. Beginning around 1980, the Division of Industrial Science and Technological Innovation within NSF began to systematically assist in building Centers, based on the “MIT model” (Schwarzkopf, 1983). During this period, the vast majority of Center planning grants resulted in operational Centers. By 1985, NSF had established twenty-nine Centers. Importantly, the expectation of sustainability was clear even for the earliest Centers. I/UCRC awardees were told they were expected to build a *permanent* organization for ongoing collaboration between industry and university. To this end NSF provided a one-year planning grant and a five-year operational grant of about $600,000 (annual NSF funding gradually declined during that period) with the expectation that industrial members and others will provide sustaining support for the Center (Gray, Johnson, & Gidley, 1986). It might be noted here that the I/UCRC launch was made via a NSF Division that was entirely focused on “industrial” programs and where there was wide sharing and tuning of best practices.[8] It was in this organizational context that the I/UCRC model was refined based on the successes and challenges identified in implementing those early Centers.

[8] As per Dr. L. Tornatzky, who ran the Innovation Processes Research program at the time.

Around 1987 the I/UCRCs *operational stage* began when the funding structure and expectations for center sustainability used in the current I/UCRC program were formalized. This structure continued to call for Centers to become self-sufficient but provided I/UCRCs with an opportunity to receive a second five-year award (10-years of funding) but at a reduced level. This decision appears to have been based on a recognition, manifested in the funding structure of the Engineering Research Centers program, that Centers needed more than five years to establish a stable technical, administrative and financial base.

## *Sustainability Expectation for I/UCRCs*

While much has changed in the I/UCRC program in the thirty plus years since the program was launched, its goals have remained relatively consistent – focused on enhancing the US's research, education and technology transfer by promoting stronger ties between university and industry. Specific goals highlighted on the program's current website (http://www.nsf.gov/eng/iip/iucrc/) include:

- Contributing to the nation's research infrastructure base
- Promoting research programs of mutual interest to industry, university and government
- Expanding the innovation capacity of our nation's competitive workforce through partnerships between industries and universities
- Enhancing the intellectual capacity of the engineering workforce through the integration of high quality interdisciplinary research and education
- Leveraging NSF funds with industry to support graduate students performing high quality industrially relevant research
- Promoting the direct transfer of university developed ideas, research results, and technology to US industry

While it is beyond the scope of this report, there is considerable evaluation evidence that I/UCRCs are in fact achieving these objectives. Readers are referred to the evaluation project website (http://www.ncsu.edu/iucrc/), specifically the "Reports, Presentations and Publication" and "Current and Recent Research" tabs, to access documentation and reports related to these findings.

Importantly, the program solicitation also makes explicit reference to the expectation that the program will lead to *long term partnerships between industry and universities that are self-sufficient*. That is, NSF expects that the I/UCRCs it launches will continue achieving its research, education and technology transfer objectives even after they have completed NSF funding. The NSF I/UCRC website *(http://www.nsf.gov/eng/iip/iucrc/)* describes this expectation as follows:

> *NSF's 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 gradually to become fully supported by university, industry, state, and/or other non-NSF sponsors. Each I/UCRC is expected to maintain at least*

*$300,000 of industrial support through membership fees, at least six industrial members, and a plan to work toward self-sufficiency from NSF.*

This expectation has significant implications for the evaluation of the I/UCRC program because it implies that the program could or should have both *direct* and *indirect* effects. That is, in addition to the direct effects a Center would be expected to have during the roughly 10-year period NSF provides operational support, a sustained Center could also have *indirect* effects by continuing to deliver various benefits and impacts years and perhaps decades after NSF funding has lapsed. Understanding whether and how to encourage sustainability and the indirect effects that might flow from it, could have huge payoffs for the I/UCRC program's bottom line.

In the next section, we review the modest literature available on program sustainability of government funded programs and specifically on cooperative research centers including I/UCRCs. This section will be followed by a brief description of the first phase of our research.

## Research on Sustainability of Government Programs

Not surprisingly, a concern with program sustainability is not unique to cooperative research centers. In fact, virtually every type of government program, from health care, to education, social service and research include time-limited initiatives, sometimes called demonstration projects, along with an expectation that the recipient of funding become self-sufficient/sustainable.

In spite of the pervasiveness of this phenomenon there is surprisingly little theoretical and/or empirical literature on program sustainability. In addition, much of the literature that does exist is difficult to find, in part, because of the differences in terminology and definitions. For instance, relevant studies may use any of the following terms: continuation, durability, incorporation, institutionalization, level of use, maintenance, routinization, stabilization, sustainability, and sustained use (Johnson, Hays, Center, & Daley, 2004).[9]

Interestingly, the theoretical foundation for much of this literature actually comes from the innovation literature's focus on adoption of organizational innovations (Rogers, 2003; Tornatzky & Fleischer, 1990; Kanter; 1988). This literature attempts to understand how factors at various levels of analysis, including the social, organizational, group and individual level, explain not only the adoption of organizational innovations but also, consistent with a focus on program sustainability, their continued implementation and routinization. Another central issue in this literature is the extent and desirability of program modification (reinvention) or continuity (fidelity) (Mayer and Davidson, 2000). This may

[9] 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).

have particular relevance for I/UCRCs, since considerable time and effort was invested in producing high fidelity program replicates. This raises the question of what happens when a Center is out of the purview of the NSF.

According to a comprehensive literature review on sustainability by McGowen (2010) a great deal of the empirical literature comes from the nonprofit sector, especially the public health field. 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. Undoubtedly, the most significant source in this literature is a comprehensive review of 19 empirical studies on sustainability of public health programs conducted by Scherier (2005).

Some relevant findings of this review include:

1. The most common measure of sustainability used was continuation of program activities, with 18 of the 19 studies using this measure of sustainability.
2. Although fourteen of seventeen relevant studies reported that 60% or more of the sites showed some sustainability" various factors make it difficult to interpret the validity of these reports (Scheirer, 2005, p. 335). There were different rates of sustainability reflected in different measures. For instance, some studies examined sustainability shortly after separation from the host program while other examined sustainability after many years.
3. Programs can undergo significant changes over time, in fact some programs lose fidelity to the innovative model on which they were based.
4. Continuing to operate is not synonymous with continuing to provide benefits to program stakeholders. Some studies reported a high proportion of sites continuing to conduct some program activities, but a lower rate of continued benefits to stakeholders. There is reason to believe fidelity and benefits are related.
5. 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.

## *Sustainability of Research Centers*

While the literature reviewed thus far sheds some light on program sustainability, it tells us little about the sustainability of cooperative R&D organizations. The sustainability literature primarily focuses on the issues faced by traditional public service organizations. However, the cooperative research-based I/UCRCs that are the focus of this study, face unique challenges including producing value when the outcome of the research activity is uncertain, meeting the requirements of many stakeholders such as industry members, university administration, faculty, students, government partners, and the NSF.

After an exhaustive review of the literature, only two studies of CRC sustainability could be found and both focused on 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. The first study by Ailes, Roessner, and Coward (2000) was conducted around the time ERCs started from 1985 to 1990 were graduating (i.e. Centers that were no longer receiving NSF support). The Ailes et al. (2000) study 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. The second study by Mujumdar (2005) examined the same cohort but looked at them five years after graduation. This study was an internal NSF effort and although no report was prepared, results were disseminated as a PowerPoint presentation.

Unfortunately, because of methodological shortcomings neither study provides definitive information about CRC sustainability. As suggested above, the Ailes et al. (2000) study collected data as ERCs *were about to graduate*. As a consequence, it examines expected rather than actual sustainability. In contrast, the Mujumdar (2005) study attempted to collect data five years after graduation. However, data was only provided by eight of the sixteen ERCs. Of the eight non-responding Centers, one Center had closed, one referred researchers to their website, and six others did not respond. In addition, no statistical analysis was conducted in either study considering the small sample size (n = 16; n=8) so conclusions are based on inference and judgment. Nonetheless, these reports do provide some worthwhile insights.

Key findings include:

1. Obtaining data from graduated Centers is very challenging. As suggested above, in spite of contacting all Centers in the sampling frame several times Mujumdar (2005) was only able to get data from half of the target sample even though only five years had elapsed. Obviously, this problem would be magnified for the longer follow up times found in the I/UCRC program (e.g., up to 20 years).
2. While an accurate estimate of ERC sustainability was impossible to calculate, Some ERCs do achieve a level of sustainability. According to Mujumdar (2005) all eight of the Centers he was able to contact five-years after graduation were still operating at some level. However, one would have to assume that the success rate would be considerably lower among the eight non-responding Centers.
3. The issue of fidelity, the extent to which ERCs maintained the Center/program model or alternatively changed or completely dropped important features was highly relevant for ERCs. According to these studies some Centers lost research coherence and the multidisciplinary focus derived from ERC strategic planning. Some became much more industry focused. Some Centers dropped their educational component, others lost much of their fundamental research focus. Others merged with, absorbed or were absorbed by other initiatives. Some faculty

involved in ERCs may have moved on to create a new Center. Which of these cases represent program sustainability is difficult to assess.

4. 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.
5. With respect to benefits, the two studies indicate sustained Centers obtained new funding and continued to conduct research, and train students, etc.[10] However, particularly given the degree of change many ERCs undergo, it is difficult to evaluate how much impact they are having compared to when they were funded by NSF.
6. Ailes et al. (2000) identified several factors they believed to impact ERC sustainability: *Infrastructure* – Centers that had dedicated space and/or equipment were better able to persist under the ERC model; *Transition Planning* – Centers that had a sustainability plan were better able to make a successful transition; *Center Management* – Centers that made positive changes in Center leadership, were better able to maintain the model; *Faculty Involvement* – Centers that developed a sense of ownership among faculty were more likely to make a successful transition; *Institutional Factors* – Centers that were provided some financial protection by their home universities made a smooth transition; *Nature of the Research Area* – Centers engaged in research that is still "hot", were better able to attract the industry sponsorship that facilitates a successful transition; *Character of Industrial Participation* – Centers who involved industrial members in transition planning, etc. were better able to persist under the ERC model.

## *Summary*

There is surprisingly little empirical research on the sustainability of time-limited government programs and even less on the sustainability of the more complex, multifaceted, boundary-spanning CRCs. As suggested earlier, sustainability is a complex phenomenon having to do with continued activities, structures, and benefits. On balance, this literature suggests that some level of sustainability is achieved by programs/centers but that the sustainability rate can vary widely, from below 20% to as high as 80%, based on a variety of factors. Evidence suggests that centers that are sustained can undergo significant changes and that these changes may affect the indirect benefits derived. In short, we know relatively little about the ability and the path that CRCs should take to achieve sustainability and to continue to deliver benefits to program stakeholders.

# McGowen's (2010) I/UCRC Sustainability Findings

The first phase of our research effort involved assessing the extent to which I/UCRCs achieve sustainability and which factors predict a successful outcome. Addressing this

[10] 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).

objective involved conducting follow-up interviews with all of the 70 I/UCRCs that had completed their NSF funding up to that time. The interviews examined the Center's status (operating or not operating), level of activities and outcomes and extent to which the Centers maintained various I/UCRC structures and protocols.

The results of this study indicated that I/UCRCs achieve a very high level of sustainability (McGowen, 2010). More specifically, over seventy-five percent of "graduated" Centers (Centers that were no longer receiving NSF support) were still in operation one year after their NSF funding lapsed (the follow-up period many sustainability studies use; Scheirer & Dearing, 2011), while roughly two-thirds of Centers were still operating at the time the study was conducted. A number of these Centers had been operating for nearly thirty years, meaning they had been self-sufficient for twenty to twenty-five years! Importantly, results also indicated that the sustained Centers were not significantly different from currently funded Centers on a wide range of activities (e.g., number of projects), structural capacity (e.g., members and income) and outcomes (e.g., students graduated, IP). These results indicated that the activities of sustained I/UCRCs produced indirect outcomes and impacts that are roughly equivalent to currently funded Centers. This meant that in 2010 NSF's investment in the I/UCRC program produced $68 million in leveraged funding, roughly double what had been reported based solely on direct effects (McGowen, 2010).

Unfortunately, the predictive analyses were less helpful in understanding why some Centers were successful or not successful in achieving sustainability. Current status (sustained or not) was predicted by whether a Center finished or did not finish their initial NSF award, their budget during their graduation year and the amount of funding US firms were spending on research during their graduation year. These variables only explained one-half of the variance in this outcome. A Center's current budget was only predicted by the number of members they had upon graduation and this only explained fifteen percent of the variance.

Interestingly, McGowen's (2010) interviews indicated successful Centers showed a fair amount of variability in their fidelity to the I/UCRC model. While many looked much like they did when they were funded by the I/UCRC program, some had dropped certain core I/UCRC features and/or added new features while others had changed their research focus or became totally involved in contract research model. However, our quantitative measures of these features (present vs. not present) did not help explain why some Centers were sustained or not.

## ***Summary***

Most federally-funded programs are premised on time-limited funding and an expectation that they are sustained after government funding lapses, and very little monetary or managerial attention is paid to what happens "after the grant." This is the case for the NSF I/UCRC program. However, little research has been devoted to assessing the extent to which these objectives are actually achieved and what factors contribute to a successful outcome. Our first objective was to determine the extent to which I/UCRCs become self-sufficient and sustain their activities and outcomes. Based on extensive interviews with directors of graduated I/UCRCs, McGowen (2010) was able to demonstrate that a very high percentage of I/UCRCs become self-sustaining (about 65%) and a surprising percentage continue to operate twenty to twenty-five years after their NSF funding lapsed. However, our quantitative analyses do not offer much insight into why some Centers continue to grow and prosper while others peter out or simply collapse shortly after they graduate. As a consequence, we cannot offer much help or guidance to NSF program managers or center directors about how to optimize their chance to achieve sustainability based solely on these quantitative results.

## Understanding the Path to Sustainability

Given the modest and somewhat obvious nature of the findings related to our second project objective, *why and how to do Centers achieve sustainability and others do not*, based on our quantitative analyses, we decided pursue this issue further but to adopt a more exploratory qualitative research strategy. Qualitative methods are much better suited for gaining an insight into highly complex processes that might play out over time and across organizational boundaries, particularly about emergent phenomena like the sustainability of I/UCRCs that lack a strong theoretical and empirical foundation.

As described in the remainder of this report, our strategy was two-fold. Initially, we focused on why some Centers fail and conducted an ad hoc multiple case analysis that compared one successfully sustained I/UCRC with four I/UCRCs that “unraveled” either early or later in their program history. These cases were produced by members of our team who served as on-site evaluators for these respective Centers and exploited their archival records and first-hand notes about the factors that appeared to either trigger or set a path toward a Center closing. These analyses were reported in a published article in *Industry and Higher Education* and this paper is reproduced here as Chapter 2, *When Triple Helix Unravels: A Multi-Case Analysis of Failures in Industry University Cooperative Research Centers* (Gray, Sundstrom, Tornatzky, & McGowen, 2011).

Our second approach was to focus our analytic attention on a small sample of sustained I/UCRCs and conduct in-depth cases studies of each. The cases were selected based on three primary criteria: the Centers exhibited a high level of success on various sustained activities, structural and outcome indicators; based on information we already possessed, they appeared likely to exhibit a relatively diverse set of sustainability strategies and organizational end-states; and Center informants were willing to commit the time necessary for extended interviews and feedback on draft cases. Based on these criteria, ten Centers were selected for further screening, one was excluded due to evidence from phase one of a reluctance of stakeholders to participate in our interviews and four were selected for in depth interview. The resulting cases are based on both archival data from our I/UCRC data base and the information provided by our interviewees.

Chapter 3 *Reinventing the I/UCRC Model* tells the story of the Center for University of Massachusetts/Industry Research on Polymers (CUMIRP). CUMIRP was beginning to decline in terms of membership, overall financial support and industrial commitment as it approached the end of its I/UCRC grant. It chose to reinvent (but not reject) the I/UCRC model by creating a set of mini-consortia under the umbrella of CUMIRP, allowing firms to join or not join specific clusters based on their particular interest. Members responded positively to these changes, and eventually the Center prospered financially and technically. More recently, the “CUMIRP model” has been adopted on a broader basis across the whole university. Chapter 4, *Success Through Fidelity to the I/UCRC Model*, tells the story of the Advanced Steel Processing and Products Research Center at Colorado School of Mines (ASPPRC). ASPPRC began their transition to self-sustainability at a time when the steel industry was going through a major restructuring that led to a much more globalized industry. With strong and continuous leadership, ASPPRC was able to weather this challenging period, continue to deliver technical value and eventually expand its operations all while remaining faithful to the prototypical I/UCRC mode of operation.

Chapter 5, *Transformation of a Small University I/UCRC*, tells the story of the Center for Advanced Communication at Villanova University (CAC). Like CUMIRP, CAC was also experiencing a decline in membership, financial support and industrial commitment as it approached graduation. After the passing of the founding Center Director, his successor was able build support for the Center within the university while converting it to more contractual one-on-one research operation. This strategy was very successful for CAC which continues to attract several million dollars of research support each year, works closely with the local economic development agencies and serves as a highly respected training lab within the university. Finally, Chapter 6, *I/UCRC as Capacity Building Strategy for State-based Economic Development*, tells the story of Ohio State’s Center for Welding Research and how very early in its development it morphed into the not-for-profit Edison Welding Institute (EWI). Although EWI is no longer directly affiliated with Ohio State University and does not follow a consortial model, it has evolved into one of the world’s pre-eminent welding research institutes, conducting approximately $25 million of research each year while contributing significantly to the economic vitality of the mid-west region and the US more broadly. Interestingly, EWI’s university connections are coming full circle since it currently provides membership support to three I/UCRCs housed at Ohio State University.

While we believe these cases will be instructive to policy makers and program managers who are interested in understanding how the obstacles that must be overcome to achieve sustainability, we hope they will be particularly valuable for center directors who are personally responsible for attempting to navigate the path to Center sustainability .

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# Chapter 2: When Triple Helix unravels: A multi-case analysis of failures in Industry–University Cooperative Research Centers[11]

**Denis Gray, Eric Sundstrom, Louis Tornatzky, and Lindsey McGowen**

## Introduction

Government-led industry–university cooperative – 'Triple Helix' – research organizations (Etzkowitz and Leydesdorff, 1997) continue to spread (Etzkowitz, 2008). This trend has been particularly true for cooperative research centers (CRCs) – organized units or organizations that perform research and that also have an explicit mission to promote cross sector collaboration, knowledge and technology transfer and ultimately innovation (Boardman and Gray, 2010). Cohen et al. (1994) identified over 1,200 such centers in the USA in the late 1980s. While a more recent census is lacking, it is safe to assume a larger number of the 13,000 university-based or non-profit research centers listed in the Research Centers and Services Directory (2009) meet the definition of a CRC. Expansions of programs to support such centers have recently been announced in Australia (Australia MIISR, 2009), Finland (Finland MTI, 2008) and throughout the EU (Government Monitor, 2009) and elsewhere in the world.

Public policy and related interest in these vehicles for promoting technological innovation and ultimately social and economic benefits have helped stimulate a relatively large, if uneven, body of social science research. According to a review of the evaluation literature on CRCs in the USA by Gray (2000), this literature can be grouped into at least three categories: *ex ante* evaluations that focus on factors used to determine whether CRC programs and/or individual centers should be funded; interim evaluations that involve data collection while the research center is operating and focus on the effectiveness of CRC structure and processes; and evaluations of outcomes that examine the proximal and/or distal outcomes and impacts of centers. Not surprisingly, some evaluations use multi-level evaluation (i.e. Gray and Sundstrom, 2009) for continuous improvement and learning (Gray, 2008). A collection of papers reflecting all of these foci can be found in a recent special issue of the Journal of Technology Transfer (Gray and Boardman, 2010).

Unfortunately, from a practitioner's standpoint, most of these studies have been conducted at the program level of analysis and provide little or no guidance on the factors that make individual centers successful. In general, this need has been met by a modest case-based literature describing 'best practices'. In these analyses, a series of cases highlights strategies and practices that have helped the centers produce valuable outcomes and beneficial results. Examples include Tornatzky *et al*.'s (2002) university-level cases presented in Innovation U, Roessner and colleagues' centre-level examination of the Georgia Tech Packaging Research Center and subsequent analysis of several Engineering Research

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Centers (Roessner et al., 2004; Roessner, 2010), and Scott's project-level *Compendia of Technology Breakthroughs* (Scott, 2007). While useful, what all these studies have in common is an exclusive focus on successful universities, centers and projects.

This strategy is limited, for a number of reasons. First, as the case study literature suggests (for example, Yin, 2002; Ruegg and Feller, 2003), one can have much greater confidence in causal conclusions (for example, internal validity) with a multiple case analysis that includes cases with varying rather than uniform levels of performance. In addition, considerable evidence suggests that valuable and unique lessons can be learned from failure. For instance, Coelho and McClure (2005) argue that, "recognizing failure is essential to success because it implies that core competencies have been identified" (p 2). In addition, Petroski (1994) suggests that failures in our increasingly complex socio-technical systems lie hidden in the interdependencies of various system components and can only be detected when systems actually fail. Similar arguments come from analyses of both personal (Shepherd, 2009) and team failures (Kayes, 2004).

Given these circumstances, it can be instructive to examine the circumstances and factors that contributed to the failure of CRCs. To this end, we present five mini-case studies from the US National Science Foundation (NSF) Industry/University Cooperative Research Centers (I/UCRC) Program. Four of the cases represent failures: Centers that closed, either shortly after opening or after sustained periods of operation. By way of contrast, we open with one brief case that demonstrates sustained operation and continued success.

Our goals are to identify: (1) *Likely factors* in the I/UCRCs and their environments that contributed to the cases of failure; (2) *Common themes* in I/UCRC failures; and (3) *Points of learning* for Triple Helix.

## NSF I/UCRC Program

The I/UCRC Program is one of the longest running Triple Helix-based center programs supported by the National Science Foundation. Its key features have been highlighted elsewhere:

> *I/UCRCs are university-based, industrial research consortia. The research performed in the Centers tends to be strategic or pre-proprietary fundamental research and is carried out primarily by faculty and graduate students. I/UCRCs follow a relatively standardized set of policies and procedures; members pay an annual fee (usually between $30,000 and $50,000 per year), and they get equal access to, and ownership of, all research and intellectual property; findings, know-how and technology are transmitted through a variety of means, including periodic reports and semi-annual meetings; and members get one vote on the Center's Industrial Advisory Board (IAB). (Gray, 2008, p. 81)*

The I/UCRC Program in 2011 supported about 54 Centers that involved over 150 universities,  730 firms, over 900 faculty scientists, more than 1,500 graduate students and

360 undergraduate students (Gray et al., 2012). I/UCRCs tend to be diverse in terms of annual budget ($200,000 to $7 million), number of research personnel (5 to 50) and number of industry members (8 to 90). These Centers also represent diverse areas of technology: manufacturing, nano-and micro technology, chemical processing, biotechnology and advanced electronics, to name but a few. Importantly, because of their consortia format all research and IP is shared equally by all members.

At the program-level of analysis, the I/UCRC Program has had an enviable record of success. Program-wide statistics indicate firms and faculty are very satisfied with their partnership, faculty continue to publish in high quality journals, students earn advanced degrees and develop skills that are in high demand, firms report a variety of direct and indirect benefits and Center research frequently results in commercialized technologies (Gray et al., 2012). Not surprisingly, the picture at the Center-level is not as uniformly rosy. This is consistent with other studies on program sustainability which have found that anywhere from 20% to 80% of programs are able to survive a funding transition (Scheirer, 2005). In fact, a recent study by McGowen (2010) has revealed that 12 percent of I/UCRCs leave the program before the end of their first five-year award and another 26 per cent do not complete a full ten years of funding. While a few Centers leave the program voluntarily to pursue other funding opportunities, we estimate that nearly one-third of all launched Centers ceased operation prematurely because they failed to satisfy the needs and expectations of one or more of the stakeholder groups involved in their Triple Helix partnership. The literature on program sustainability suggests that programs that survived in the long run are more likely to have completed their grants than are those that do not survive (Goodman & Steckler, 1989; Scheirer, 1990). However, what else can the research literature tell us about the factors that contribute to the failure of these Centers?

A small but growing body of literature focuses on what happens to programs in the long term, after their initial funding ends. This concept of program sustainability has been researched most heavily in the public health field (Scheirer, 2005). However, there has been very little research on the sustainability of science and technology Triple Helix based programs.

The exception has been two studies on the NSF Engineering Research Centers (Ailes et al., 2000; Mujumdar, 2005). These two studies are complementary 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 those centers several years after the grant ended. However, these studies were methodologically limited in terms of timing of data collection, attrition, sample size, and a lack of any inferential statistics. Nevertheless, they did identify the importance of some factors that may predict long term program survival. In particular, Ailes et al. (2000) discuss the importance of center management, adequate infrastructure, transition planning, faculty involvement, institutional support, the research area and industrial participation. Unfortunately, there have been no empirical studies on what predicts whether Triple Helix based programs will survive in the long term. However, many of the conclusions drawn by Ailes et al. (2000) and Mujumdar (2005) are supported by the wider literature on program sustainability. Scheirer (2005) conducted a meta-analysis of empirical program sustainability studies and identified the ‘Big 5’ predictors of program sustainability: program adaptability, the presence of a program champion and strong leadership, a fit with the host and stakeholder organizations, benefits to stakeholders, and support from the larger environment. The case studies described below will examine the importance of these and other factors for the long term success of Triple Helix based programs and how their absence can lead to program demise.

## Methodology

The I/UCRC Program has adopted a customer-driven, decentralized evaluation approach that involves an on-site evaluator and observational and survey-feedback methodologies. The linchpin of the I/UCRC evaluation system is the on-site, local evaluator. This individual is responsible for implementing a standardized assessment protocol on an annual basis, including collecting qualitative data via observation and interviews and quantitative data via the 'process/outcome' questionnaire (Gray, 2008). A more detailed description of the evaluation effort and results can be found at: www.ncsu.edu/iucrc.

The cases described below were prepared using annual case reports prepared by the on-site evaluator, archival records and interviews with center directors. The first case highlights a Center that operated successfully with NSF funding and continued to prosper after NSF funding ended. The remaining four cases focus on I/UCRCs that successfully launched, operated at least a few years with NSF funding, then failed. Organizational and operational information on the cases is summarized in Table 1.

Table 1

*Characteristics of Formerly Funded I/UCRCs: Centers A, B, C, P (Failures), and Z (Success)*

| | Center A | Center B | Center C | Center P | Center Z |
|---|---|---|---|---|---|
| Year Founded | 1981 | 1985 | 1986 | 1996 | 1984 |
| Years Operating | 3 | 4 | 20 | 11 | 27 |
| Years Sustained | 0 | 0 | 0 | 1 | 13 |
| N of Sites | 3 | 3 | 2 | 3 | 1 |
| Starting N of Members | 7 | 5 | 7 | 19 | 7 |
| Ending N of Members | 2 | 2 | 11 | 20 | 26 |
| Ending Budget | $200K | $320K | $735K | $1.7M | $1.8M |

## Sustained Center Success: Center Z

A single-university I/UCRC since its founding in 1984, Center Z continues as a scientifically robust, organizationally stable and industry-responsive Center today, in its 27th year of operation.

## *Development and Growth*

Foundations for Center Z developed years before its launch, through collaboration between Professor K and Professor M, the initial Center Director and eventual successor respectively. Both were endowed professors in advanced materials at the host institution, with decades of working together on research projects and day-to-day curricular and academic matters. The co-founders cooperated in leading Center Z, which expanded as industrial organizations and newly hired faculty scientists joined. When the original Director retired, the host University supported the Center by making new hires in the same technical area. The host university also provided continued fiscal support for the Center: for example, the university supported laboratory expansion and renovation.

Center Z followed the NSF guidelines for an I/UCRC, by developing and implementing decision-making processes for selecting, managing, and funding its industry–university projects. As described in an early analysis by Yin (1981), the Center developed regular practices by addressing one-time problem-solving *passages* or transitions, with the solution replicated routinely through subsequent *cycles* of activity. For example, the Center developed and then replicated annually its cycle of research agenda-setting and funding in semi-annual Center meetings of the Industrial Advisory Board of member representatives. Member companies could allocate their fee among three areas for new projects. One novel feature was introduced and continued whereby a company could allocate a fraction of its fee to a small EDR (extra designated research) project in which results would be company-specific. These decision-making processes remain intact today. The leaders of the Center made sure that members saw benefits from the decision-making approach.

## *Coping with a Challenge to Survival*

About 10 years after the Center opened major changes in the technical and business environment threatened its survival. When founded, Center Z's member companies consisted almost entirely of large, historically prominent firms based in North America. However, subsequent globalization and changing markets introduced turbulence in the industry. Many member firms were acquired or merged. Market-leading firms in the relevant technologies were increasingly based in Europe and Asia. As one indication of the impact of this environmental turbulence for the Center, it had an average of about 20 member organizations during any one year, but over its history had about 60 companies as members. Some members left the consortium while others disappeared or merged with other firms. Some new member companies were unaccustomed to, or even suspicious of, a consortium approach to R&D with universities.

Center Z responded to the changes in its industry and markets by developing and executing a new, more proactive approach to marketing the Center and recruiting members. The Director and Center scientists consulted with member companies, conducted seminars and visits with member organizations, visited prospective member firms and made research presentations at international conferences that enabled contacts to be made in the emerging industry. At the same time, the Center maintained the basic decision making processes, policies and practices that had developed in its first 10 years.

## *Success Factors*

Arguably, five factors contributed to the sustained success of Center Z. First, the Center had an effective, committed leadership team with a shared intellectual history and vision. Second, the Center's host university has provided consistent organizational support throughout the Center's operation, including staffing and updating the Center's facilities. Third, Center Z's leaders developed a comprehensive business model, based on the practices of the I/UCRC Program, a defined mission and customer-focused processes, and maintained a disciplined adherence to that business model through periods of turbulence in the industry and environment. Fourth, the Center's co-founders managed an orderly transition in the role of director, ensuring leadership continuity. Fifth, the Center managed a nimble, flexible and rapid response to major changes in its international technical and industry environment.

# Case Studies of Early Failure

## *Center A*

Center A was a multi-university I/UCRC based in a US commonwealth territory during the early 1980s that focused on pharmaceutical manufacturing. The managing site was at a moderate-sized public university with partner sites at two small nearby private universities. The Center began operations with seven industrial members and about $500,000 in total funding.

***Development and Growth.*** At launch the Center appeared to have a number of strengths. It was located in an area that had a large concentration of pharmaceutical manufacturing firms. In addition, the participating universities had a long track record of performing contract research for those firms. Furthermore, Center A was the brainchild of the managing university's dean so it had strong support from this primary university. On the negative side, the participating universities only had Master's degree-level chemical engineering and pharmaceutical science programs. The memberships came from local units of the participating firms, none of which had on-site R&D capabilities. Finally, Center leadership was assumed by a senior but non-tenure track faculty member.

***Decline and Dissolution.*** While Center A operated for a couple of years, it never really reached the level of research performance and cohesiveness demonstrated by most successful I/UCRCs. Within three years of start-up the Center began to close its operations and it is clear that a number of deficiencies contributed to its demise. While the university scientists and local firms were very comfortable engaging in one-on-one research, moving to a consortia form of collaboration created a number of problems. For example, firms were reluctant to discuss and share with their competitors the more applied problem-solving research they had been doing with the local universities. While the Center tried to move toward a more fundamental precompetitive research program, this caused its own problems.

It became clear that the participating Masters-degree granting universities did not have capabilities to perform this kind of research; and the units of the sponsoring firms, lacking an R&D function, did not have the absorptive capacity both to define and exploit these types of studies (Zahra and George, 2002). Finally, as the Center began to unravel, it became clear that the non-tenure track Director did not have credibility with the participating faculty nor the political strength and authority necessary to hold the Center together. In the final analysis, it became clear that Center A lacked the ingredients necessary to become a successful I/UCRC and was forced to close down.

## *Center B*

Center B was launched in the mid-1980s. It focused on topics related to molecular biology and it was novel in a number of respects. It was the first I/UCRC to conduct research targeted at the quickly maturing biotechnology-based pharmaceutical industry (Blumenthal et al., 1996). It adopted what was then – and still is – a very high annual membership fee of $75,000. It was also one of the first multi-university I/UCRCs supported by NSF. It began with two universities and eventually added a third, all in relatively close proximity. It is worth noting that each participating university was considered nationally, if not internationally, prominent in one or more biotechnology-related areas. Finally, the Center adopted a novel management structure wherein a state-funded science and technology agency served as the organizational home for the Center and provided its management support.

***Development and Growth.*** Center B got off to a very good start from both a financial and technical standpoint. By its second year of operation the Center had grown to five members and had an operating budget from all sources that approached $750,000. The Center attracted proposals from some of the participating university's strongest faculty. Members seemed very pleased with the quality of the research proposals submitted by the participating faculty as well as the early results that were produced. Concurrently, about five additional firms were evaluating the Center's research program and were actively considering membership.

***Decline and Dissolution.*** Unfortunately, within two years the Center's membership had declined to two firms and total Center funding had declined to about $300,000. Not surprisingly, interest in submitting proposals, especially by high profile investigators, had already begun to diminish. One year later, the Center's leadership decided not to submit a renewal proposal to NSF (which would have provided a second five-year award) and began closing down the Center.

What caused the demise of Center B? It had a number of things going for it. First, it possessed a capable and highly motivated leadership team including individuals who had worked in the bio-pharma industry. Collectively, the three universities had one of the most well-respected groups of faculty (academic staff) in the country, if not the world. In addition, Center B was partnering with a fast growing industry that had 'deep pockets' and was not reluctant to invest large sums of money into university research (Blumental, 1996). Interestingly, it was not the Center's very high fee nor its novel multi-university structure and external management structure that led to its downfall. In our opinion, two factors were critical in the decline and eventual demise of this Center: the biotechnology industry's desire for strong, exclusive intellectual property (IP) rights and the large amount of funding readily available to faculty from other federal sources.

Most significantly, it gradually became clear that firms involved in the highly competitive and proprietary-focused biotechnology industry were not comfortable with a consortia center model wherein firms shared what was supposed to be pre-competitive research. Two failed attempts to recruit members during this period illustrate this vividly. In one case, scientists employed by a firm favorably reviewed the Center's operations and research program and recommended joining the Center, only to be overruled by the company's corporate lawyers. The lawyers argued that even if the Center pursued a relevant and relatively novel pre-competitive research program there was a chance that the program might accidentally coincide with internal research that would be used to support exclusive patent claims within their firm. The lawyers successfully argued that the potential risk to the firm's IP claims posed by participating in Center B was too great to justify membership. In another case, a firm enthusiastically reviewed Center B's research capabilities and gave every indication they would join; but they did not. One month later that firm signed a $500,000 exclusive research agreement with one university site that gave it first-refusal rights to all IP created under the agreement. Gradually, Center B's fee-paying members appeared also to conclude that the risk versus reward involved in consortia research did not justify their continuing involvement in the Center. One-by-one the Center's founding members decided to discontinue their participation.

Although the biotechnology industry's aversion to consortia research would have eventually doomed Center B, another factor, the government funding environment faculty scientists experienced, helped weaken the university side of Center B's partnership. During this time period, the National Institute of Health (NIH) was beginning to experience the budget increases that would eventually lead to a commitment to double its budget beginning in 2003 (Korn et al., 2001). In spite of the fact that Center B faculty appeared to enjoy and benefit from interacting with industrial members, as soon as it became clear to faculty that a well-conceived Center proposal might result in a $50–100,000 two-year award while a successful NIH proposal might yield a $2–3 million four-year award, faculty interest in submitting their research to Center B began to wane. It is ironic that despite the general goal of all these various government funding sources to accelerate moving scientific solution into practice, the funding stream with the most university-industry linkages lost out to others where university PIs had more independence to pursue untrammeled science.

It is worth noting that these two factors, a desire for exclusivity in IP and ample government funding opportunities, appear to continue to work against the development of successful biotechnology-focused I/UCRCs. While NSF has developed numerous successful I/UCRCs in a variety of scientific and technical fields, with the exception of centers focused on the processing side of bio-pharma manufacturing (something firms are willing to collaborate on) few I/UCRCs focused on biotechnology-related issues have been launched and fewer have passed the test of time.

# Cases of Late Failure

## *Center P*

Center P successfully launched and operated for five years as a single-university I/UCRC, evolved smoothly to become a three-university I/UCRC, expanded to become a model I/UCRC with more than 50 member organizations in its seventh year, and operated through its tenth year. In its 11th year the Center dissolved and ceased to operate at its lead site. However, one of the three university sites continued to operate its component of the I/UCRC as a sustained CRC with essentially the same research program and sponsoring members – mainly in defense-related industries – as it had when it operated a site of the larger I/UCRC. This example of what might be described as a spin-out CRC is still operating today.

***Development and Growth.*** Center P began in the late 1990s as a single-university I/UCRC, operating from a large, research-oriented, state university for five years, serving mainly the chemical industry and a few manufacturers. By its fourth year the Center had 25 member organizations, a research laboratory with $4 M worth of testing equipment and a research budget of over $1 M per year, with I/UCRC funding supplemented by state grants, NSF research grants and industry contracts. Center P had a half-time Director, a half-time administrator, and affiliated faculty scientists in three departments. The Center produced an impressive flow of scientific publications and graduate degrees and represented a model NSF I/UCRC.

After its first 5 years, Center P joined with two state universities in other regions of the US to form a multi-university I/UCRC. Both partner universities ran independent, industry-funded research consortia with complementary research programs. The new Center added research initiatives at the new sites that attracted sponsors among defense contractors, aerospace firms and the auto-makers, in addition to charter members in the chemical industry.

The new, three-university Center received its second 5-year NSF I/UCRC award in the early 2000s, during an economic downturn, and still retained a total of 34 member organizations. Of these, half consisted of non-voting 'affiliate' members that paid 40% of the regular member dues, had access to the Center's research but had no rights to commercialize it. Although affiliate members had no vote, the Director negotiated one-to-one with them to design research projects that met their needs, often in exchange for in-kind contributions of equipment and testing materials.

Center P grew rapidly, despite losing a few memberships in the chemical industry when member companies merged. After two years as a multi-university I/UCRC it had 34 voting member organizations and 19 affiliate members. Its sites at all three universities had half-time administrators who managed relationships with the member organizations affiliated through their sites. Each university had four or more Center projects specifically designed for, and primarily funded by, one or two member organizations. Affiliate members continued to negotiate privately for projects on the Center's research agenda. The Center had few projects involving cooperation among industry member organizations and practically none involving cooperation by scientists across the three sites.

***Decline and Dissolution***. Seven years after opening, and two years after Center P expanded to become a multi-university I/UCRC, the founding Director left. A scientist at the lead university who had worked with the Center since it had opened reluctantly took over the post. Unfortunately, the lead university did not appear to appreciate the workload and responsibility involved in managing the Center and did not give the new Director release time for the role. The new Director continued to work as a full-time academic and delegated leadership of the Center to the half-time administrator.

Two years later the Center lost its long-time administrator. The lead university named a replacement with a nominal commitment of 20% to Center P, in addition to another, full-time job on campus. Until then the Center had maintained relatively stable operations.
At the end of the fourth year as a multi-university I/UCRC, Center P had 26 voting members, 15 affiliate, and 8 in-kind-only members.

Center P approached the end of its second, 5-year renewable NSF I/UCRC award with a leadership vacuum. Neither the new Director nor site Directors at the two other universities took the lead on writing the renewal proposal. Even after a year's extension from NSF, the Center still had no director willing to lead its next five years as a multi-university I/UCRC. The Center had 20 voting members when it dissolved after slightly more than 11 years of operation.

Despite the failure of the multi-university I/UCRC, many of the research projects continued at the three university sites. At the lead university, scientists continued to conduct contract research for several of the member organizations. Each of the two partner universities re-opened the industry consortia they had started before joining the I/UCRC. At least one is prospering today, re-constituted as a self-sufficient, single-university CRC, not affiliated with NSF. This spin-out CRC retained about half of the member organizations from the former I/UCRC – mainly in the relatively prosperous defense-related industries.

One obvious factor in the failure of Center P as an I/UCRC was the lack of an effective succession planning process at the host university, resulting in an unfilled leadership vacancy that arose when the founding Director departed after seven years in the job. The reluctant replacement Director did not exercise leadership and realistically could only have done so with some release time from academic duties. Nevertheless, the Center's research program continued largely as before, with most of its industry support, for another three years. The Center's part-time site administrators managed day-to-day operations and faculty scientists managed relations with industry members, including some recruiting. In effect, members of the Center's leadership teams and faculty scientists compensated by taking on parts of many of the leadership tasks left undone by an inactive Director. Unfortunately, the task of leading and drafting the proposal for renewal of the NSF I/UCRC award required a single, Principal Investigator to take responsibility.

A second, contributing factor in the Center's failure involved a management vacuum resulting from the departure of the Center's half-time administrator. The nominal replacement, an already overloaded employee, had no time for the job. For all practical purposes, the Center had no staff at its main office in its ninth year, when it should have been preparing for its post-NSF transition. Although the faculty scientists at the lead site continued their research and the two other sites operated as usual, the day-to-day work at the lead site fell behind, notably in billing members for their fees.

A third, less obvious but perhaps more fundamental factor in the failure concerned the lack of institutional commitment by the lead university. The dean of the college that launched the Center and campus research officers declined to arrange release-time for a faculty member as replacement Director, did not support hiring a replacement for the departing half-time administrator and opposed a bid by one of the partner universities to take over as lead site of the multi-university Center. A difference in any of these decisions might have led to a different outcome.

Another non-obvious factor in the failure of this I/UCRC concerns the lack of a cohesive group of industry stake-holders actively engaged with the university on behalf of the Center. Under similar circumstances at other I/UCRCs a very dedicated and cohesive industry group might have lobbied the university for more resources and commitment as a group. Instead, the industry members maintained relationships mainly with individual faculty scientists, especially at the lead university.

Center P's one-to-one research funding approach contrasted with the collective approach in other I/UCRCs. Ideally the IAB cooperates to define a shared research agenda of projects of interest to many of the member organizations. At Center P, the IAB had little input into the research agenda, because decisions had been made one-to-one. Many member representatives did not even attend IAB meetings; and many of the member organizations sent different individuals to IAB meetings. As a result, the IAB had no appreciable continuity and developed no cohesion as a group. The IAB chairperson for most of Center P's history was the CEO of a small, local firm – one of very few individual, industry representatives who came to more than two or three IAB meetings. In a Center with a more engaged IAB, multiple industry representatives can act as advocates for their Center in dealings with the host universities. At Center P the IAB never operated as a Board and took no advocacy role.

## *Center C*

Center C developed and prospered for ten years as a single-university I/UCRC, expanded to a two-university I/UCRC, continued an expanded research program through its 20th year, then closed.

***Development and Growth.*** Center C opened in the late 1980s as an inter-disciplinary, industry–university research consortium at a research-oriented, state university in cooperation with one of the US National Laboratories. It received an NSF award as a single-university I/UCRC in its first year, funded mainly by member organizations in the chemical and pharmaceutical industries. The Center operated with about a dozen members for its first five years under the leadership of its full-time, founding Director, who then retired.

In the early 1990s a second, full-time Director actively led Center C in obtaining a second, five-year I/UCRC renewal award from NSF as a single site at a large state university. The staff included a full-time administrative assistant and a full-time book-keeper. The Center had a budget of about $500k and a dozen member organizations eventually supporting research by 9 scientists at 3 university campuses and a National Laboratory.

Center C became a model I/UCRC in the early 1990s, serving primarily the chemical industry – which was relatively stable and profitable at the time. Representatives of Center C's member organizations cooperated in a cohesive IAB to guide its research agenda. The 12-member Board selected 9 to 11 projects for funding, based on collective deliberation, and supported the research program with contributions of testing equipment, supplies and use of their facilities. Center C produced a steady stream of scientific publications and graduates and, around its tenth year, invention disclosures and patent applications.

After ten years, Center C's funding as an NSF single-university I/UCRC ended. The Director had planned to expand Center C to a multi-university I/UCRC with a broader research program with some new specialties. Negotiations with two potential university partners took longer than expected. Proposals by faculty scientists for a new research initiative at one prospective partner site did not interest the current IAB and the partner site did not have enough industry sponsors to support the new research area. At another state university, the prospective site Director was an untenured faculty scientist who struggled to find sufficient committed industry support. The first proposal to NSF for a multi-university I/UCRC was rejected.

In Center C's 13th year, a second proposal to NSF for a two-university I/UCRC succeeded, with a site at another state university and a total of 20 member organizations through the two universities. The Center had operated for three years without an I/UCRC grant, relying on its industry support and individually funded research by its scientists, including NSF project grants. During the transition the Director reduced to half-time to cut costs. The site Director at the second university tried, with little success, to take over some leadership tasks, including member liaison. Within a year the Center hired a 15%-time co-Director of industrial relations.

***Decline and Dissolution.*** Center C struggled after making the transition to a two-university I/UCRC, partly because the lead university site discontinued cost-sharing support. Through the Center's first decade the lead university contributed a full-time administrative assistant, an accountant and at least part of the Director's salary. This support ended at the lead university at around the time the dean of engineering who had served as the Center's institutional champion departed unexpectedly and the Center's first multi-university I/UCRC proposal went unfunded. The Center then had to use external funds to support its administrative assistant and other staff. The executive Director took another job, reduced to 10%-time long enough to hire a part-time, interim Director, and then resigned.

Meanwhile, companies in the Center's primary constituency, the chemical industry, experienced budget pressures as global competition increased, and some consolidation. Two of the Center's member companies in the chemical industry merged and retained just one membership; another large chemical company downgraded to non-voting membership; others were acquired and departed. To adapt to changing economic conditions, the Center recruited member companies in the pharmaceutical industry, for whom the Center's current research program represented a good fit with their R&D priorities.

Two years and two interim Directors later, one of the Center's founding research scientists at the lead university took over as Center Director. Meanwhile, at the second university the site Director had resigned, a second Director had taken over and resigned and an associate dean had been appointed as Director. The new site Director suffered an extended illness and Center C's faculty scientists at the site cooperated to manage relationships with the remaining 3 member organizations there.

By the end of the Center's 15th year the Center still retained 19 member organizations. This reflected both the loss of one or two members each year and compensating gains through recruitment which resulted in expansion into the automotive and other industries, including equipment manufacturing. The second university site continued to retain only 2 to 3 members. Unfortunately, when the new Director took over, several current member representatives expressed dissatisfaction with the Center's management and/or research program during the preceding years of interim directors.

The new Director's tenure coincided with the economic decline of 2001, which adversely affected Center C's member organizations in the chemical and pharmaceutical industries with particular severity: that year, Center C lost five members. The next year another four members withdrew.

By the end of its 19th year of operation, Center C had only eight members, including two non-voting members (allowed when the Board agreed to a second category of membership). Center C had fallen below the minimum level of membership support needed for renewal of the NSF multi-university I/UCRC award. The Center sent a renewal proposal anyway, including letters of interest (not commitment) from some prospective members. It was returned for clarification; and NSF funding expired.

Center C's Director, with another, newly appointed Director at the second university, conducted energetic (some said 'heroic') campaigns to recruit enough new members to achieve the minimum required for a continuing I/UCRC proposal. These efforts proved unsuccessful. Center C's Director and site Director both announced their resignations after the Center's 19th year. An assigned, interim Director closed the Center a year later, after overseeing completion of projects for the remaining industry members.

At Center C, as in the other case of failure at Center P, a contributing factor involved turnover in the role of Center Director. At Center C, however, the highly effective Director wanted to stay, but departed because the host university withdrew financial support for the Center and, specifically and critically, for the Director's salary. Appeals to the lead university by members of Center C's active and supportive Industry Advisory Board failed to regain even limited, financial support from the host college.

Turnover and inexperience in the role of site Director at the second university site probably contributed to the failure of Center C as a multi-university I/UCRC. The initial site Director at the second university site, an un-tenured faculty member, had little experience with industry and had little success in recruiting member organizations, even on a sabbatical leave from teaching. The first Director was replaced after less than two years: the role then had three more incumbents in the subsequent five years, all with full-time academic jobs. The second university site struggled the whole time to attract even the minimum membership support required for the site to qualify for the NSF award.

The economic downturn of 2001 probably contributed to the loss of at least nine of Center C's member organizations in the chemical and pharmaceutical industries in a period of just two years. Contributing factors may also have included mismanagement of the Center's research portfolio, as it replaced topics important to the chemical and pharmaceutical industries with topics designed to attract new members in the automotive and other industries. However, the reasons mentioned most often by member representatives in explaining their decisions to leave involved chaos in the Center's management and/or problems with leadership. The Center never recovered from the setback of losing nine members, which amounted to the loss of its critical mass.

## Discussion

Our four cases of failure suggest that a variety of factors can contribute to the demise of an I/UCRC in the US and, by extension, other types of CRCs and Triple Helix initiatives operating around the world. Further, our single case of success may begin to provide some insight into how to avoid the plight of those that failed. Not surprisingly, our analyses suggest that centers need certain capabilities to succeed and the absence of some key ingredients can contribute to failure. For instance, the lack of doctoral-level programs at Center A was certainly a key reason for its failure. Such deficiencies are difficult to compensate for and have a relatively immediate effect on survival. Obviously, this is something we could have inferred from studying the characteristics of successful centers. However, our results also suggest that even robust and successful centers can unravel if they confront a hostile environment and/or mishandle key transitions that established centers must navigate. In addition, centers appear to be particularly vulnerable when they have to grapple with multiple and/or cascading challenges.

Our analyses suggest that a variety of environmental factors can contribute to the demise of a center. Attempting to fit a consortia partnership into an industry where firms are averse to sharing research results with other firms (Center B), or simply have a history of working in a more one-on-one fashion with the PIs (Centers A and C), can prove challenging. In addition, attempting to maintain the interest of talented faculty stakeholders when large sums of extramural research support are readily available from other sources (Center B) can be a difficult task. Finally, maintaining the commitment of firms that are sympathetic but lack absorptive capacity to utilize these findings is probably a losing battle (Center A).

At the same time, even robust and initially successful centers encounter transitions that, if not handled properly, can cause them to lose momentum and eventually unravel. While previous research and analysis has pointed out the importance of leadership in successful centers (Ailes et al., 2000), our cases illustrate the frequency with which founding directors depart and highlight the importance of succession planning in sustaining successful centers, an issue we noted in particular in earlier work (Tornatzky et al., 1999). Both Centers P and C were quite successful for an extended period of time but eventually suffered when less capable and less dedicated leaders assumed the director's role. In the case of Center C, turnover in the director role led to inconsistent and inattentive leadership, which the Center could ill afford. In contrast, the successful Center Z made a smooth transition to its second Director, a co-founder able to provide continuity of leadership for the Center as it coped with environmental turbulence.

The impact of external, economic conditions for the Centers in these cases apparently depended largely on how the Centers dealt with changing conditions in their environments. For example, Centers P, C and Z were all affected by the economic downturn of 2001 and responded in very different ways, with differing results for the Centers' failure or success. Center P, with a new and inexperienced Director, made essentially no change in its mode of operation after the economic decline of 2001 because the new Director exercised no meaningful leadership role. The Center retained its one-company, one-project mode of research management. The Center's scientists made limited efforts to recruit new members in the same industries as before, mainly from the troubled chemical industry at the lead university site, before Center P dissolved after practically no Center-wide attempt was made to deal with the economic recession. Center C, also operating with a new and inexperienced Director, apparently mismanaged its research portfolio by replacing projects of interest to its primary membership in the chemical and pharmaceutical industries with new projects designed to appeal to other industries, and failed shortly thereafter.

In contrast, Center Z's more experienced Director responded to the economic setbacks of 2001 by maintaining and enhancing the Center's cooperative approach to research management and mounting an extensive, proactive and globally diversified campaign of recruiting new member organizations. As a result, Center Z weathered the challenging economic conditions by essentially re-constituting the Center's membership with firms from around the globe that survived the economic downturn and subsequently prospered.

Another important factor in tipping the scales toward failure or success involves institutional support. In both of the cases of long-term failure the host university failed to demonstrate the willingness to invest the resources necessary to attract a qualified and motivated leader. In the success case, on the other hand, the host university has provided sustained support for Center Z: this support even extended to hiring new faculty scientists in key research areas and providing renovation of Center facilities. Of course, host universities need to select which initiatives they will invest scarce resources in and which they will not. Nonetheless, in the cases recounted here the failure of the universities to provide even modest sustaining support appeared to be the ‘kiss of death’ for these still-viable but struggling partnerships.

During a period of interim or reluctant leadership, additional problems surfaced at the failed Centers. At Center P, after the founding Director departed and the replacement Director did not make the necessary effort to support and develop the Center, the lack of cohesiveness and commitment by the IAB became an important problem. In truly consortial centers, cohesive groups of member firms have effectively lobbied the host university to commit the resources needed to sustain a center. However, because Center P used a more one-on-one mode of research sponsorship its members failed to see and/or use the influence they could wield as a unified group.

Thus embedded in our failure cases are concerns about the extent to which centers that fail actually confront multiple and cascading challenges. Center B had to cope simultaneously with declining interest from member companies and faculty. Stakeholders associated with Center A tried to make it work but the challenges posed by a lack of doctoral level research, member firms with limited R&D capabilities and a Director who lacked the influence that comes with being a tenure-track faculty member were too much to overcome. Both Center P and Center C attempted to manage a leadership transition without much institutional support and while confronting other problems, including a declining economy. In both cases the inability to handle a fairly routine management challenge – replacing the founding director – appears to have contributed to and exacerbated other Center deficiencies (for example, a lack of cohesiveness among the member’s consortia) and resulted in the demise of what had been a successful Center.

Since all of our failure cases involved multi-university Centers, the question might arise as to whether this structural feature contributed to the failures. However, we are aware of a large number of successful multi-university Centers, and unsuccessful single-university Centers and thus we suspect this factor, by itself, more likely represented a complicating rather than a contributing factor. In a multi-university center, the host university may resist providing additional support during stressful times until partner universities ‘ante up’ their share; or actually cut support, as happened at Center C before it unraveled. Equally, in a leadership vacuum, as at Center P, where no site Director exercised leadership in negotiating equitable institutional support from three universities historically willing to provide it, the Center unraveled. A multi-university center arguably has greater complexity, and more ways to fail, than a single-university center. These conclusions are consistent with the findings of Cummings and Keisler (2007) who concluded that multi-institutional collaborative arrangements involve a coordination burden that may detract from scientific and related performance.

If we probe more deeply into what contributed to success or failure in all five cases it appears to come down to leadership. All of the failure cases involved shortcomings of leadership: directors departed, did not devote enough time, were marginalized because they were not tenured, or failed to lead their Centers through key transitions. In contrast, the successful Center Z had effective leadership, continuity through a transition in the role of director and effective leadership in coping with environmental turbulence that threatened the

Center. Social capital theory points to key ingredients present in the success case and absent during the decline and dissolution of the failure cases (Adler and Kwon, 2002; Woolcock, 2001). At Center Z, the broad experience of Center leaders, the continuity of their tenure, the rich decision-making processes and the intensive outreach to member companies may have built social capital via technical and non-technical interactions. In turn this may have built trust and connectivity and contributed to Center success and survival.

Recent research has identified twelve key dimensions of leadership in CRCs (Craig et al., 2009). While they include research-related qualities such as technical expertise and broad thinking and personality characteristics such as ambition and a strong work ethic, many of the dimensions relate to the social and boundary-spanning aspects of leading a complex Triple Helix organization, including balancing competing stakeholders, leveraging social capital, granting autonomy, interpersonal skills and team building and maintenance. When a disruption in center leadership occurs, as in Centers C and P, what is lost is not just the thread of the R&D agenda but, perhaps more importantly, the connections, informal relationships and friendships that constitute the social capital that bind the participants together.

Research in the general innovation literature supports this proposition. For example, Landry et al. (2002), in a survey of 440 manufacturing firms, found that technological innovation was enhanced by network participation and relational assets. Similarly, a review by Nahapiet and Ghoshal (1998) supports the premise that social capital in the form of networks is related to the development and sharing of intellectual capital. An intra-firm survey by Tsai and Ghoshal (1998) indicated that social capital, in the form of inter-unit resource exchange, was related to product innovation. While none of these studies, nor the larger social capital literature, have focused on Triple Helix organizations, our cases suggest obvious questions for future research at CRCs.

## *Implications for Triple Helix Organizations*

CRCs are prototypical Triple Helix organizations. For a center to be successful it requires a complex balance of institutional resources at the host universities and capabilities within the center to meet the expectations and needs of the diverse stakeholders. Our analyses suggest that centers can be launched successfully but may falter quickly if they possess some fatal flaw such as limited institutional support on the part of university or limited absorptive capacity by industry. In addition, industries such as biotechnology that place very high importance on exclusive IP rights may decide their needs are not compatible with the very collectively-focused I/UCRC model and hence withdraw their support.

Our analyses also suggest viable mature centers can unravel when they fail to address organizational problems or challenges – for example, external pressures created by economic recession or changing global markets, or internal transitions such as turnover in the role of Director. Apparently minor problems can multiply and have cascading effects. Obviously, it is in the best interests of centers and the stakeholder groups they serve to understand what key challenges/transitions they are likely to face and prepare to handle them quickly and effectively. To this end, we hope our paper has highlighted some of the more important ones. However, our analyses suggest that at a fundamental level many of these Triple Helix failures derive from a lack, or loss, of effective leadership. This is an issue we have begun to explore in more depth (Rivers and Gray, 2010) and one that we think deserves more attention from the scholarly, policy and managerial communities interested in the success of Triple Helix organizations.

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# Chapter 3: Reinventing the I/UCRC Model: Center for UMass/Industry Research on Polymers University of Massachusetts

www.pse.umass.edu/cumirp/

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## Introduction

The Center for University of Massachusetts / Industry Research on Polymers (CUMIRP) was one of the original Centers operating under the NSF I/UCRC program. Established in 1980 it has been in operation ever since, although in the early 1990s it underwent a redefinition to stay current with changing industrial needs, which led to the dramatically transformed Center that currently exists. From the perspective of the NSF I/UCRC program, the Center at the University of Massachusetts is a “graduated” program; nonetheless as far as CUMIRP is concerned there is a self-conscience and continuous lineage to its NSF origins, despite the changes in how it currently operates. Its website proudly notes the NSF origins.

Those dramatic changes, which will be described in more detail, could perhaps be best described as both a reinvention of the I/UCRC consortia model and a very creative approach to services diversification that is more attuned to the needs and business models of the companies it serves (Gray & Walters, 1998). While very definitely an industry/university center, it is a Center that offers many options and mechanisms to tailor the University research interactions to the company’s needs.

## An Overview of the Center

This overview describes the founding period of the Center, its redesign and its evolution to a $2+M dollar R&D operation. The narrative is based on published case histories, current interviews and information garnered from program documents.

### *Organizational Context: The Hosting Institution*

University of Massachusetts Amherst began as a Land Grant agricultural college, established under the Civil War era Morrill act of 1863. It continues some of that tradition, with a College of Agriculture and some of the mission and outreach responsibilities that are typically associated with a Land Grant campus. However, as the University matured and grew, it expanded curricular offerings and its mission to become much more prominent in engineering, math and computer sciences, the physical sciences and more industrially focused disciplines. The past several decades have witnessed the University’s accelerated growth and research prominence. From 4,000 students in 1954, the campus Fall 2011 enrollment was 28,084 students, with 6,272 being graduate students (UMass website, 2011). Including CUMIRP, it has ten nationally prominent Centers or Institutes, with several others emerging. In FY 2011, the University realized \$143M in research awards, and research expenditures reached \$139M, with the life sciences accounting for roughly 36% thereof. In the area of polymer science and engineering, the University of Massachusetts, Amherst is one of the top graduate polymer programs in the nation. In terms of ratings by the National Research Council, Polymer Science at the University ranked 2$^{nd}$ nationally in the quality of education and 7$^{th}$ in the quality of scholarship among all Materials departments.

The University is on an aggressive growth trajectory. Consistent with its Land Grant heritage, the University's office of Commercial Ventures and Intellectual Property (CVIP) is actively working to strengthen regional economic development by assisting both student and faculty entrepreneurs, creating spin-out companies and, when possible, licensing its intellectual property within the New England area. The University has a history of successful technology transfer and is expanding its efforts in invention assessment, protection and marketing. According to the Association of University Technology Transfer Managers (AUTM) data for 2010, the UMass system has a comparatively high rate of invention disclosures, patent applications, issued patents and licensing revenue (AUTM, 2010). In recent years, the UMass Amherst campus has created several venture-quality startup companies which created nearly 100 jobs and raised over \$40 million in investment funding. The campus receives one disclosure for every \$3.2 million of sponsored research and for the past five years, completed an average of 15 license or option agreements annually.

At its inception CUMIRP was nominally located in the department of Polymer Science and Engineering (PSE), but also included several faculty from the Chemical Engineering and Chemistry Departments. The Center was established to report to the Office of the Vice Chancellor for Research, so that it would not reside within any one department. . As the Center has grown and evolved, it continues to involve individuals from other departments where polymers are central to the research.

The planning for CUMIRP began in 1977 and numerous issues were identified and had to be addressed before its official launch in 1980. Richard Stein (Chemistry) and Otto Vogl (PSE) were the original faculty members charged with addressing these issues and in planning the Center with the NSF and industrial partners. A first hurdle was how to deal with any intellectual property that might be created with NSF funds. This was prior to the Bayh-Dole Act, so an agreement with the NSF had to be reached regarding intellectual property. These discussions resulted in the NSF agreeing to relinquish its intellectual property rights provided they be shared equally with industrial participants. A second issue that surfaced was concerns about anti-trust laws, since many of the potential industrial collaborators were also competitors. There were numerous legal discussions to define the guidelines upon which competitive companies could collaborate on research and new technologies. In fact, it is safe to say, CUMIRP helped pioneer many of the policies and procedures that have become tried-and-true I/UCRC "best practices".

As mentioned previously, the Center originally reported into the Office of the Vice Chancellor for Research so that it would not be part of any one department. The oversight board, CUMIRP Steering Committee, was designed to include representatives of several organizations on campus and included the Head of the Department of Polymer Science and

Engineering, the Director of the NSF-Materials Research Laboratory (later, the NSF Materials Research Science and Engineering Center) and two CUMIRP Co-PIs. This Steering Committee was charged with oversight on any major decisions of the Center. Consistent with other I/UCRCs, the program also had an Industrial Advisory Board comprised of participant industrial members to provide guidance on the research at the Center and its relationship with Industry. There were several issues of concern at the outset, one of which was the impact of funding on UMass faculty. A number of faculty saw the Center as competing for external research funding, although this perception never materialized.

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After marketing outreach and discussions involving upwards of 35 companies, thirteen companies constituted the original CUMIRP membership. The original annual membership fee was $ 40,000. After the launch of the Center in 1980 with 13 member companies it continued as a classic NSF I/UCRC with member companies from various sectors of the polymers industry, including Allied, American Cyanamid, ARCO, Celanese, Dow, DuPont, Eastman Kodak, Exxon, General Electric, Monsanto, Tennessee Eastman, Union Carbide among others. Industrial interest in the program was mainly two-fold; (1) the research being conducted in the program and (2) access to faculty and students. Many of the companies saw this as a worthwhile investment as a recruitment tool for future employees. Early meetings focused on selecting out from the broader agenda of potential projects those for which there was a plurality of members. Consistent with other I/UCRCs, by agreement of the Industrial Advisory Board and the CUMIRP Steering Committee, the research projects were selected and conducted under the direction of involved faculty.

A relatively unique feature of CUMIRP's operations over the years has been the involvement of several faculty with significant industrial experience as part of the Center's management team. In 1980, management of the Center was administered by the two Co-PIs, Stein and Vogl. Soon thereafter, Eugene Magat, a recent retiree of DuPont, joined the Center as the General Secretary to handle the administrative duties of the program. This position evolved into the center director position, but was still only a part-time position. In 1983, Magat was succeeded by Simon Kantor, a former General Electric employee. In addition to the part-time director position, Kantor also developed a strong research program at UMass.

Leadership responsibilities of the Center were shared between scientific leadership (PIs) and administrative management (the Project Director). Early in the history of the Center the incumbents in these positions changed as faculty members (PIs) left the university for other positions and the administrative Director was replaced. For much of the 80s and 90s there was no full-time director position.

***The Organizational Context over Time.*** The basic structure described above served both the industrial participants and the UMass faculty quite well during the 1980s. Faculty research flourished in the polymer community and the industrial organizations had access to the research and the student body. During most of this time Center membership hovered around 20 members. However, in the early 1990s industry changed its research model and the basic R&D conducted by central research laboratories shifted to business units. In this environment university research support needed to be linked to the business unit priorities and broad-based consortia were not seen as having the focus needed. By 1993, when CUMIRP was approaching the phase out of NSF funding, industrial membership had dropped to seven companies, with 4 of them threatening not to renew. The CUMIRP Steering Committee and the Industrial Advisory Board realized the changing business needs and the need to adapt CUMIRP to the business of the 90s.

The result of all of these trends and pressures was that CUMIRP, with the blessing of the Vice Chancellor for Research, went through a dramatic re-structuring of its organization, "services" and pricing in 1994, and has continued to operate in this revised format through today. However, rather than abandon its consortial roots and revert to a contract research-for-hire Center, like some graduated I/UCRCs have done (See Chapter 5, Center for Advanced Communication), CUMIRP decided to both expand and reinvent the I/UCRC model.

The reorganization was quite comprehensive in that it had to address the changing needs of business, had to create a director's role consistent with the needs of a self-sustained center, had to satisfy the faculty and students needs and be acceptable to University administration.

The major changes to the Center involved the following key elements:

(a) the center director position was elevated to a full-time position to manage and administer the Center and excluded research activities;
(b) the general consortium program was modified to have thrust areas that *de facto* served as mini-consortia, along with a new fee structure;
(c) the Center would also facilitate sponsored research and grants from industrial partners;
(d) the University agreed to a costs structure to provide for self-funding of the Center.

The end result was to provide for a structure and mechanism that allowed CUMIRP to become a full-service Center for its industrial clientele.

> *… rather than abandon its consortial roots and revert to a contract research-for-hire Center, like some graduated I/UCRCs have done, CUMIRP decided to both expand and reinvent the I/UCRC model.*

The new Center offered different mechanisms, or "Parts", for the program as follows:

*Part I: Continuation of the Consortium with Size-Specific Pricing and Content-Specific Clusters.* The basic I/UCRC model was continued, but was sub-divided into thrust areas known as 'Clusters'. These Clusters were based on research emphasis areas at UMass and industrial interest. The membership fee was reduced from $ 40,000 to $25,000 annual for large companies to participate in a Cluster. Additional annual fees categories were created ($ 5,000 and $ 15,000) for small and mid-sized companies to allow for participation beyond large organizations. The annual Cluster dues were based on company size (annual sales) and the number of clusters in which they participated (discounted rates were available for multi-cluster participation).

The current Cluster array includes: Research Cluster B-Polymers in the Bio arena, Research Cluster E- Polymers in Energy, Research Cluster F – Fire-Safe Polymers and Polymer Composites, Research Cluster M – Mechanics of Polymers and Composites, Research Cluster N – Nanostructured Materials and Research Cluster R – Roll-to-Roll Processing. By design, one of the advantageous features of the Cluster structure is that clusters can come and go, depending on the interests of member companies and the research thrust areas at UMass, thus yielding greater flexibility in the overall agenda that is offered to members.

Each Cluster is led by one or more faculty coordinators, and each Cluster has at least two company sponsors but ideally at least five or more. Companies can participate in more than one Cluster, with additional Cluster sponsorships discounted. In recent years, approximately 22 companies participate in the consortia program, with several of those joining multiple clusters. This organizational innovation has enabled companies to stay involved in early stage faculty research that is directly related to their business unit's interests, participate with other companies therein and also to have wider choices among research emphases.

*The basic I/UCRC model was continued, but was sub-divided into thrust areas known as 'Clusters'. These Clusters were based on research emphasis areas at UMass and industrial interest.*

*Parts II, III and IV: Sponsored Research and Unrestricted Grants and Awards.* In addition to the dramatically re-designed consortia component of the CUMIRP program described above, the organizational changes introduced in 1994 created two other options that have little to do with a consortia approach, but nonetheless permit a company to realize value from CUMIRP and participate in its programs. Part II of the CUMIRP Program allows the Center to coordinate one-on-one sponsored research programs and Part III provide for unrestricted grants. In 2002, as a result of discussions with the IAB, Part IV was added to address short duration scoping projects. In recent years, approximately 30 companies participate annually in Part II, Part III or Part IV, and of these, one-forth, on average, also participate in the Part I consortia program. The Part II-IV components of CUMIRP are very much catered to member companies' specific interests beyond the consortia venue.

It is worth noting that with the exception of Part I, less formalized versions of these new features can be found in other I/UCRCs. This is not the case with the Part I "clusters" approach to creating a consortia. Since NSF guidelines require that an I/UCRC must have at least $300,000 in industry membership support and that all members must have access and rights to all research, CUMIRP's cluster approach would only be acceptable to NSF if at least one cluster achieved that level of funding. To the best of our knowledge, none of the currently funded or graduated I/UCRCs use this approach.

The descriptions of these non-consortia components of CUMRIP follow. However, in considering these other Parts it would be an error to consider their intent or objectives of the companies that participate as “anti-consortia.” These program options simply enable companies to still participate as a member in CUMIRP, but in a way that is more consistent with their business and technological objectives. Companies that participate in any Part of CUMIRP are granted the general benefits of the program that include: use of the CUMIRP office to assist with addressing their research needs, invitation to CUMIRP lectures, symposia and meetings (including electronic copies of presentations and annual poster symposium), arrangements for visiting scientists, assess to Center trained students, discounts to Part I memberships, access to University facilities and other special arrangements as needed.

*Part II: One-on-one Sponsored Research.* Under this component a participating company can engage a faculty member and his/her team to conduct a sponsored research program whose details are mutually agreed upon between the university and the company. These projects carry the normal university indirect cost rate. In turn, by participating in the Part II program, the company gets access to the research results and the right of first refusal to obtain an exclusive or non-exclusive license to any patents resulting from the project. The duration of the projects are one year or more and research is conducted by graduate students or post-doctoral fellows. The research should have both scientific merit and address the specific need(s) of the industrial partner. These fundamental research programs have become more important to industry as central research organizations have shifted to support of business unit activities. As noted above, member companies that participate via Part II also can participate in a Part I cluster at a reduced fee.[12]

*Part III: Unrestricted Research Grants.* This Part provides a conduit or a venue by which a company can support a particular faculty investigator and her/his research group to pursue a promising line of inquiry in a kind of a “no strings attached” format. Support under a Part III grant may simply be to generally support a faculty’s research area (and be kept informed of the research progress) or may be directed to support internships, lectureships and industrial research professorships. The funding amounts vary widely. This mechanism is useful when there is no specific research project, no need for a formal agreement (including intellectual property arrangements) or for general support of a faculty or departmental efforts. It should be noted that unrestricted grants to universities have decreased in the past decade, due to business cost reductions, however this remains a useful mechanism for general support. As in much of the CUMIRP structure and product mix, sponsors of Part III work can also participate in the Part I program with a significant (40%) discount in membership therein. Part III projects also carry a lower indirect cost overhead as compared to Part II efforts.

*Part IV: Scoping Projects.* This mechanism was initiated in 2002 as a result of discussions with the IAB. There was a need to do short duration, scoping projects that could

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[12] Part I members do not get a discount on Part II projects.

be started quickly without significant manpower efforts to initiate. This program component permits the funding of short duration projects (generally 1-3 months) with generally limited scope of effort and cost (usually less than $20K) and only executed with the agreement of the participating faculty member and the Center Director. The scope and focus of projects is specified in a Memorandum of Understanding (3 page form), that specifies the nature of the work and the objectives of the project. The simplicity of the agreement and the nature of the mechanism allows a quick way to 'scope' out potential research ideas without committing significant legal/management time in agreement negotiations or large amounts of funding. Part IV projects have been used in effect as "launching pads" for potential Part II projects or other program initiatives. Again, this kind of program option enables more flexibility and innovation than might be realized with only a consortium structure.

*The simplicity of the agreement and the nature of the mechanism allows a quick way to 'scope' out potential research ideas without committing significant legal/management time in agreement negotiations or large amounts of funding.*

One could ask why would a company that is primarily or exclusively interested in one-on-one contract projects or grant donations not go directly to the grants and contracts function of the University and simply bypass the Center?

The answer is that the CUMIRP program offers a 'one-stop shopping' service whereby it can facilitate all of the arrangements and transactions with the University. The Center can facilitate sponsored research agreement so that there is one point of contact rather than have discussions with the sponsored research office, the intellectual property office, legal counsel, the accounting office, and other University entities involved with research contracts. CUMIRP can also facilitate non-disclosure agreements and materials transfer agreements when necessary. If there are questions, problems or information needed during the contract arrangements or at any point of the research program, the industrial partner has the Center to contact. The CUMIRP office works with its industrial clientele to figure out the best mechanisms to address the company needs and prides itself on being a full service Center. This has sometimes resulted in firms that initially wanted Part II-IV work, deciding to join one or more of the Part I clusters.

In all 'Parts' of CUMIRP, a percentage of the funding is returned to the Center to support the administrative cost of operations. This provides the incentive for the Center staff to operate effectively and efficiently, and is in the University's best interest to maintain a strong industrial collaborations program.

## Center Leadership

There have been two eras of leadership structure and function during the life of CUMIRP as mentioned previously. From its early planning and formal inception in 1980, faculty members in the University executed the Director function. From 1983 to 1993, the position was part-time with the Director also actively involved with research. This is not unlike the typical passing around of department chair positions seen in many academic organizations, with leadership performance varying widely from era to era. With the Center redesign in 1993, it was evident that the Center needed a full-time director who was focused on the Center and not directly involved in research efforts. Importantly, the Center's leadership team has included someone with significant industrial experience almost from the very beginning. In 1994, Bradley Moynahan became the first full-time Director after retirement from an industrial career. Moynahan provided significant leadership during this new era and was responsible for implementing the revised Cluster structure. The focus at this time was to demonstrate to industry that the Center was adaptable to industrial needs while at the same time, continuing with its excellence in polymer research.

## *Center Leadership over Time*

The current Center Director, James Capistran, came on board in 1996 and has been in place over the past 15 plus years. His background 'fit' with the position. He had been educated at UMass (B.S. in Chemistry; M.S. in Polymer Science and Engineering) and had a 15 year industrial career, with experience ranging from bench scientist through senior corporate director. Aside from his experience base and corporate mindset, Capistran was notably the first long-term, full-time Center Director. This had several implications for the growth and sustainability of CUMIRP.

> *Importantly, the Center's leadership team has included someone with significant industrial experience almost from the very beginning.*

First, by approving the creation of a full-time dedicated director (as well as approving the structural and financial changes), UMass was demonstrating its commitment to the long-term success of CUMIRP. Second, there was continuous leadership and vision to expand and consolidate the internal reforms in structure and operations (the Parts, Clusters, business-unit pricing) that were begun during the 1994-1995 period. Over the long term, these alternative structures and operations had huge fiscal benefits for the Center and the university and, more importantly, educational benefits for the students it has supported over the past thirty years. During its early years, virtually all of the Center's income was derived from the I/UCRC consortium. Currently, of the total annual research funding of approximately $2M, less than half (45%) is derived from the Part I consortium component.

Third, there have been considerable benefits of long-term full-time Center leadership in managing the Center. The Center has gained in reputation, not only nationally, but globally. This reflects well on the campus and aids in other federal proposals where there needs to be a strong industrial component. More locally, the continuity has enabled the Center to establish good relationships with the various administrative offices on campus. This is important when there is a change in administrative personnel (a constant), and especially important in maintaining the self-funding mechanism for the Center. It also aids in addressing the issues challenging an industrial center such as intellectual property policies. Change in University (at least public universities) tends to be slow, so moving policies and procedures forward takes time.

An additional major benefit of having a highly diversified Center with continuity in Center personnel is long term relationship development and maintenance. In the past decade, many corporations have undergone re-design, consolidation and/or change of ownership.

These events often led to a loss of personnel who were key links for a university collaboration. Maintaining these relationships relies on multiple contacts within a company and at various levels and positions.

## Organizational Structures and Processes

During its first dozen years of operation organizational structures and processes, particularly decision processes generally matched up well with the approved I/UCRC approach. Thus, there was an Industrial Advisory Board structure, with member companies sending the requisite number of representatives. Similarly, there were twice-a-year Center meetings that included a fairly routinized approach to pick each year’s program of projects, and providing feedback to project progress and outcomes.

*An additional major benefit of having a highly diversified Center with continuity in Center personnel is long term relationship development and maintenance.*

### *Organizational Structures and Processes over Time*

How the Center conducts business has changed significantly as a function of the structural and decision-making innovations that were introduced in the 90s and elaborated over the years. The Cluster groups meet twice per year at Spring / Fall Polymer Events. Cluster meetings are only open to members of the Cluster although once each meeting a high-level presentation on a single Cluster is given in order to give all companies an overview of the Cluster research to attract new potential members. The elaborate voting procedures for selecting projects as practiced in early years of the I/UCRC consortium have been replaced in the Part I consortium of CUMIRP by a “more interactive dialogue and informal conversations” according to the Director. Cluster member representative still review the research biannually, comment on the research performed in the prior 6 month period and suggest new directions and decide on which new projects should be launched.

Additionally, the results of a Part I consortium work may inspire a member company to get involved in a Part II independent project based on the fundamental research in the cluster. This derivative project would then be directed toward the specific company interests outside of the consortia format. So too the greater variety of the Cluster format within the consortia component of the program yield more variety in member involvements and more degrees-of-freedom in company choices.

Membership in CUMIRP’s overall IAB is by invitation of the Steering Committee. The IAB discusses and offers advice on strategic and policy issues that affect the Center. Since the Advisory Board no longer has the same kind of project selection authority as it did under the official I/UCRC model, and is more “advisory” in flavor, it tends to be populated by companies that have more long-term substantial involvement with CUMIRP. The Advisory Board provides council on the overall Center operation and may from time to time act as an ‘Advocacy Board’ on Center issues. For instance, it was actively involved in recommending changes to the university patenting policies to make them more “user” friendly.

## Technical Focus and Industry Participants

In the early days of the Center, the member companies were very large chemical companies, and virtually all of the early member companies had large internal laboratories. The relationship between these corporate labs and the polymer research at UMass was based on mutual need. The UMass polymer faculty wanted to keep abreast of what was industrially important and the real world needs. UMass had become well known for its basic and fundamental science in the field of polymers and industry wanted to be associated with good programs. Industrial labs could capitalize on this broad-based basic science as they developed new materials with specific performance properties and novel or more efficient processes for polymer production. As described above, as the corporate research moved from large scale corporate labs to business unit R&D labs in the 1990s, university research needed to be relevant to the business, hence the restructuring of the consortium program into Clusters. The research was still basic, but needed to be organized into thrust areas that could be associated with an application. The current Cluster titles reflect this change:

Cluster B: Polymers in the Bio-arena (2003)
Cluster E: Polymers in Energy (2008)
Cluster F: Fire Safe Polymers and Polymer Composites (1996)
Cluster M: Mechanics of Polymers (1999)
Cluster N: Nanostructured Materials (2002)
Cluster R: Roll-to-Roll Processing (2012)

Cluster groups and topic areas come and go based on the research thrusts at UMass and company interest. Past clusters have focused on polymer blends, polymer synthesis, continuum mechanics, and polyolefins. However, these were not sustainable due to the broadness of the topic area and lack of company interest and research funding.

Clusters may also originate or function in slightly differing ways. Some Clusters have arisen from a specific area need, such as Cluster F on Fire-Safe Polymers. The original challenge for new fire-safe polymeric materials was put forth by the Federal Aviation Administration. Seed funding is provided by the FAA and augmented with industrial funds. This program, in its fifteenth year, has been very productive and resulted in several classes of new fire-safe polymers, 43 publications, 3 patent applications with 3 more applications pending. Other Clusters have evolved from other research Centers or institutes results where the basic and fundamental research has led to slightly more applied research, which fits the cluster model well.

A good example of the ‘life’ of a cluster is Cluster G: Green Chemistry and Physics of Polymers. This Cluster had been very active from 1999 through 2007 with over $ 1.6M of direct cluster funding from 15 sponsors. The research thrust was in the area of solvent-less polymer processing and environmentally friendly polymers. This was the basis for a federal proposal that led to the formation of the New England Green Chemistry Consortium (NEGCC), which brought together the 6 land grant institutions in New England. The NEGCC was funded via the EPA and was the first regional green chemistry collaboration in the US Unfortunately, the NEGCC funding ended, and industrial participants did not see the value of the research within the Cluster. However, this cluster will likely re-emerge with a focus on polymers from renewable resources, one area of research where industry still has an interest. This Cluster is undergoing a revision in its research focus and direction and will be re-launched in the future.

## Assets: People and Physical Plant

The Department of Polymer Science and Engineering at UMass is a nationally prominent unit. Moreover, CUMIRP has been able to involve individuals and units from across the campus that can contribute to the much larger agenda of R&D being executed by the Center, provided polymers is a key component of the research. Approximately 20 – 25 faculty members utilize the Center annually, with support for approximately 40 graduate students and post-docs. Due to its origin, most faculty are based in the Department of Polymer Science and Engineering, but the Center also works with faculty in the Department of Physics, Department of Chemistry and Department of Chemical Engineering, among others. Over its thirty years of operation CUMIRP has provided several hundred student-years of support to a very talented group of graduate students and has helped UMass maintain its elite ratings among programs nationally.

CUMIRP also benefits from working relationships with other Centers and Institutes on campus. These include the Materials Research Science and Engineering Center (MRSEC) on Polymers, the Center for Hierarchical Manufacturing (CHM), an Energy Frontier Research Center (EFRC), National Nano-manufacturing Network (NNN), along with several state funded centers including Mass Center for Research on Energy, Science and Technology (MassCREST) and the Mass Nanotech Institute. Many of these Centers and Institutes provide a basis for research that may eventually lead to the formation of a research Cluster where there is industrial interest and a need for slightly more applied research.

*Over its thirty years of operation CUMIRP has provided several hundred student-years of support to a very talented group of graduate students and has helped UMass maintain its elite ratings among programs nationally.*

CUMIRP's research success can also be attributed to having access to a range of laboratory equipment and facilities, some of which are departmental, some supported by the Centers or Institutes noted above and some of which is space shared more widely among researchers across the campus. UMass has some of the best polymer research facilities in the world with over $30M in capital research equipment in the Conte National Polymer Research Center facilities alone. In addition to the fairly common general faculties, (SEM, NMR, X-Ray, etc.), UMass, through the centers and institutes, has developed very specialized facilities such as clean rooms for polymers in electronic, photo-voltaic fabrication facilities for polymers in the solar cell and energy areas and several other area-specific facilities or equipment.

# Impact on Graduate Student Education and Faculty Perception

In 2006, the Head of the Department of Polymer Science and Engineering wanted to see if having a strong industrial center had an impact on the quality of education for the graduate student body. The UMass School of Education conducted a survey of the PSE graduate students to determine the impact of the CUMIRP program and the interactions with industry on their graduate education and career training. The results were very positive in that the majority of students saw the interactions with industry and the associated research broadened their educational experience (Mendoza, 2007). As a follow up to the student survey, the PSE faculty were contacted and interviewed about industrial interactions. Again, the faculty involved in the survey found the CUMIRP program and industrial interactions as very favorable from both the research and educational perspectives (Mendoza & Berger, 2008). In addition to working with students and post-doctoral fellows during their educational training, the Center assists with employment preparation providing workshops on resume preparation, interviewing skills and developing effective presentation skills. For those students and post-doctoral fellows seeking an industrial career, the Center is a well-used resource.

# Critical Transitions and Long Term Sustainability of CUMIRP

As described above the most critical transitions occurred during the 1990s when two things occurred: (1) the original I/UCRC model of operations was both reinvented and expanded in favor of one that was more responsive to more focused or applied interests and modes of support (e.g., contract project model); (2) the Center acquired and retained a full-time managerially-talented Director who had the vision and experience to implement the changes that would enable long term sustainability. Given its declining membership at that time, if these changes had not occurred during this period it is unlikely that CUMIRP would have survived, and highly unlikely that it would have reached the scope of operations that it currently enjoys. This case is an important example of a university-based research center that "re-invented" itself in response to a rapidly changing industrial constituency as well as a dramatically expanding field of research. As a result, a program that involved a few hundred thousand dollars of federal investment in the 80s and 90s has evolved in a stable R&D Center that has served hundreds of companies with zero NSF support after the initial investment period. This is both a technical tour de force as well as an example a longitudinal public policy success story.

> *This case is an important example of a university-based research center that "re-invented" itself in response to a rapidly changing industrial constituency as well as a dramatically expanding field of research*.

## Notable Technical or Business Accomplishments: Extensions beyond CUMIRP

Since the redesign in 1994, CUMIRP was interested in attracting more small and mid-sized companies to the program (hence the dues structure). Over the years, there have been a few dozen mid-sized companies and a handful of small businesses that have participated in the program. The small number of participants is mainly due to lack of available funding to support research directly and a lack of awareness of the polymer research at UMass. Because they became interested in the needs of these types of firms, UMass submitted a proposal to the NSF Partnership for Innovation program that focused on connecting local area small and mid-sized business with UMass science and technology. In 2009, UMass (Capistran, PI) was awarded the grant to work with local area companies and determine best methods for connecting a large research institution with small businesses to translate new technologies and create new business and jobs. It has focused on helping meet the needs of the local regional precision manufacturing industry to bring new technologies to these businesses to expand their markets and create new jobs. This program was active through June 2012 and has expanded to include the local polymer related companies and roll-to-roll processors.

## Future Challenges and Opportunities: A New Direction

The CUMIRP narrative is in many ways a tale of novel organizational changes being developed and implemented by visionary leadership, which in turn led to a new era of expanded financial support, industrially-relevant education for graduate students and a much larger group of involved companies. Despite various changes in R&D administrative leadership and policy directions at the University, the Center has been able to maintain its novel and more expansive vision of industry-university R&D cooperation.

While some graduated I/UCRCs have decided they needed to abandon the consortia-based format that is at the core of the I/UCRC model in order to sustain themselves, UMass and CUMIRP took a different path. They decided to create a different and more multi-faceted form of industrial consortia. In doing so they have celebrated their I/UCRC roots by inviting NSF officials to attend their anniversary celebrations. In our view, NSF would be well advised to consider at least experimenting with these procedures in its currently funded Centers.

Recently, CUMIRP has taken a critical look at where it is today relative to the changes in industry. Companies are looking more and more to universities to bring research closer to application and closer to their R&D platforms. Many federal agencies want to see more science and technology ‘breach the valley of death’ and make it to commercialization and the public sector (Markham, Ward, Aiman-Smith, & Kingon, 2010). CUMIRP is looking at these needs and what it might do to adapt yet again to respond to the current times.

Based on the history of CUMIRP, as well as the trajectory of failed Centers presented in Chapter 2, the most worrisome potential challenge is to maintain direction and leadership energy. CUMIRP is undergoing that challenge and a leadership change. The recent Director, Capistran, has accepted a new position as the Executive Director of the UMass Innovation Institute (UMII), a portal for all industrial relations across the Amherst campus. Given Capistran's long history with the CUMIRP program, much of what was developed and learned will be brought campus wide. The new CUMIRP Director will be charged with establishing the new direction for the Center. It will be critical that the positive directions, novel programs and open mindset that have succeeded in CUMIRP be reviewed, course-corrected and adapted to current-day industry. A smooth transition of leadership will be critical to CUMIRP's future success. Of course, maintaining vision, mission and energy over time and transition is always a vexing problem for any technology-based organization.

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# Chapter 4: Success through Fidelity to I/UCRC Model: Advanced Steel Processing Research Center Colorado School of Mines

aspprc.mines.edu

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## Introduction

The Advanced Steel Processing and Products Research Center (ASPPRC) has a 25-year history that encompasses founding, growth, adaptation to external changes and sustainable stable functioning. Founded in 1984 via a National Science Foundation I/UCRC planning great, it grew from six member companies at launch to over 20 members by its 7th year (1991). Today is has 28 dues paying members. Center consortium research is focused at the interface between users and producers of steel and thus the Center has attracted participation from a diverse group of steel producing and using companies including automotive, heavy equipment manufacturers, etc. It has clearly been a highly successful Center, in terms of industry involvement and international visibility in a technical field. Initially formed to support North American industries, the Center was well-positioned to respond to changes in the relevant industries due to corporate globalization and consolidation that evolved in the mid 90s. As a result, today corporate members represent companies from around the world. From a public policy perspective this Center is a notable success. It has operated independent of direct Federal or state[13] funding since 1993 and has been fully supported by industry member companies who reap benefits of new knowledge in an important technical domain.

## An Overview of the Center

In this section various aspects of the organizational history of the ASPPRC are described. These include changes in functions, structures and activities over the past 25 plus years of Center operation.

### *Organizational Context: The Hosting Institution*

The ASPPRC's home base is in the Department of Metallurgical and Materials Engineering (MME) at the Colorado School of Mines (CSM). In terms of the history of CSM it would be difficult to find a more substantively congenial and mission-congruent home for a Center focused on problem-solving research in the steel industry.

The Colorado School of Mines was founded in 1874 as a territorial school and became a state institution when Colorado became a state in 1876. The university was

[13] Consistent with most all I/UCRCs the Colorado School of Mines provides cost sharing through a reduction in the indirect cost rate applied to Center consortium funds.

established to support the growth of exploration, mining, production, and utilization of minerals as the US population moved west. The University focuses on engineering and the physical sciences and has a current student population of approximately 4,500, which is small compared to the other Colorado research institutions: University of Colorado and Colorado State University. Student admission is highly selective.

From the mission statement as written into a state statute:

> *…The Colorado School of Mines shall have a unique mission in energy, mineral, and materials science and associated engineering and science fields…*

Interestingly, of the 7 current members of the Board of Trustees, five have degrees in engineering or a physical science, and four of them from CSM.

CSM research funding is unique amongst most US universities with almost 40% of research expenditures based on corporate funds. Research funding at CSM has been growing rapidly to a level of $55.7 M in total research expenditures in FY2012 from all sources (NSF, 2012). Notably, the MME Department accounts for a significant percentage of the total. Clearly, the Center is in a high-achieving department in a university that also is primarily focused on areas of science that are quite congruent with the research program of the ASPPRC.

***The Organizational Context over Time.*** For 25 years CSM has been a supportive and adaptive organizational host for the Center. During founding and early growth, the CSM administration accommodated to the policies and procedures mandated by the NSF model (e.g., reduced indirect cost rates). There have also been positive initiatives taken by CSM leadership that have made the flourishing and continuity of the Center easier. As one notable example, Hill Hall, home to the Department of Metallurgical and Materials Engineering, was expanded and completely refurbished in 2000. The "new" Hill Hall provided significantly improved facilities for all departmental activities, including ASPPRC.

*CSM research funding is unique amongst most US universities with almost 40% of research expenditures based on corporate funds. Research funding at CSM has been growing rapidly to a level of $55.7 M in total research expenditures in FY2012 from all sources*

## Center Leadership

The Center was established in 1984 with a unique partnership between Profs. George Krauss and David K. Matlock, both holders of endowed chairs in the Department of Metallurgical and Materials Engineering. Through the 1970s they had worked closely together on several steel research projects. Prof. Krauss was the original ASPPRC Director. At the time ASPPRC was established, he had an international reputation in steel. Dr. Krauss also had extensive connections and a relationship with companies in the metals industries, understood the logic and mechanisms of the I/UCRC program, and was extraordinarily effective in quickly bringing the Center up to speed in structures and decision processes.

In 1993, Prof. Matlock became ASPPRC Director. Prof. Krauss continued as an active member of ASPPRC and the MME Department and retired in 1997. However, in retirement, he continues as an active participant in many ASPPRC programs. In 1997, Matlock had been at CSM for over 20 years, was a tenured Professor in the MME Department and had an international research reputation, particularly in the areas of mechanical properties of steels. Based on interviews with CSM senior leadership, the general perception is that the Center is a model of continuity of leadership.

Three significant faculty changes advanced by ASPPRC are noteworthy. In the late 1980s, Profs. Krauss and Matlock wrote a proposal to the Forging Industry Educational and Research Foundation (FIERF) to establish a chaired professorship, until recently held by Prof. Chester Van Tyne. The FIERF Professor is an active member of the ASPPRC staff and a member of the MME Department. Secondly, in 1997 on the retirement of Prof. Krauss, CSM was able to attract a top researcher in ferrous metallurgy, Prof. John Speer, who joined the MME and ASPPRC faculties after a successful career with the Bethlehem Steel Corporation. More recently ASPPRC provided CSM funds to allow the University in 2008 to hire Prof. Kip O. Findley, a new tenure-track faculty member. Prof. Findley, a critical new member of the ASPPRC staff assumed Prof. Matlock's teaching responsibilities. This latter hire was very unique as it provided the opportunity to hire Prof. Matlock's replacement long before he actually retires from CSM.

## *Center Leadership over Time*

During the 1984-present period it would be difficult to describe a Center that had a more wired-in leadership function and a seemingly effortless transition from launch leadership to ongoing direction. Krauss and Matlock were the leadership of the Center. Moreover, this continuity of mindset and goals paid off in a stability of organizational forms and processes that was a major asset as the Center successfully dealt with the dramatic changes in the steel industry (See below).

# Organizational Structures and Processes

The ASPPRC has adopted and adapted most of the standard features of an NSF I/UCRC, with some interesting organizational innovations of its own. The organization is led by a Director who is a full-time member of the MME faculty and has a full-time office manager for support. The Center Director reports directly to the MME Department Head and indirectly to the Vice President for Research and Technology Transfer.

*During the 1984-present period it would be difficult to describe a Center that had a more wired-in leadership function and a seemingly effortless transition from launch leadership to ongoing direction.*

There are two intersecting layers of self-governance, involving representatives from member companies as well as faculty attached to the Center. Like all high-fidelity I/UCRCs, this Center has an Industrial Advisory Board (IAB) that meets twice a year at the semi-annual ASPPRC review meetings, typically held in March and September, and includes one representative from each member company. Faculty members attached to the Center also participate in its meeting and the meeting is chaired by a senior member of the Center faculty, currently Prof. John Speer. The IAB reviews and approves Center operations, staffing, and budget.

To manage the diverse interests of the ASPPRC participating companies, research in the Center is divided in three categories based on products produced or purchased by participants: Sheet and Coated Steels (i.e. "sheet"); Bar and Forging Steels (i.e. "bar"); and Plate and Hot Rolled Steels (i.e. "plate"). Each member company indicates how they want their annual consortium fee distributed between these three groups and the summed distributions provide guidance for ASPPRC expenditures and staffing. Research on special alloys and stainless steels was a separate topic area in the early days of Center operation and still remains a critical part of the Center research, but topics in these areas are not included in one of the three primary research sub-groups. During the semi-annual review meeting, workshops are held in each of the three areas and all projects are reviewed. New projects are identified at special steering committee meetings that are scheduled at the direction of the IAB. Each of these is focused on a different product group (e.g., bar, sheet and plate), and a member company can send representatives to any or all of the Steering Committees. The menu of projects evolves over the years, influenced by both the changing needs of companies as well as the changing interests of faculty researchers. Of note, the success of ASPPRC has also been enabled by a Center policy – agreed to by members as a condition of joining – that calls for an automatic inflation escalator in membership fees of $2,500 every two years. However, another fiscal innovation has likely helped to keep members in the fold in the form of extra designated research (EDR) projects, funded in addition to consortium annual fees by individual ASPPRC member companies that address a company-specific problem, with results restricted to the company that funded the EDR project. While this accounts for only a small fraction of total Center spending (7 to 8%) it is seen as an important feature that retains members.

The primary technical discussions that lead to research direction and identification of new research projects are within the semi-annual workshops and steering committee meetings. However, direct meetings between Center representatives and companies, as part of the ASPPRC organized technology-transfer program also offer opportunities for project identification and are an extremely important component of ASPPRC operations. This Center is "in the field" a great deal, attending conferences, visiting member companies and making presentations at technical meetings. In comparison with most other Centers they do more of this than do their peers.

*Of note, success of ASPPRC has also been enabled by a Center policy – agreed to by members as a condition of joining – that calls for an automatic inflation escalator in membership fees of $2,500 every two years.*

## *Organizational Structures and Processes over Time*

For this Center the organizational structures and processes described above were identified at the inception of the Center and have remained essentially unchanged throughout the Center's history. The primary changes that have been experienced by the Center have evolved in changes in the industry itself due to globalization and consolidation.

# Technical Focus and Industry Participants

Since its inception the ASPPRC has concentrated on research "at the interface between producers and users of steel"(Matlock, 2009). The research agenda, in turn, has been focused since the inception of the Center around three major categories of steel products: (1) bar and forgings; (2) sheet and coated steel; and (3) plate and hot roll. User member companies range from automotive and heavy equipment to precision bearing companies. Steel producers include companies that are multidimensional in their processing capacities to others that are more specialized, such as mini-mills or precision casters.

## *Technical Focus and Participants over Time*

While the three-pronged research agenda has remained constant over time, the specifics of the project agenda has shifted as the member companies – particularly users – have addressed new and changing markets and customers. For example, because of both regulatory pressures and shifting consumer tastes, the auto industry has been moving toward vehicles that are both lighter (to enable fuel efficiencies and enhanced performance) and stronger (to meet safety regulations). For example, steel in roof pillars is stronger allowing the design of lighter-weight structures with increased safety. Other Center developments have led to steels for use in heat treated gears that operate at higher loads allowing for the design of smaller, more efficient, components of the automotive power trains, e.g. gear boxes, differentials, etc.

At the same time, an increasingly globalized economy has changed the physical location and nominal nationality of the member firms. Thus, at the onset of the Center all of the member companies were headquartered (and had most of their facilities) in the US or North America. Currently the membership includes companies in South America, Europe, the Middle East and the Far East. Moreover, the company names have changed, including those still based in the US, as a result of consolidations, mergers and acquisitions. Only Timken has been a member company of the Center since its launch.

# Assets: People and Physical Plant

In addition to the leadership of the Center discussed above, the ASPPRC has been blessed with outstand advantages in both people and physical facilities.

*At the same time, an increasingly globalized economy has changed the physical location and nominal nationality of the member firms.*

Regarding the former, the Center has had a cohort of faculty members that have been highly productive researchers generally, but individuals who have been enthusiastic about working in a context of a cooperative center. There is a lot more interaction with member companies that needs to take place as a center research agenda is shaped and executed than might be experienced with securing a government grant for a project. Faculty members, as well as students, need to have the mindset to make this personal investment in time and attention. Interestingly, there are also strands of intellectual heritage shared by core faculty members of the Center. For example, there is a strong Lehigh University linkage among several, and all are very active in national groups and organizations that deal with the science of steel. Over the years, this group of faculty members and the Director has been extraordinarily productive, with over 385 publications from the Center program, all available to member companies.

In parallel, the Center has been consistently active in producing human capital in the form of students completing graduate degrees; with roughly 4-5 Masters degrees and 2-3 PhDs every year. Many of these work on Center activities and often their thesis or dissertation is directly linked to a Center project selected by members. Nearly 200 graduate students have been affiliated with the Center.

Over the past 25 years the laboratory facilities available to the Center have increased in scope and sophistication. It should be noted that essentially none of the investments in physical infrastructure come from member firms. Currently the research facilities have capacities to conduct metallographic characterization, do hot reformation studies, perform tension and compression testing, conduct formability testing, do forming of flat and bar stock and stretching of sheet metals and conduct fatigue and toughness studies.

## *Changes in People and Physical Assets Over Time*

The people and physical assets of ASPPRC have paralleled its success in attracting and maintaining member companies worldwide. There are more graduate students than in the early years with increasingly notable credentials. Moreover, program graduates have migrated to increasingly influential positions worldwide.

It is perhaps in the area of physical facilities such as laboratory space, equipment and facilities that the growing success of the program is illustrated.

## *Evidence of Success*

Over the past two years alone Center-affiliated faculty, students and graduates have won eight different “best paper” or “best research project” awards from a variety of professional organizations including Association of Iron and Steel Technology. During the same period four students were awarded fellowships from various organizations including NSF, Department of Energy and Japanese Society for the Promotion of Science. Since 2003, John Speer, a professor of metallurgical and materials engineering, has been working with students to formulate a process called "quenching and partitioning" (Q&P) in which steel is heated and cooled in such as a way as to create a novel microstructure that is at once stronger and more formable than previous steels. One sponsor from the Chinese steel industry, Baosteel, is currently evaluating the process in its own facilities, eyeing Q&P steels as next-generation lightweight materials for use in automobiles. Increased demand for Center research and graduates are anticipated based on growth in wind energy, nuclear energy, off shore oil production and natural gas pipelines.

## Critical Transitions and Long Term Sustainability of ASPPRC

Every I/UCRC has had to make and manage changes in some aspect(s) of its operations in order to continue to maintain and grow its agenda and its financial health. Centers differ in terms of which features are critical for survival. For the ASSPRC, leadership was nearly constant over the years, basic organizational structures and processes changed little after the launch and the main categories defining the research agenda have changed little over 25-plus years. However, addressing the following transitions have been critical:

### *Growing and Maintaining an International Center*

As noted above, the geographic home of member companies has changed significantly over the history of the Center, from one that was concentrated in North America to one that includes companies from around the globe. Two transition challenges have accompanied this trend. One has been to blend several different mindsets or expectations about how universities and companies interact around R&D. In the US and Canada, for example, there is a fairly robust experience of universities and companies being involved in collaborative research, either in arrangements such as embodied in the NSF cooperative center model, in straight contract research relationships or in partnerships to work together to commercialize[14] early stage research by licensing, startups and other relationships. Thus, some US universities, and in particular CSM, received significant research support from industry. The environment is quite different in much of Europe for example, with a much more bureaucratic approach to the allocation of mostly government funds, and in other settings a hands offs relationships between university and industry. As the ASSPRC added member companies from other countries, these kinds of policy and cultural differences have been addressed and ASPPRC has responded to the specific needs expressed by individual companies. For example, visiting scientists from corporate facilities located outside the US have spent time at CSM and ASPPRC to participate in Center research in order to gain insight on Center operations, advance specific research topics, and in some cases obtain advanced degrees.

In parallel with the accommodations discussed above, there is the issue of maintaining a communicative partner relationship with member companies strewn across the globe. It is notable that the ASSPRC has devoted extensive effort to attending meetings and conferences as well as visiting member companies as part of the organized technology transfer program. Arguably, this has been a critically important tactic for sustaining a stable

[14] The Bayh-Dole bill of 1980 of course enabled much of this area.

cadre of member companies generally, but has in many cases been particularly useful with international companies.

## *Keeping Track in an Era of Corporate Reshuffling*

ASPPRC's success has been in large part dependent on the Center staff getting to know individuals within sponsor companies so that when primary champions retire or change responsibilities, the interactions between the Center and the companies continue. For any consortium-type program it is very important for the research-performing organization to be knowledgeable about who are the champions, clients and funding decision-makers within member companies. This is a critical issue, particularly given the dynamics of private companies – people move up, people move out. However, it is particularly acute in companies that go through a merger, acquisition or other organizational reshuffling.

This in fact was the environment in the international steel industry as well as among the major users of steel products during the life span of ASPPRC. As noted above, the Center has been very adept and nimble at replacing departed and disappeared member companies. Over the 25-year history of the Center a total of more than 60 companies have been supporting members. Many former sponsors still participate as part of a new company that has evolved out of corporate mergers. The ability to anticipate and act quickly in this market environment is an important key to the sustainability of the Center.

This success in shifting with the tides has several components. For one, the leadership and faculty members associated with the Center have knowledge that goes beyond R&D issues per se; they know the industry that they serve. They work directly with individual companies in a variety of contexts: visits, conferences, and national committees.

> *Many of former sponsors still participate as part of a new company that has evolved out of corporate mergers. The ability to anticipate and act quickly in this market environment is an important key to the sustainability of the Center.*

## Conclusions from the ASPPRC Case

This Center has carved out a commendable record in sustaining an industry-supported research center for more than 25 years. In most respects, what it does and how it operates closely follow the model that the National Science Foundation developed and promulgated in the 1980s and afterwards (Gray & Walters, 1998).

However, this Center has been particularly adept in making adjustments to a rapidly changing technical and business environment. This seems to have been enabled by the following:

- Having an unusually stable leadership cohort that enabled a disciplined and constant attention to developmental issues and program sustainability
- Getting on top of the internationalization of the steel industry as well as the shifts in product needs

- Building and maintaining an aggressive technology transfer program and early-warning function that went far beyond the more typical conference-attending behavior of academic researchers
- Benefitting from a consistently supportive university organization at CSM where industry-based research is viewed as extremely important.

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# Chapter 5: Transformation of a Small University I/UCRC: Center for Advanced Communications

## Villanova University

*www.villanova.edu/engineering/centers/cac/*

**Louis Tornatzky, Denis Gray, and Lindsey McGowen**

## Introduction

The Center for Advanced Communications (CAC) has been operating in one form or another for 20 years. It was founded in 1990 as a National Science Foundation I/UCRC, with member companies and much of the same organizational and procedural processes as any other NSF Center. However, from the beginning it was tied to a state technology-focused economic development organization – the Ben Franklin Technology Partners – and as such had somewhat atypical relationships with small companies and state-based enterprises in Pennsylvania. The CAC graduated in 2000 after 10 years of able leadership by Dr. Joseph DiGiacomo, who passed away in 2002 and, and was succeeded by Dr. Moeness Amin a fellow Villanova faculty member in the Electrical and Computer Engineering Department.

The Center has survived, and flourished in terms of the scope and breadth of its R&D. However, the survival strategy implemented by Dr. Amin has transformed the CAC into a very different kind of Center than the one that was operated during the decade of the 90s. In addition to being a successful Center, the CAC is an excellent and rare example of how to sustain and grow a research operation in a smaller university that is by no means nationally competitive in terms of sponsored research in science and engineering.

## An Overview of the Center

This section describes the organizational history of the CAC, particularly those fairly dramatic shifts that occurred after the death of the founding Director.

### *Organizational Context: The Hosting Institution*

The CAC host organization is Villanova University, a private Catholic institution that was founded in 1842 and has a national reputation as a high quality primarily undergraduate university (e.g., *US News and World Report,* #1 regional ranking for Masters category). The University has four undergraduate/graduate colleges: College of Liberal Arts & Sciences, School of Business, College of Nursing, the College of Engineering (which hosts the CAC), plus the School of Law. There are approximately 6,300 enrolled undergraduate students at Villanova, with a total student population of slightly over 10,000 in addition to its non-credit continuing education programs.

It should be emphasized that the mission of Villanova is overwhelmingly focused on student education and community engagement, and sponsored research is given minimal, but in the past decade, accelerating acknowledgement. In fact, the mission statement and objectives of the College of Engineering are very focused on the substantive and moral impact that its students will have, as illustrated in this introductory statement to the College Objectives (2012):

> *The College of Engineering strives to prepare its graduates to understand their roles in a technological society, to make constructive contributions to it, and to provide ethical and moral leadership in their profession and communities. It accomplishes this by various methods, but primarily by integrating into the curriculum the values and morality of the University's Augustinian heritage. In addition to being professionally competent, graduates are expected to have an understanding of their professional and ethical responsibilities, the impact on engineering solutions in a global and societal context, knowledge of contemporary issues, and an appreciation of humanistic concepts in literature, the arts, and philosophy.*

In this context the role of faculty research is primarily as a vehicle for professional development to better serve students and enable the Augustinian goals of community improvement – although recent (2003-2010) the current academic strategic plans have given much greater emphasis to research as an essential role of the University. These contextual aspects of Villanova and the College of Engineering within the University are important influences on how the CAC evolved in terms of its organizational structures and processes.

The College of Engineering is also ranked by *US News and World Report* #10 nationally in terms of its undergraduate engineering program, although it does offer a combined Bachelors and Masters program, as well as Master's degrees in all programs in the College. At the time the Center was launched Villanova University did not offer a PhD program in Engineering. According to National Science Foundation institutional profiles for FY 2007 Villanova reported a total of $9.077M in federally financed R&D expenditures, of which most ($3.666M) was in the College of Engineering and most of that ($1.657M) was in Electrical Engineering. From all sources, Villanova reported $10.473M in research expenditures, with $735K (roughly 7%) coming from industry (NSF, 2012a).. Federal obligations (not expenditures) totaled $3.318M, with nearly all of that coming from DOD ($1.6M) or NSF ($0.95M) (NSF, 2012b).

As should be obvious from the above data, Villanova is not by any stretch of the imagination a research-intensive institution in terms of how those designations are usually bestowed. In fact, it barely cracks the top 300 ranking in the NSF database of Academic Institutional Profiles (NSF, 2012a). That said it is indeed an accomplishment for Villanova to mount the research talent, lab facilities and entrepreneurial mindset to successfully maintain, and in fact grow, the CAC. Even more interesting perhaps are the strategies and tactics developed to keep it alive and thriving.

# Center for Advanced Communications

There have been two quite distinct "eras" in terms of the organizational structures and processes of the CAC. During the 1990-2002 period, the Center functioned mostly along the lines of the traditional NSF I/UCRC model. That is, there were member companies, each of which participated financially through a dues structure and that sent representatives to semi-annual meetings in which the project agenda was determined collectively and reports on completed projects discussed. The university showed its support for the Center by not charging indirect on membership fees. It had an Industry Advisory Board that followed the policies and procedures that were standard in that time period. Faculty members and graduate students had primary responsibility for executing the project agenda. Like most I/UCRCs from this era the Center involved faculty from a single university.

> *…it is indeed an accomplishment for Villanova to mount the research talent, lab facilities and entrepreneurial mindset to successfully maintain, and in fact grow, the CAC.*

There was one significant deviation from the standard model I/UCRC during that early period. The Center at Villanova had a strong working relationship with Pennsylvania state government, in particular the Ben Franklin Technology Partners (BFTP). This program provides funds to universities in the state to enable them to work closely with state-based technology companies. In the context of the CAC, the BFTP investment was used for short-term projects ranging from $10-15K and with wide-ranging focus areas. BFTP would approach the Center with a possible project, and the Center Director would then look for a faculty member who was willing and able to undertake the project. The projects covered a relatively wide range of engineering disciplines. These procedures are no longer operative, as the CAC no longer accepts any projects outside its focus areas.

During its NSF-supported lifetime, CAC's funding from all sources ranged from $250,000 to about $500,000 and membership from five to ten members. At the time NSF funding ended and a new Director assumed leadership, CAC membership had declined to none.

## *The Center over Time*

Coincident with the change in leadership of the CAC, precipitated by the death of the founding Director, it became in effect a different kind of organization. It transitioned from a Center that operated primarily on a consortium model, with shared governance between Director, faculty and industry participants, to one in which a series of essentially parallel contract research projects were executed. The consortium model no longer exists, and in fact was disbanded when Dr. Amin assumed Center Directorship.

In terms of the scope of R&D that can be executed under those consortial and contract kinds of organizations, they are roughly equivalent – person-days of research effort are limited by demand and by the amount of research staff available to execute the work. Nonetheless, the quality of the relationships among industry participants and between university performers and industry participants is quite different, comparing the consortium versus the parallel grants and contracts model.

> *It transitioned from a Center that operated primarily on a consortium model, with shared governance between Director, faculty and industry participants, to one in which a series of essentially parallel contract research projects were executed.*

The consortium organizational structure (essentially the NSF I/UCRC prescribed model) is one which encourages and in fact requires interaction among industry partners, as well as an active role on the part of Center leadership in promoting agenda-setting and collective project reviewing by the member companies. The parallel contract research model, is one in which each company participating in the Center negotiates with the Center leadership what is in effect a private, more proprietary agenda of work. These are very different kinds of organizational forms. However, it should also be emphasized that both kinds of organizational models can work in an academic setting. The contract research model can sometimes involves a more hectic pace of project work with the overall program including short-time projects, long-term projects and issues of allocating research personnel. In the consortium (I/UCRC) model the intensive interactions tend to be confined to those periods when an annual agenda of shared work is discussed or reviewed. In an academic setting, it can be much easier to execute and maintain a consortium model than a contract research model.

Regardless of these operational differences, from a strictly financial standpoint, it is clear the transition has gone very well. At the time this report was prepared, CAC annual revenues were approximately $2.5million. These funding revenues stem from various types of industry and government awards that can range from only $5K to a total of $ 1.5M a year.

This is what makes the CAC case a very interesting situation. As a function of differences in the experience and orientation of the two principal Directors to date, a rather abrupt change in organizational structure of the Center was made and the CAC not only survived, but also significantly increased its annual revenue. Much of the several-fold increase in revenues is attributable to the new Director's active pursuit of individual project funding and in parallel, his active technical leadership as PI and Co-PI on projects. In addition to growing funding from Industry, the CAC, since 2002, has been awarded several grants and contracts from federal research agencies. These include the NSF, via back-to-back awards from the Partnerships for Innovation program, the Office of Naval Research, Army Research Lab, Air Force Office of Scientific Research, Air Force Research Lab, US Office of Research and Development and DARPA.

> *Much of the several-fold increase in revenues is attributable to the new Director's active pursuit of individual project funding and in parallel, his active technical leadership as PI and Co-PI on projects.*

# Issues of Change and Stability

As indicated above, CAC has evolved into a very successful university-based center. Below we discuss some of the factors that were critical to making the transition successful and some of the consequences of these developments.

## *Center Leadership*

The original Director of CAC was Mr. Joseph DiGiacomo, who died in 2002 approximately 12 years after the Center was founded. As noted above, Dr. Moeness Amin replaced him thereafter. It should be emphasized that there have been two very different "leadership eras" for the Center. During both periods, the Center remained under the College of Engineering, and its Director reported only to the College Dean, and not to a Department Chair. When Mr. DiGiacomo was succeeded by Dr. Amin, the modified I/UCRC model described above was abandoned, and the Center became a contract/grant-funded organization as opposed to one that was primarily funded by member dues. Dr. Amin came out of this orientation and was very effective in landing grant and contract monies from a range of NSF and other federal programs, as well as expanded contract revenues funded by individual companies in electronics, communications, and signal processing fields. However, in order for this new strategy to achieve these results a number of complimentary physical, organizational and human resources changes and investments had to be made.

## *Physical Infrastructure*

A significant enabler of CAC's success was the establishment of five state of the art research labs, corresponding to five well-defined research tracks under the Center. The labs serve as a magnet for attracting external funding and sponsorship. They have become instrumental for conducting and validating research ideas and newly devised techniques and algorithms. They also attract international visitors to spend short and long stays at CAC. Each of the five Labs has a director who is responsible for maintaining, upgrading and growing the lab. As described by the Center Director, the development of the lab complex was critical:

> *I was convinced that this is a MUST do. I asked the University for additional space to house three new labs, which was granted. Two of the labs share the same space. The forth lab was already operational under ECE Department, but was moved to be under CAC, due to its pertinence to CAC research. The money for establishing the new labs came out from CAC research contracts/grants as well as two DOD DURIP successful grant proposals, exceeding $500,000. I was the PI on both of these grants.*

All labs work individually and in concert and support research in the five areas that define the Center: Radar Imaging, Antenna Research Lab, Wireless Communications and Positioning, Acoustics and Ultrasound Lab and RFID. Each laboratory has its own director and the revenue stream from grants and contracts supports lab operations. Each Lab Director works very closely with the Center Director and consults with him regarding research directions and external funding opportunities. Initial establishment of the labs was also enabled by a series of DOD grants, and the labs are continuously updated via both direct charges for equipment from external sponsorship and from overhead distribution coming back to the Center. Illustrative of the capacities of the lab facilities, the Antenna Research Lab has measurement capacities to assess pattern and gain of antenna structures at a level of precision that is rare in university-based facilities. The Radar Imaging Lab is a multi-million dollar facility which, according to DARPA is unmatched by other similar facilities at any US academic institution.

## *Staffing*

To accelerate and cement this model, and in view of the undergraduate emphases of the university and the relative light volume of research conducted by the faculty in the focus area of the Center, Dr. Amin moved to hire three Research Professors, all supported from external funding. Two of these professors currently head two of the CAC's most productive research labs and have been with the CAC since 2002. Dr. Amin concluded that given the heavy normal teaching loads at an institution such as Villanova, hiring Research Professors was the most viable route to sustain and grow a research program. These Research Professors are now among the most productive faculty in the College of Engineering and they advise M.Sc. and PhD students as well as assume the role of PIs and Co-PIs on their own grants and contracts. Each of the research professors provides scientific leadership in one tract or domain emphasis of the overall program (e.g., radar signal processing; wireless; antennas; RFID), with post-docs providing additional staff along with PhD candidates and Masters students.

In terms of administrative arrangements, the Research Professors are issued one-year contracts, contingent on external funding availability for that year. Each year the Center provides the University with information on how the CAC, through its grants/contracts, would cover their salaries before the employment contracts are issued. In this respect, in "dry years" it kicks in overhead returns to CAC to fill out the annual contracts for the Research Professors. This juggling is obviously a recurring managerial and fiscal challenge. As the Center Director describes the process: "It is not easy! But we did it over so many years now!"

*These Research Professors are now among the most productive faculty in the College of Engineering and they advise M.Sc. and PhD students as well as assume the role of PIs and Co-PIs on their own grants and contracts.*

## *Organizational Structures and Processes*

For the CAC, the organizational structures and processes changed dramatically over a short period of time, but have stabilized and allowed a somewhat different kind of Center to survive and prosper long after the organizational models of the NSF I/UCRC were mostly discarded and its financial support ended.

One discarded I/UCRC organizational feature in particular had significant and positive implications for the financial future of the re-engineered CAC at Villanova. Virtually all of the I/UCRCs that have been established under the NSF banner have charged industry participants significantly reduced or no indirect costs on the research fees. This has been a powerful draw for companies that has been grudgingly agreed to by universities. When the CAC at Villanova went to a grant/contract model, an agreement was worked out with the University that an indirect cost rate of 30-50% would be levied on all CAC projects, with the Center keeping almost half of those monies. As long as new grants and contract came in the University received income, as did the Center. This enabled it to weather downtimes between projects, cover administrative assistance and secretarial costs, invest in lab infrastructure and equipment and otherwise enhance the research program. These arrangements were developed immediately after Dr. Amin assumed the role of the Center Director, which was the same time that the I/UCRC member structure model was disbanded.

## *Technical Focus*

To its advantage the CAC has throughout its history focused on a domain of science and technology, information systems and communications, that has concurrently with the history of the Center, witnessed dramatic changes and advances. The development and growth of information technologies over the past few decades has been one of the great success stories of the late $20^{th}$ and early $21^{st}$ centuries.

> *…an agreement was worked out with the University that an indirect cost rate of 30-50% would be levied on all CAC projects, with the Center keeping almost half of those monies.*

As articulated and pursued at the CAC, this agenda has been expressed in several areas of R&D, which correspond to somewhat different but overlapping external partners. These include digital and wireless communications, GPS, antennas, microwave and RF microelectronics, radar and RFID. Industry participants have included large corporations with a major business interest in these areas as well as smaller more specialized enterprises. The focus areas of GPS, radar, and RFID were introduced when Dr. Amin assumed the Center Director position and, since then, have been an integral part of the CAC research portfolio.

## *Industry and Other Partners*

Throughout its history there has been a geographic tilt in the composition of its industry partners that has been influenced and enabled by working agreements between the CAC and the Ben Franklin Technology Partners. This in effect directed a fraction of CAC work with industry to involve smaller companies located in southeastern Pennsylvania. Interestingly, the Ben Franklin relationship, under Dr. Amin’s leadership evolved to be more of a two-way street. Now, the Ben Franklin Technology Partnership (BFTP) can receive support from CAC as part of its involvement with other externally funded projects.

Roughly coterminous with the changes in leadership and organizational processes in 2002 described above, there was also a shift in the composition of Center participants. Rather than operating as a tight club of I/UCRC-related member companies plus work with and for Pennsylvania-based companies enabled by the Ben Franklin relationship, the Center began to dramatically expand its range of participants – in terms of the range of both private and government funders, as well as research-performing partnerships.

As stated earlier, industry collaborations have expanded beyond the boundaries of BFTP's small short-term agreements of approximately $10-15K for individual projects to much longer and more involved contracts, independently sought out by CAC through its direct contact with mid-size companies and large corporations. The BFTP supported projects have included work with Artisan Laboratories Corporation, Smart & Complete Solutions, LLC, Navmar Applied Science Corporation, Teletronics Technology Corporation, and VerdaSee Solutions, Inc. The industry-funded projects outside the BFTP agreements have included Comcast, Sarnoff, Cellnet + Hunt, Boeing Company, Eureka Aerospace and many other companies. It should also be noted that the back-to-back NSF PFI awards enabled the CAC to expand work in two distinct and orthogonal technologies, namely RF Communications and Acoustic/Ultrasound Diagnostics. In part based on this support, the Acoustics area became the Center's fifth lab.

*The Center began to dramatically expand its range of participants – in terms of the range of both private and government funders, as well as research-performing partnerships.*

As another example of partnership relationships, a significant grant from the NSF Partnerships for Innovation program placed the Center into the position of acting as a leader of a coalition of federal labs, academic institution and several information technology companies. The Center also functioned as a technical partner with startup companies to secure SBIR and STTR funds, and via a $1M DARPA award, work collaboratively with a select group of companies that was developing new technologies in the radar imaging area. DOD-related funding agencies have been prominent over the past several years, including contracts or grants from the Air Force Office of Scientific Research, the Air Force Research Lab, and the Army Research lab, the Naval Surface Warfare Center, the Naval Undersea Warfare Center and the Office of Naval Research. All of these funding agencies have a heavy mission investment in advanced information systems.

In terms of maintaining and in fact enhancing the scope of R&D performed by the Center, this is a commendable record of accomplishment. What has changed in parallel to some undetermined degree is the field of application and potential commercialization. An important theme of the historical I/UCRC program was that the research agenda was mostly influenced by private companies, presumably competing in free markets, and that the range of commercial applications would be market-driven. The caution of any research activity that is predominately steered by defense interests is that the utilization of research findings in civilian application may be slower. Nonetheless, enhancing the defense capacities of the US is also an important mission goal of the Federal government and some of the research problems addressed by the CAC may be particularly germane to DOD issues.

With the expansion of private and agency-funded grants and contracts, the CAC became much more open to working with other universities. In the past several years the CAC has funded, through subcontract agreements, work performed at the University of Pennsylvania, Drexel University, Temple University, Widener University, University of Tennessee, Gwynedd-Mercy College, and Bucknell University. There is no overhead charge on these subcontracts. In most cases, the partner will participate in writing sections of a proposal; in others, the CAC Director would decide about subcontracting needs after the money is received, and then make a case to the sponsor. In short, when it makes sense CAC can and does act as a virtual university consortia that involves research performers from a variety of other universities.

## Academic Integration and Graduate Education

Aside from a core group including the Director, an administrative aide and the Research Professors, staffing of the Center is continuously in flux and dependent on the ebb and flow of contracts and grants. In addition to the core group, there is one faculty member who is actively involved in the Center on a continuous basis and several others who may be pulled into a particular project depending upon the substance and scope. This capability was greatly enhanced by the creation of a PhD in Electrical Engineering in 2003. In fact, the volume and scope of research conducted by the CAC played an important and early role in arguing for the need for the PhD program as by demonstrating that it could provide research venues and funding from sponsors for dissertation research. On average, there are two Masters students and one PhD student graduating each year who worked on CAC sponsor projects. There are now more than 20 students enrolled in the four Departments of the College of Engineering.

In effect, there is a total staff "pool" that comprises 9-12 PhD-level individuals, plus graduate students, and to some degree, undergraduate students. Villanova administration has enabled this kind of flexible personnel deployment system by establishing procedures for faculty members to be involved in Center projects. In terms of teaching load, the same arrangement and release time, in essence, is given to the faculty member irrespective of the nature of the project, (i.e., whether the project proposal was submitted and secured under or outside the CAC).

> *…the volume and scope of research conducted by the CAC played an important and early role in arguing for the need for the PhD program as by demonstrating that it could provide research venues and funding from sponsors for dissertation research.*

## Center Outcomes and Impacts

It is worth noting that the CAC has done more than survive and prosper financially since graduating from the I/UCRC program, it has also been recognized for the quality of its research and it has produced a variety of scientific, technological and socially valuable outcomes. For instance, CAC's faculty and students have made advances in Through Wall

Radar Imaging that has been recognized via various awards including: *2009 Individual Technical Achievement Award from the European Association for Signal Processing*, the *2010 Best Paper Award from the IEEE Signal Processing Society* and the *2012 best paper award from the IEEE Sensor Array and Multichannel Signal Processing Workshop.* The Center's wireless networking work was recognized by a *Best Paper Award* at a *2009 International Signal Processing for Communications Symposium.* CAC work has also contributed to the commercialization efforts of several small firms. For instance, CAC worked with Ablaze Systems, LLC to develop a wireless system for restaurants that has been adopted by over 80 restaurants including nationally known franchises TGI Fridays and Applebee's. It has also worked with firms that are developing products for the sports industry (a sensor) and the pet industry (RFID detection application). From an educational standpoint, CAC students have won *Graduate Medals* four years running from the College of Engineering and many of their graduates have taken job with leading commercial and defense companies.

## *Summary*

As noted above, the transition from a traditional I/UCRC – that was having some difficulty in retaining member companies under the rules then operative – to a program that is significantly more entrepreneurial and oriented toward a changing portfolio of grants and contracts, was a major and important shift. It is not clear whether the original program design was fiscally and operationally sustainable in its original form, in the context of a university that is not research-intensive and not particularly oriented toward graduate education at the doctoral level. Thus, one of the great accomplishments of the CAC is to mount and sustain a modestly-sized, but nonetheless visible, viable and highly productive, research center in the context of a small, liberal arts oriented Catholic university with essentially no history of significant sponsored research.

*Thus, one of the great accomplishments of the CAC is to mount and sustain a modestly-sized, but nonetheless visible, viable and highly productive, research center in the context of a small, liberal arts oriented Catholic university with essentially no history of significant sponsored research.*

## Critical Transitions and Long Term Sustainability of CAC

In contrast to most I/UCRCs where programmatic and fiscal transitions are relatively gradual, and solutions are developed over a period of a few years, the CAC in 2002 responded quickly to an abrupt situation – the death of the founding Director – and a context in which it was not clear how the program could survive under the I/UCRC model. There were three factors that have enabled the CAC to survive for 20 years and in fact thrive, in terms of both scientific and fiscal criteria.

## *The Right Director at the Right Time*

In 2002 the CAC has been in operation for 12 years and had few member companies, along with Ben Franklin Technology Partners participation. Its annual budget was mostly that from the NSF I/UCRC support, with very limited research and funding activities outside the perimeter of monies given by BFTP small projects and NSF and members. There were some cracks emerging and signs that it would be difficult to grow the scope of the program.

The appointment of Dr. Amin was critical in insuring the survival and growth of the Center. It should be noted that prior to taking over as CAC Director, Dr. Amin had limited involvement in the Center program. But he observed how the Center needed to strengthen the level of technical depth and scholarship which are key to establishing credibility and confidence in the Center's abilities and deliverables when working on very challenging and pressing problems that require long term, continuous efforts and research. Dr. Amin had long been a successful and well –funded researcher, competing for federal agency grants and industry contracts. When he took over as CAC Director, his plan was to enhance the Center stature in the region and make the Center known among government circles and universities.

*The appointment of Dr. Amin was critical in insuring the survival and growth of the Center.*

## *The Right Organizational Model at the Right Time*

While a highly competent, energetic Director can accomplish a great deal in growing and maintaining a Center that is focused on a portfolio model of grants and contracts, there are also organizational understandings with institutional leadership that are very important. The new organizational model needed to address two principal problems: (1) growing a flexible pool of research-performing personnel; and (2) enhancing the financial situation of the Center so as to enable year-to-year fiscal stability. The new organizational model that was being developed in the 2002-2003 timeframe needed to involve other Villanova participants outside of Dr. Amin and faculty members that had been historically been associated with the Center, as well as be more viable from a financial perspective.

Regarding the former issue, given the limited resources at Villanova in terms of student and faculty participation in the Center, the research program needed to be expanded. Several changes in this area were implemented. One was the addition of three Research Professors, dedicated to essentially full-time research careers. Second was the development of working relationships with other universities in the region, which enlarged the de facto pool of researchers that could potentially be deployed on projects. Third was the establishment of a PhD program in the College of Engineering, which created the opportunity of using graduate students on Center research projects. Fourth was the increasing practice of hosting Post-Doctoral researchers that could also be deployed on Center projects.

Nonetheless, these new and novel approaches for enhancing the Center manpower pool could not be implemented without changing Center finances. To put things in perspective, the funding necessary to cover two Research Professors and four Postdoctoral

Fellows currently employed by the CAC is about $600,000/year, not counting any students, faculty, or administrative cost. That could not be possible at all with the I/UCRC model in place. In addition, budget support for the Director and Center faculty for writing, submitting, and winning higher levels of grants and contracts was essential. As noted above, an important key to current Center success was moving to an indirect cost rate which is shared with the Center itself. This ended up being a 30-50% indirect rate charge, with almost half of that going to the Center.

## *Building Lab Capacity*

At the time of the leadership transition the research labs available to the Center program were adequate but not exemplary. One of the priorities of the new leadership was to enhance the scope and quality of the lab system as a vehicle to attract external funding partners, private and public. A parallel goal was to use the labs as a venue that would attract researchers and students to affiliate with the program. As described above, over the past 8+ years significant improvements have been completed in terms of space, equipment and capacity. The funding mix for these changes has largely been from external grants.

*Nonetheless, these new and novel approaches for enhancing the Center manpower pool could not be implemented without changing Center finances.*

# Conclusions from the CAC Case

This Center is an interesting case that is of particular importance to chief research officers or provosts in smaller universities that nonetheless have aspirations to mount significant research programs in areas of niche expertise. However, one lesson that should not be taken away from the CAC case is that the I/UCRC model, or other manifestations of a multi-client consortium approach to industry-sponsored research, is that it cannot be successfully executed in a smaller institution. It can and has been done by a number of smaller institutions. Usually, the scope of the research portfolios executed by the junior partner is smaller, the number of involved faculty researchers is less and there are ongoing struggles about enabling policies and procedures. Nonetheless, it is possible.

However, the CAC is a different countervailing model. By embracing the I/UCRC model Villanova was able to build its scientific capacity and establish its credibility to conduct high quality and industrially relevant research. With the leadership of a very productive, forceful and, from a grantsmanship perspective, entrepreneurial Director a significant new partnership-oriented research program was launched and sustained. These activities have helped enhance Villanova’s graduate engineering program and produced important scientific, technical and educational outcomes. However, the efforts of a forceful competent Director alone may not carry the day. There also needs to be “give” on the part of the hosting institution in terms of policies and procedures. Two areas that seemed particularly important in the CAC case were flexible policies on indirect cost sharing on grants and contracts, and enabling approaches to adding research-dedicated PhD-level researchers to the mix. At Villanova this included the creation and recruitment of Research Professor positions, dedicated to the CAC research domain, as well as the incorporation of post-docs, graduate students and researchers from other contiguous universities into the manpower mix.

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# Chapter 6: I/UCRC as Capacity Building Strategy for State-based Technology Economic Development: Center for Welding Research/Edison Welding Institute Ohio State University/Ohio Edison Program

http://ewi.org/

**Louis Tornatzky, Denis Gray, and Lindsey McGowen**

## Introduction

This case is a unusual example of an NSF I/UCRC that was reasonably successful and growing as such, but which relatively early in its history contributed to the creation (with NSF staff as midwives, and state government funding) of a different and larger organization. Edison Welding Institute is an internationally prominent not-for-profit institute that operates in a much larger context and developed a more entrepreneurial kind of business model. Moreover, that "successor" organization has survived and grown over 30 years, and is an excellent example of how a well-grounded academic organization like an I/UCRC can morph into something that has much larger ambitions. It is also an example of how the evolution of a center can be considerably altered by economic and political events in its environment.

## An Overview of the Center as It Became an Institute

In this section we will describe various aspects of the organizational history of the Center for Welding Research (CWR) as it became the Edison Welding Institute (EWI). This will include changes in sponsorship, foci, functions, structures and activities over the 30-year period in which one transitioned to the other.

### *Organizational Context: The Hosting Institution*

The Center for Welding Research (CWR) was an early NSF I/UCRC, founded in 1980 under the leadership of Professor Roy B. McCauly, who had headed the Department of Welding Engineering at The Ohio State University for many years. He was assisted in these early formation efforts by Dr. Karl Graff, a senior professor, who went on to become Chair of the department in 1979. At that time Ohio State was a top-50 university in terms of research expenditures having major strengths in its College of Engineering, including a nationally unique Welding Engineering Department. The university was located in a state that was strong in durable goods manufacturing and in a city that was home to state government as well as a nationally prominent technical organization, Battelle Memorial Institute.

A number of factors helped set the stage for the initiation and development of CWR.

First, the College of Engineering was in the process of rethinking its own organizational mission and strategy including a renewed focus on opportunities for Welding

Engineering. At the time the Welding Engineering Department had the unique status of offering the only BS degree in welding engineering in the country. However, due to retirements, the department had declined in size to only three faculty slots when Dr. Graff transferred from another department to head Welding Engineering. In 1978, the Engineering Dean launched an initiative entitled "The Engineering College Alliance with Industry" and in parallel challenged the Welding Engineering Department to come up with a plan for creating a welding center.

At the same time, events like *Welding Research and Development: Problems and Opportunities* meeting held in Henniker, New Hampshire in 1976, were providing an impetus within industry for the development of a national welding research strategy. In fact, a significant component of the meeting's agenda was how to develop a national welding center, much along the lines of those operating in Europe at the time.

Subsequently, various funding and organizational venues for an industry-focused center were examined by OSU representatives, with interest finally focusing on the NSF I/UCRC program. During the latter part of 1979 three additional faculty members were added to the Department of Welding Engineering and a planning grant proposal was submitted to NSF for an I/UCRC. This led to a full proposal for a Center with six founding members and a subsequent award of $1M over a five-year period by NSF. The first meeting of an Industrial Advisory Board was held in July 1980, and the Center was launched, with seven initial candidate projects, which were subsequently consolidated to five. During 1980-1982 recruitment of new members and expansion of the Center moved slowly. Around this time Dr. Graff, the Welding Engineering Department Chairman, replaced the original Director and an Associate Director for Development was hired to focus on marketing the Center to potential member companies.

***The Organizational Context over Time.*** While CWR slowly grew and developed its research activities during its early years (1980-1983), the larger economic context grew worse. As it did, it become clear that other major stakeholders believed there was a need for a much larger, more diversified and grander vehicle for strengthening the technological capabilities of the welding sector. These circumstances helped create the opportunity for CRW to eventually transition from a modest sized university-based I/UCRC into a large scale not-for-profit research institute.

> *…it become clear that other major stakeholders believed there was a need for a much larger, more diversified and grander vehicle for strengthening the technological capabilities of the welding sector.*

For instance, in 1983 there was a movement afoot in the national welding community (e.g., The American Welding Society and the Welding Research Council) to establish an American Welding Technology Application Center (AWTAC) which would ostensibly be involved in more applied, problem-solving work for the welding industry. To some degree the model – and competitor – organization for this planning and strategizing was the UK-based The Welding Institute (TWI), which had a number of US member companies. While

OSU did not win the competition for AWTAC,[15] the competition helped reinforce interests in Ohio, at OSU and in industry to leverage the success of CWR in order to build a larger more impactful welding R&D organization.

A key consideration in these discussions in the early 1980s was the economic situation in the upper-Midwest manufacturing economy. Auto, steel and other durable goods industries were under major competitive pressure from a variety of sources, and the region – particularly Ohio, Michigan, Pennsylvania and Wisconsin, being described as the “rust belt” – was experiencing plant closings, high unemployment and significant political pressure to do something.

In response to this situation, Ohio and other Midwestern states were moving forward on what was in effect their own science and technology policy initiatives that went beyond in scope and daring of what the federal S&T establishment was willing or politically capable of implementing (Osborne, 1988). All of these state initiatives were designed to buttress the strengths of existing business and industry via programs of applied R&D, often with links to major research universities.[16] In Ohio in 1983, under the leadership of then-governor Richard Celeste, the Thomas Edison Technology Centers program was launched. The initial request for proposals resulted in the funding of six Edison initiatives including an Edison Welding Institute in Columbus.

The winning EWI proposal involved a partnership on the part of Ohio State’s CWR and Battelle Memorial Institute, with the latter functioning as an administrator in the early years of the EWI, as well as in effect transferring its cohort of welding professionals to the new organization).

*All of these state initiatives were designed to buttress the strengths of existing business and industry via programs of applied R&D, often with links to major research universities*

## Transitioning to a State Center of Excellence

While CWR was a reasonably successful university-based Center in the NSF model, the economic and political situation in Ohio and in the manufacturing-intensive states demanded something that went beyond the I/UCRC model. In effect, the enhancement of welding and joining technologies and their rapid deployment in relevant industries had a much higher priority than the more fundamental research agenda of the I/UCRC approach, with its emphasis on graduate training and partnering with a necessarily limited number of Center member companies. The industry needed contract research and consulting, technical

[15] Despite a strong joint bid on the part of OSU, Columbus and Battelle, and a site visit in 1984, the selection committee chose Knoxville as the winning site, and the renamed American Welding Institute (AWI) was established there.

[16] For instance, the Industrial Technology Institute (ITI) was established in Ann Arbor, with a link to the University of Michigan, and the Michigan Biotechnology Institute was established in East Lansing with similar links to Michigan State University. Comparable programs were established elsewhere around the country; many of which failed and ultimately disappeared.

assistance, training programs and the like. Moreover, these needs were on a far greater scale than could be provided by the CWR, or would be within the mission constraints of a research university. For example, there were hundreds of companies that could be logical users of the services of a more expansive organization.

However, based on case reconstructions from involved informants (e.g., those involved in both the proposal-writing and proposal reviewing processes), the EWI would probably never have happened unless there had been a well-functioning CWR that preceded the Edison program, along with key roles played in the proposal process by CWR and OSU staff.[17] Thus, the I/UCRC program had played a critical capacity building role in the development of EWI. One could argue that a key element of this role was the human capital that NSF had helped build within CWR. Specifically, the then-Director of the NSF Center for Welding Research, Dr. Karl Graff, was instrumental in the winning EWI bid, but also in its downstream growth and survival. Thus, although Ohio State had a relatively prestigious Center in hand, that foundation gave it the opportunity for something larger, and something that could perhaps have more direct impact on the corporate welding community as well as the citizens of Ohio.

It is worth emphasizing that Ohio's 1980s era Edison Program has not only survived, but continues vigorous, this for over 30 years and several changes of State administrations and party affiliations. Notably, the Edison program is repeatedly pointed out in the "best practice" literature on state-level technology-based economic development (TBED) programs. In fact the continuity of the overall Edison program contributed to the survival of the EWI offshoot of the original NSF-initiated CWR.

*Thus, the I/UCRC program had played a critical capacity building role in the development of EWI. One could argue that a key element of this role was the human capital that NSF had helped build within CWR.*

## *Center Leadership and Institutional Affiliations over Time*

As noted above, during the 1980s Dr. Karl Graff was instrumental in the founding and growth of the CWR, and was its Director during the mid-to-later stages of its existence as an NSF I/UCRC as well as a prominent researcher and administrator at Ohio State. He provided assistance in forming the research agenda of the Center program and in developing the original cohort of member companies.

During 1983-1984, while still Director of the OSU CWR, Dr. Graff played an active an important role in launching EWI, which was to become the successor to the CWR. An initial step in this process was the drafting of a successful Edison Center proposal. The organizational partnership articulated in that proposal included CWR as an academic partner and the welding R&D facilities/staff at Battelle which were to be merged with the proposed

[17] As an interesting sidelight of the passage of CWR to EWI, at the time that the State of Ohio was planning and designing the Edison program, they received non-paid technical assistance from the head and staff of the Productivity Improvement Research Section (PIR) program at the National Science Foundation.

Edison Welding Institute. A positive funding decision was made by the State of Ohio in July of 1984 and EWI was formally incorporated in October at the time it received a $4M multi-year grant from the state's Edison program. It began operations in facilities adjacent to the OSU campus, which amounted to an in-kind contribution on the part of OSU to the emerging EWI. This was followed by an agreement that brought in The Welding Institute (TWI), a prominent UK-based welding R&D organization, as the third "founding member" of EWI. The terms of the agreement resulted in transfer of TWI's 85 US members into EWI membership.

In the early days of EWI (1985-1987) its CEO was a business-savvy executive, who had wide experience in manufacturing automation and industrial processes, who proceeded to quickly develop an agenda of work, which was organized into both longer-term cooperative research projects, as well as more company-specific contract projects that might include consulting and proprietary technology development. Industry membership began a steady growth, as did industry project and as part of the cooperative relationship with Ohio State the Institute's 46,000 square foot physical facility went through a major renovation. Another $3.23M in funding from the State of Ohio Edison program was also secured.

In 1987, the founding CEO was replaced by Dr. Graff who had retired as Chair of the Department of Welding Engineering at OSU. The fiscal circumstances of the Institute led Graff to eliminate the Centers within the EWI that focused on education and on basic research. The latter in effect led to the elimination of the Center for Welding Research at OSU. While the EWI would continue to have a cooperative relationship with Ohio State, through the EWI Cooperative Research Program, the parallel CWR went away. Henceforth, research at EWI would become oriented to nearer term problems of member companies and conducted in a contract format. Contract research grew to become an increasingly important part of EWI revenue.

Dr. Graff served for 13 years as CEO, and is an academician making an effective transition to an industry/market-oriented entrepreneurial environment. One of the most important accomplishments during this period was winning the national competition to establish and operate the Navy Joining Center (NJC), which was oriented toward advanced materials and defense applications, with participating companies drawn from major DOD suppliers. The Navy has repeatedly renewed the NJC contract, with EWI now being in its $4^{th}$ contract cycle, with NJC funding providing a major ongoing component source, as well as projects typically having longer-term focus. Also during Graff's tour as CEO, additional funds were secured (including $2M from the state of Ohio) to expand EWI facilities. This facility took the form, in 1996, of a new $9.5M Edison Joining Center facility, owned by EWI and located in the Ohio State Research Park adjacent to campus. The 130,000-$ft^2$ facility more than tripled EWI's original building rented from OSU. EWI was also successful in maintaining a strong but informal relationship with OSU and the Department of Welding Engineering.

> *... research at EWI would become oriented to nearer term problems of member companies and conducted in a contract format.*

## *Organizational Structures and Processes*

The CWR during its existence until 1987 implemented the standard structures and processes of the I/UCRC model. It had an Industrial Advisory Board (IAB) encompassing all the member companies, which met twice a year; the selection of projects involved a substantive dialog between faculty and researchers associated with the Center and all participating companies shared the results of projects. The Center Director, Dr. Graff, had reporting relationships to the Dean of the College of Engineering and the OSU Research Foundation, the Center drew its project staff from faculty and graduate students at OSU, and the CWR was an excellent asset for Ohio State. When the CWR morphed into EWI, and eventually was disbanded, except for the IAB concept and that of a cooperative research program, its structures and processes were not otherwise replicated in its successor.

***Organizational Structures and Processes over Time.*** The organizational structures and processes of the CWR just described continued in large part for the history of the Center, but for all practical purposes the OSU-based Center became a minor player relative to what was going on at EWI. After Karl Graff retired and assumed CEO responsibilities at EWI the story moves to what was implemented there.

The structures and processes of EWI were significantly different in scope and kind. EWI was an independent, nonprofit corporation (IRS 501 C3) governed by a Board of Trustees selected from its member companies and its three Founding Members, OSU, BMI and TWI. Many of its business practices were adopted from TWI, who placed a number of staff at the institute in its early years. The foundation of EWI, like that of TWI, was its fee-paying membership base. This, of course was similar in concept to that of the CWR, except on a much larger scale. Thus, at the time of EWI's formation, there were only a few (possibly 7-8) remaining member companies to be transferred to EWI. However, the previously noted transfer of 85 TWI members (several of whom were also CWR members) resulted in a 90 member start-up base. Member fees were based on the TWI model, and thus variable, depending on the size and industry sector of the company (versus a fixed fee structure of the CWR). In the late 1980s, these could range from $10,000 per year to as high as $100,000 for some companies.

In the ensuing years since its formation, EWI membership continued a steady growth, and is currently about 250 companies. According to its website, "EWI provides applied research, manufacturing support and strategic services to nearly 1,200 member company locations worldwide. Likewise, the fee structure has gone through evolutions over the years, both as to its industry sector organization and fee levels. A major adjustment in structure within the last three years has actually reduced fees, so that the current range is approximately $7,500 to $25,000, depending on type of company and its size.

The cooperative research program (CRP) continued as a critical part of EWI's actions and mission. Its partner TWI had a long-standing similar program, dubbed in their case the "Core Research Program" – and hence still the "CRP" by either practice. In the early to mid-years of EWI, OSU continued as the primary contributor to the EWI CRP. While the concept of CRP being, per its name, research focused, there was a definite trend of the research to move from the more basic to the more applied, with one-to-two year horizons. This trend resulted in some reduction of OSU work, and an increased share of the projects being done at EWI.

*In the ensuing years since its formation, EWI membership continued a steady growth, and is currently about 250 companies.*

Once a company becomes an EWI member, a range of services become available to it as a "prepaid" member benefit. Possibly the most important is the ability to call, e-mail or otherwise directly contact EWI staff on technical inquiries. The commitment is made for very rapid turnaround on these inquires, with a commercial computer tracking of this activity now used. This service extends to visits to EWI to directly confer with staff. An information services staff provides a complete search and retrieval capability for technical articles, with a rapid turnaround commitment. A member-only web site and a periodic newsletter is another of the pre-paid benefits, as well as discounts on seminars and courses. Automatic receipt of all CRP reports is of course also a key benefit.

The above benefits notwithstanding, the usual key reason companies become EWI members is to have important issues addressed, from immediate welding problems to long term systems development. This is done on what is essentially a fee-for-service project basis, with projects that can range from short engineering tests of a few days and a few thousand dollars to placing an engineer at a customer's site to multiyear programs that can be well into six figures.

This range of services, with emphasis on "services," exemplifies the fundamental difference between EWI and its predecessor CWR or, for that matter, a typical university research center. The critical importance of serving the needs of its customers, whether they be companies or government agencies, is absolutely central to the mission of EWI, and must, in effect, become part of the corporate DNA. In contrast a university center must, and should, march to a different drummer, that of its own fundamental mission of education and research. EWI, through its origin at OSU, and with its continued range of cooperative activities with OSU (and other universities) has evolved into a unique link between the more immediate needs of industry, and the basic research drivers of the university.

To summarize the changes in organizational structures and processes, the CWR operated in a university-based industrial consortia framework, with decision-making, project selection and project review a shared process that was enabled by the governance and member agreements. In contrast, EWI operates as a not-for-profit research institute that is market driven in the usual sense of that term, and for the most part serves the specific needs of individual member companies for services. While the structure and processes of EWI do permit activities and projects that involve more than one company at a time, that is not the primary model of interacting with its customers. A partial exception to this mix of organizational structures and processes is found in the relationship that EWI has with the Navy Joining Center. In this instance EWI is in effect the contracted manager and operator of the Center. While it may conduct specific technical projects for Joining Center its larger role is to steer the overall program, so its role is both collaborative and managerial.

*EWI, through its origin at OSU, and with its continued range of cooperative activities with OSU (and other universities) has evolved into a unique link between the more immediate needs of industry, and the basic research drivers of the university.*

## *Technical Focus and Industry Participants*

The CWR as operated in the early 1980s had less than 10 member companies, drawn primarily from major durable goods manufacturers, industrial users of products with major welding applications and representatives of the welding equipment industry. Given the scope of the industry constituents, and the consortial model, the range of technical foci and number of projects was limited. During its history, which terminated around 1987 the CWR never was involved in more than a handful of individual projects that encompassed a relatively narrow research thrusts which included topics such as: sensing variables in arc welding automation; weld solidification; improvement of weldabiltity; strength of resistance welded structures; and weld discontinuity analysis.

***Technical Focus and Participants over Time: The EWI Experience.*** Early in its launch period (1984-1990) EWI had dozens of member companies, largely transferred to them by TWI. Over the years, membership grew to over 200 companies with a wide range of interests and priorities. EWI's web page lists eleven different sectors/technologies as areas of expertise (e.g., materials engineering; modeling and simulation). Today EWI's website indicates that its 150 employees provide services to over 1200 member company locations world-wide. It had sales of $30 million in 2000. In addition, EWI has through various federal grants and contracts become the manager and program facilitator of some large technical programs. This includes the Navy Joining Center. Another change over the years has been a more significant participation of EWI in the productizing and commercialization of welding innovations. Part of this is a natural outcome of company-specific contract projects in which EWI may develop novel technology that can be patented or otherwise protected. However, there are also increasing opportunities for EWI to become involved in startups and new ventures. In terms of new substance and new business relationships, EWI has been involved in the development of friction stir welding, particularly in the context of a multi-year contract with the US Army Research Laboratory. Developments such as these are enabled by EWI successes in securing a larger portfolio of longer-term R&D relationships, such as with the Ohio Supercomputer Center, and Oak Ridge National Laboratory. More of this is surely in EWI's future.

# Critical Transitions and Long Term Sustainability in the CWR/EWI Case

On the face it would appear that the Center for Welding Research and Edison Welding Institute are distinctly different organizations with perhaps different variables accounting for their successes. After all, CWR was a university-based consortium of companies and faculty researchers, while EWI became a large internationally prominent, but separate organization that was distinctly market oriented. However, this case analysis takes the position that in effect we are taking about a stream of development involving a launch welding organization (Center for Welding Research) that morphed or transitioned to another kind of organization (Edison Welding Institute) and that the key transitions and influences were actually shared. They include the following:

## *Continuity in Executive Leadership*

Dr. Graff was involved in several phases of the two organizations. He was an early instrumental player in strengthening the OSU welding engineering capacities, leading the Department of Welding Engineering to excellence, and then being a Director of the CWR, collaborating with various state and university interests to pull together a winning Edison Center proposal and becoming a long serving CEO of the EWI. As organizations go through various transitions because of external events it is often fatal if they lose the thread of what they are, what is the vision and what needs to be done to realize that vision. For the CWR/EWI case it is unlikely that the successes that have been realized over the past 25 years could have happened without the presence of Graff.

## *State Technology Based Economic Development (TBED) Patience*

As has been noted above, there is a 30-year history of states being involved in TBED programs and initiatives. Unfortunately, a close look at that history reveals that initiatives get started with great enthusiasm and a bubble of funding, and then governors or legislators exhibit limited patience with the slow growth of economic development outcomes (Plosila, 2004). Funds go away and programs disappear, and five years later the consultants are brought in to do an analysis and then perhaps a new "novel" approach to TBED is launched.

Ohio has been distinctly different. Despite various attacks, the Edison Program in Ohio has persisted. In the case of EWI this has meant a much longer history of investments by the State of Ohio as the Institute has expanded. This is a very interesting counter-example of what is too often a discouraging national practice. The reality is that states have the capacity to be much more targeted and smart in executing technology-based economic development initiatives than does the Federal government when it gets outside the Beltway. This case is a good example.

## *The Role of Ohio State*

This case is an excellent example of the executive leadership of a major university betting heavily on a larger potential future, in effort and monetary expenses, at the risk of impacting an existing program. In the early 1980s Ohio State had a strong Department of Welding Engineering and a fairly prestigious Welding Research Center, and could have turned its attention away from what was going on the political and economic climate at the time. It did not. The institution became an active player in crafting proposals and expanding relationships with external partners such as Battelle. Once EWI was funded and launched, it also played an important role as an investor in-kind and cash in the development of facilities that would be appropriate for what was hoped to become an internationally prominent Institute. Moreover, Ohio State has stayed the course over the past nearly 30 years in working with and for EWI. One reward for this investment and patience is that Ohio State is now home to three welding related I/UCRCs (Precision Forming at Ohio State and Virginia Commonwealth University; Smart Vehicles at Ohio State and Texas A&M; Center for Integrative Materials Joining Science for Energy Applications at Ohio State, Lehigh University, University of Wisconsin – Madison and Colorado School of Mines) that are currently supported by the EWI! This is an excellent example of far-sighted and entrepreneurial institutional leadership.

*One reward for this investment and patience is that Ohio State is now home to three welding related I/UCRCs that are currently supported by the EWI!*

## *The Role of National Science Foundation*

A narrow, and in our opinion misinformed, construction of what happened with the CWR/EWI transition might be that a promising federally funded, university-based S&T initiative was both co-opted and corrupted by a large state-funded program. That this transformation sucked the academic content out of the university center and produced a short-term focused not-for-profit business. In our view nothing could be further from the truth.

If one looks closely, the goals of the I/UCRC program are primarily about capacity building including: "contributing to the nation's research enterprise by developing long-term partnerships among industry, academic, and government" and "expanding the innovation capacity of the nation's competitive workforce through partnerships between industries and universities" (NSF, 2012). Consistent with this focus, the I/UCRC and NSF more generally, played a critically important capacity building role in the establishment and longevity of the significant national asset that EWI has become.

First, the opportunity presented in the I/UCRC program served as a catalyst for OSU to expand its investment in their declining academic welding program. In addition, the I/UCRC award sent a signal to the external welding community about the high quality of the OSU program and its willingness to partner with external stakeholders. It also provided valuable start-up funding and technical assistance that led to the establishment of an organizational foundation and a leadership team that formed the basis for a successful Edison Technology Center proposal. The fact that a sister program within NSF was simultaneously advising Ohio and several other Midwestern states on developing various types of centers of excellence programs only strengthens NSF's role in the development of EWI and the highly regarded Edison Technology Centers program. Finally, the fact that EWI has become a dues paying member of three university-based I/UCRCs, driven in large part by the desire to support the human capital-building mission universities excel at, demonstrates the academic legacy of the CWR I/UCRC has also been sustained and strengthened by the development of EWI.

# References

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