An Analysis Of Sustained Collaborative Research Activities Between University Organized Research Units And Industry: A Case Study Of Three Institutions

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AN ANALYSIS OF SUSTAINED COLLABORATIVE RESEARCH ACTIVITIES BETWEEN UNIVERSITY ORGANIZED RESEARCH UNITS AND INDUSTRY: A CASE STUDY OF THREE INSTITUTIONS

BY

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Submitted in Partial Fulfillment of the Requirements of the degree of Doctor of Philosophy
Seton Hall University
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I have devoted six years of my life in pursuing and completing my doctoral requirements. During this endeavor I not only developed an in-depth understanding of the field of Higher Education Administration, but perhaps more importantly, I realized that I am surrounded by so many wonderful people—both professionally and personally.

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Life is a succession of moments. To live each one is to succeed.—Corita Kent
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CHAPTER I

Introduction

Background of the Problem

Over the last 15 years an increase in international competition and the introduction of rapidly changing technologies have contributed to an uncertain economic environment for several US industries. This highly competitive economic environment, coupled with changing societal priorities, contributed to a change in federal level policies that resulted in a reallocation and/or decrease in funding for several government supported research and development programs. Concurrently, US industry's investment in Research & Development (R&D) at technologically oriented academic institutions increased in real terms from 1980-1997. (Engineering Research Centers, 1998). In response to the change in societal priorities, funding and economic climate, research universities were compelled to assess their existing research infrastructure and make modifications, if necessary, to ensure that their program was relevant in meeting national needs.

A number of engineering and technologically-based universities to ensure responsiveness created structures to engage industry that were similar to the Organized Research Units (ORU) that emerged at a limited number of leading research universities in the late 1950s and early 1960s. Top ranked US research
universities led the creation of an organized research agenda using the ORU model as the organizational structure. ORUs located at these research universities (e.g. University of California, Berkeley) have been credited with expanding the university’s research program and raising the institution’s reputation. (Geiger, 1990). Through the organized research structure, universities increased the responsiveness of the research and educational program in meeting the needs of external constituencies. This responsiveness expanded the potential pool of funding resources to support the ORU activities.

The ORU organizational model promoted a multi-disciplinary and industrial research focus which diverged from the single discipline academic driven focus. This divergence raised concern among the members of the academic community who were skeptical that the close relationship with industry may compromise the educational program (ERC, 1998). However, as a result of the changing environment and a desire to have universities focus on more relevant complex problems, support for this model both by industry and the federal government grew. (Suh, 1987; Pipes, 1987). Over the years, ORUs have continued to serve as an important organizational locus for attracting research funding and the conduct of research at major research universities. (Stahler & Tash, 1994). Due to the favorable results attributed to these nascent ORUs, a shift in federal funding support for research, and the need to secure funding from other sources, other universities have made investments in their research capacity and have begun to replicate these organized research units. These newly established models for engaging in collaborative research activities were based on the limited amount of
accessible information on the development, managerial practices, and technology transfer policies of ORUs.

**Organized research units.**

A review of published material provides substantial descriptive information on Organized Research Units from a historical perspective. The literature describes ORUs as being distinct in their mission and purpose, reflecting the characteristics of the research activities and the needs of the sponsoring university and funding streams. Most ORUs are aligned outside the traditional departmental organizational structure, target the full linear sequence of research activities (basic to applied), advance an entrepreneurial philosophy, and are comprised of faculty and non-faculty members. The research program promotes collaborative research activities with faculty from multiple disciplines and different universities. This system diverges from the prevalent traditional single discipline scientist working on a sole source funded, narrowly focused project. The collective term “ORUs” represents a broad range of nomenclature. The most popular designations are Centers, Consortia/Consortiums, and Institutes. The diverse types of organizational structures developed reflect the complexity in approaches of meeting the expectations and requirements of all entities involved in the research activities. (Cromie, 1983).

To integrate a more industrial-based focus, universities have begun to place a greater emphasis on the advice of industrial technical staff in the development of ORU research activities. Funding support for the ORUs is often provided through a consortium of companies according to a formal membership
fee structure and provide opportunities for technology transfer and commercialization of the research results and outcomes.

**Organized research units and industry partners.**

The private industrial sector exists in a highly competitive, profit-oriented environment. Historically, companies have developed their own culture to conduct research, owned and operated their own facilities staffed by company employees, and invested a percentage of revenues to support R&D activities. University professors often participated with industry in their research activities by consulting on projects, working as a visiting faculty researcher, or by receiving funding for targeted research projects. Formal research partnerships or alliances with other companies or universities were few in number. Globalization of the marketplace, increasing competition, escalating R&D expenses, shortening product life-cycle, and a convergence of technology motivated many corporations to seek the creation of collaborative research relationships with external organizations. (Hergert & Morris, 1987).

Industry was interested in engaging in alliances that would expand their source of knowledge and skills through a shared risk partnership model for the development of innovative technologies and application-oriented research. (Maclachlan, 1994). From the industry perspective, universities were a potential partner which to conduct research activities, an excellent source of technical expertise, a source of current scientific information and provided access to top quality students with experience in one or more related areas of technology. (Emmert & Crow, 1989; Sparks, 1985; Hattery, 1986; McDonald & Gieser, 1987,
Averch, 1989; Azaroff, 1982). The research universities today may be more responsive to the needs of society than at any time since the Second World War. The development of alliances between universities and industry is perceived as a contributing factor to strengthening the US industry position in the internationally competitive environment. (Mayfield, 1987).

**Organized research units: Issues.**

Establishing an engineering and science-focused ORU requires the development of a mission, a strategic plan to achieve that mission, allocation of resources for facilities and equipment, and institutional and external funding support for research activities. The number of universities creating ORU structures in the field of Engineering and Technology to facilitate research collaborative partnerships has grown over the years. In 1979 there were 338 ORUs in this field, by 1997 the number had grown to 1277. (Dresser, 1979; Dresser, 1998). Initially, ORU research activities were conducted primarily by faculty members who pursued the traditional academic career track. As societal and industrial needs changed, universities responded by integrating industry management and technical staff into the research program for guidance and technical expertise.

Building university-based research collaborative relationships with industry require skilled individuals who are familiar with the culture, proprietary nature, and pressures of the industrial environment. Forming alliances among private and public sector partners and conducting research projects that involve collaborative relationships is a new experience for most faculty members. This innovative model may present a potential conflict with traditional university norms that foster the
"pursuit of disinterested research" and timely dissemination of research results. (American Association of University Professors, 1983). Organizational cultures, workplace characteristics, research priorities, and intellectual property issues differ for both universities and industry. For a university-industry partnership to sustain, two inherently different sectors must adapt to each other's needs. It has been suggested that for these relationships to mature, each sector would develop a different set of norms and processes in comparison to those researchers in non-collaborative activities. (Martin, 1985). Studies supporting or disputing this argument are limited and fragmented.

Regardless of future governmental support for research, considering the competitive marketplace environment, it seems reasonable to assume that research consortia of various forms, often involving universities, will continue to constitute a greater portion of overall industrial R&D. (Press, 1983). Prior to any new or further investment made by universities to foster ORU research relationships with industry, strategies and activities need to be well planned. They need to continue to advance the educational mission of the university, and optimize the benefits of collaborative research activities for all partners while minimizing the possibilities for conflict within the two sectors. To make an informed decision, university executives need to assess research conducted on the effectiveness of the broad range of ORUs, be aware of benefits and perceived disadvantages, and foster processes and procedures that enable ORUs to build and sustain collaborative research activities with industry.
Statement of the Problem

One goal of the research university’s mission is to conduct world-class research, disseminate the findings to the public and to integrate the newly generated knowledge into the educational program. This sequential process contributes to the development of students by strengthening their skills to meet the future needs of society and industry. Building and sustaining a strong university research program merits greater knowledge about the traditional and innovative models that facilitate the attainment of these desired research, educational and technology transfer goals.

In response to shifting governmental priorities and escalating research costs, faculty and administrators at engineering and science-based universities created collaborative research models—Organized Research Units, to engage industry in supporting the university research program. The number of universities that have established ORU models as a structure for university-industry collaborative research activities has proliferated in recent years, easing the connection between industrial researcher and the university investigator. (Bement, 1986; Campbell-Daza, 1997). Remarkably the number of ORUs continues to increase even though research findings from studies that explore issues involving university-industry collaborative research activities are limited.

Purpose of the Study

Faculty and administrators at engineering and science-oriented colleges and universities are continuously seeking proven models to support the research and
educational program. Many university executives have established or plan to establish ORU structures to engage industry in collaborative research activities similar to those models credited by leading research universities with expanding the research program at their institutions. Faculty members and administrators who are advocating the ORU model as a mechanism to maximize the benefits and investment in university-industry collaborative research have limited resources to assess research conducted on the effectiveness of the ORU model to fully understand the benefits, disadvantages and development issues that may impact the ORU's effectiveness in building and sustaining collaborative research activities with industry. Despite the increase in popularity of ORU as a mechanism to nurture university-industry collaborative research activities, these units have not been thoroughly studied in higher education. A review of the literature indicated a limited amount of empirical data and information that explored the strategic policies, procedures, and experiences of the senior research core to develop and sustain industry-university collaborative research activities.

A common approach to studying ORUs has generally been through a survey approach, collecting and assessing information on a specific variable from many universities. This information is useful, however, the approach has resulted in a fragmented view of ORU's interactions with industry.

Comprehensive studies have been conducted by federal agencies on federally funded research programs that fall under the collective title of government-university-industry partnerships, specifically National Science Foundation sponsored University/Industry Cooperative Research Centers
(UICRC) and Engineering Research Centers (ERC) programs. Each of these programs have best practice manuals authored by individuals involved in these government funded programs. The manuals highlight the application of business models and the building of these centers from the Director’s perspective. (ERC, 1998; Gray & Walters, 1998). Since they receive significant funding from government, these centers must comply with governmental policies and regulations. Unless they received funding support under these government-sponsored programs, university-based ORUs were not included in the studies. The intent of the research proposal was to provide an in-depth study and analysis of existing ORUs to understand the issues involved in building and sustaining collaborative research activities with industry.

Design of the Study

The following study using a Case Study Design investigated how mature university-based organized research units (ORU), based at the top 40 Carnegie Classification I Research Universities sustained collaborative research activities within the information technologies manufacturing industry. An interview protocol with open-ended questions was developed to provide a structure to the data collection phase. Initially, 14 senior ORU team members were interviewed. A majority of the information gathered for this study was collected through face-to-face interviews (N=10). However, due to scheduling challenges three interviews were conducted over the telephone (N=3), and one interview was conducted via electronic mail (N=1). A majority of the sample interviewed have faculty appointments in National Research Council top quartile ranked departments within
the School of Engineering. Because of the complexity of the research problems addressed by the ORUs, other departments outside engineering also participated in the research program. The main focus of the study was from the university perspective. As data was collected from the interviews, several faculty suggested complementing their information with the perspective from industry. In response to this suggestion, an executive from the industrial consortium (N=1) and two industry senior executives (N=2) who represented companies who were sponsoring members of the ORUs were interviewed via the telephone to gain their insight. Industry representatives were only asked to respond to sections 2, 3, 4 of the interview protocol. In total 14 university senior members and three industry representatives were interviewed. An extensive follow-up study addressing the industry perspective is suggested.

Significance of the Study

The ORU research program is unique in that it pools the talent of key faculty members who apply their expertise in solving complex industrial problems. This comprehensive study targets one specific industry and looks beyond the ORU Director's perspective by including the experiences of the entire senior research core who interact with industry. Expanding the study to include the views of the Research Thrust Area Leaders was based upon my experience in building research center programs and is corroborated by the work of Hickey that found that faculty may have more current and acute knowledge of needs and opportunities of the external partners. (Hickey, 1993). This approach provides an in-depth insight that may assist all academic institutions as they compete for limited funding support to
enhance their research and educational program. The study is also significant in that it includes the experiences from ORUs that do not receive support under the NSF supported programs. Research studies of non-government sponsored ORUs, which represent the majority of ORUs, are very limited.

A structured interview protocol was prepared to ensure that all topics were presented. The personal interview format encouraged all participants to freely express their experience with industry. The openness of the interview format permitted the respondents to introduce other topics not included in the protocol. This openness contributed to a greater understanding of how these ORUs sustain and continue to expand their research program with industry.

The conceptual framework for the study is based on the following four criteria: 1) Data collected include the viewpoint, perceptions, and experiences of all senior members of the research core who interact and are responsible for sustaining collaborative activities with industry; 2) All three ORUs conduct research relevant to the information technologies manufacturing industry; 3) All three ORUs were established over 10 years ago and continue to work closely with industry; 4) All ORUs receive at least $1M annually in financial funding from industry.

Research Question

Primary question

What strategies and processes do Directors of Organized Research Units, based at three Carnegie Classification I Research Universities that specialize in
research relevant to the information technologies manufacturing industry, utilize to develop and sustain collaborative research activities with industry?

Subsidiary questions.

#1 How do ORU Directors establish research program priorities that involve industry?

#2 What are the processes that ORU Directors utilize to expand industrial research collaborative programs?

#3 How do ORU Directors motivate research team members that participate in research activities sponsored by industry?

#4 What activities do the ORU Research Thrust Area Leaders perceive are employed by the ORU Director to achieve sustained collaborative activities with industry?

#5 What activities do the ORU Research Thrust Area Leaders employ to maintain sustained collaborative activities with industry?

Definitions of Terms

Organized research unit.

ORUs are based at research universities and provide for a pooling of talents and efforts that make large ventures possible within a shared multi-sector framework. Within the university system, ORUs fall outside the traditional university departmental structure and are classified under a number of different titles: research institutes, centers, consortia, and other structures geared towards technology transfer. Research activities place a premium on multidisciplinary cooperation and application-oriented activities. They are a mechanism for
attracting funding—particularly from industry—and for promoting interdisciplinary cooperation, while providing a buffer against direct involvement in commercialization. (Geiger, 1990).

**Officially recognized organized research units.**

An officially recognized Organized Research Unit is formally acknowledged by the Board of Trustees of the University. These Centers typically report to the Vice President for Research or Graduate Studies and are required to submit annual reports. These Centers undergo an extensive five, ten or fifteen year review process by the university in order to maintain their official status.

**Sustainable.**

For this study, sustainable is defined according to the literature as proposed by VanSant for the USAID (1989). It is described as the continuation of valued benefit flows or outcomes with or without the programs or organizations that stimulated those benefits in the first place. The nature of these benefits may change, their sources may shift, or responsibility for their costs may be assumed by a new mix of benefactors.

**Collaborative activities.**

Any research related activity involving representatives from both university and private industry. (Fox & Faver 1984).

**Industry.**

Any branch of trade, business, production, or manufacture.
ORU director.

Position responsible for providing research vision, direction, and overall management of the ORU.

ORU research thrust area leaders.

Tenured and non-tenured research positions responsible for research thrust areas, projects or project areas.

National Science Foundation.

The National Science Foundation is an independent US government agency responsible for promoting science and engineering through programs that invest over $3.3 billion/year in almost 20,000 research and educational projects in Science and Engineering. (NSF, 1999).

NIST Advanced Technology Program.

The National Institute of Standards and Technology (NIST) Advanced Technology Program (ATP) is a unique partnership between government and private industry whose mission is to accelerate the development of high-risk technologies that have promise for significant commercial pay-off and widespread benefits for the economy. The program supports enabling technologies that are essential to the development of new products, processes, and services across diverse applications areas. (NIST, 1999).

Limitations of the Study

The strategic approach employed in this study centered on using the Case Study Method to collect data for analysis and to draw conclusions related to patterns, trends and procedures that may be significant in sustaining industry-university collaborative research
relationships. A limitation of this method concerns the relatively small size of the population upon which the data was collected. This method coupled with establishing two highly selective sample characteristics 1) ORUs in the study must be located at a Carnegie Classification I Research University and; 2) a major component of the research program must focus on the same highly specialized information technology manufacturing industry, may limit the transferability of the generalizations and conclusions to other industries and other than Carnegie Classification I Research Universities. It is suggested that further studies be conducted that build on the results of this study by employing quantitative analysis methods to test for validity and reliability and/or investigates other ORUs that conduct research relevant to other industries and explores universities other than those at the Carnegie Classification I Research level.
CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

To provide a foundation for understanding the significance, the framework and contribution of this study, the Review of Relevant Literature covers the period from 1980 to the present. The rationale for selecting this time period is based on a shift in governmental and industrial strategic plans in response to changing societal, economical and technological requirements. (National Academy of Sciences, 1986, Lindsay & Neuman, 1988) Economic, political and social policies implemented during this period contributed to the proliferation of the Organized Research Unit. (Geiger, 1986, 1990, Whiston & Geiger, 1992). The overall strategy for this section is to examine multiple sources of information to obtain a comprehensive understanding of the different systematic processes in the development and assessment of ORUs and possible issues related to sustaining university-industry collaborative research activities.

Evolution and perceived significance of organized research units

As more universities look towards Organized Research Units as a viable structure in building and sustaining a strong research program, it is important to begin by assessing the research conducted on these units concerning their historical development and perceived significance in meeting the university’s research mission. University Engineering education and research programs, due to the application oriented focus of the field, were
impacted more than other fields to these external policy changes. As a result several universities sought to adopt a cross-disciplinary and product driven research program that utilized the ORU structure. (Pipes, 1987). A wealth of descriptive information providing a detailed history of the evolution of the ORU is available in the literature. (Geiger, 1986, 1990). In 1998 two comprehensive manuals or handbooks addressing the business development and management issues of the National Science Foundation (NSF) Engineering Research Center and the NSF Industry/University Cooperative Research Center Programs were published. (ERC, 1998; Gray & Walters, 1998) This study builds upon the information in these manuals to provide a more qualitative and in-depth experiential understanding of their successes in engaging industry. More qualitative and quantitative studies to assess the impact, perceived value and future contributions of ORUs are limited. An examination of the literature identified two studies that shed some light in this area. One study found that ORUs were generally complementary to the research efforts initiated through academic departments. Also, that the largest funded centers at the fastest growing universities typically complemented and enhanced the academic role of departments and were perceived to be an essential element in the expansion of research at these institutions. (Stahler & Tash, 1994). A study conducted on large centers within the Biotechnical field located at fast growing Tier 1 research universities confirmed the significance of the contribution of the ORU structure. (Fairweather, 1989). This information is in conflict with the findings of another study conducted at second tier universities that have not found compelling evidence that concluded ORUs are more effective than departmental research. (Friedman & Friedman, 1982, 1986). The discrepancy between these two studies may be related to the
characteristics of the sample studied. Other studies have found that regardless of the
departmental or ORU affiliation, faculty described industry funding as usually less
desirable than government grants. (Dooris & Fairweather, 1994)

Funding support.

To fully understand the environment in which ORUs evolved, it is useful to include
a review of governmental, non-profit organizations and industrial consortiums that provide
funding support for university’s research activities. Federal and State governments,
Foundations and Industry-specific consortiums support a myriad of research activities. For
relevance to this study programs were investigated that require or advocate a university-
industry collaborative approach to R&D activities. Prior to the late 1970s a majority of
Federal research and development policies that supported collaborative research activities
among industry, universities and the Federal government were financed exclusively or
substantially under the Federally Funded Research and Development Centers Program
(FFRDC). FFRDC’s performed research and development activities and/or R&D
management either upon direct request of the Federal Government or under a broad
charter from the Federal Government. In either case the centers were under the direct
monitorship of the Federal Government. Examples of the FFRDCs administered by
universities include: Brookhaven National Laboratory and Los Alamos National Scientific
Laboratory. Industry administered FFRDCs are: Oak Ridge National Laboratory and
Sandia National Laboratory. (National Science Foundation/SRS, 1993). A literature
search and a written request to the Federal Government identified no published studies
conducted assessing the policies or procedures of these centers. An in-depth literature
review identified a relevant study of a government-sponsored program that was conducted
under mandate of the Director and General Counsel of Advanced Research Projects
Agency (ARPA). The study surveyed a sampling of a special category of research units
called "Other Transactions". These are agreements with industry and universities
characterized by enhanced flexibility and reduced administrative burden. Several of these
programs are based at universities and closely resemble the autonomous structure of
ORUs, however, are government outcome driven. Conclusions from this study, stated that
forming a consortium can be difficult and time consuming, cited intellectual property
issues as the basis for most disagreements and suggested that to ease the starting up of
new consortia, the sponsoring federal agency should provide greater involvement and
guidance. (Akin, Entlich, & Lightfoot, 1995).

During the late 1970s, shifting Federal R&D policies provided the basis for a
number of new research programs, each with a different research focus. The programs
which included Science and Technology Centers, Engineering Research Centers and
University/Industry Cooperative Research Centers initiated new program policies and
requirements where the Federal Government participated as a partner along with
universities and industry in leveraging the resources and skills of each participating
organization. Under these programs, a significant amount of funding is provided by the
Federal government, however, each partner must match the federal contribution in a cash
and in-kind formula. In addition to the funding match requirements, each recipient must
provide a 3 to 10 year workplan that included strategies for sustainability. A number of
federal reports based on reviews conducted on these programs by a technical panel
provide some insight into the factors that contributed to the success of some Centers while
also identifying common problem areas. Program success/problem areas evolved around
the vision, the talent of the staff and consistency of support from multiple funding streams. (NSF., 1987; Colton, 1987; Iverson, S., Jorgensen, J., 1987; Bell, 1996; Mayfield, 1987).

**State programs.**

All fifty states have implemented a State and Technology Strategic Plan (STS) that includes various programs that support collaborative research activities involving both universities and industry. These research programs have a near term application focus and are measured in terms of economic impact. (Coburn & Berglund, 1995). Feller conducted a study of the impacts of State Technology Programs on American Research Universities and concluded that further studies need to be conducted to determine whether these activities have simultaneously satisfied the dual criteria of relevance to a region's economic needs and to areas of academic excellence. (Feller, 1992).

**Foundation programs.**

A review of Foundations suggests that supporting university-industry collaborative research activities directly is not within the scope of most Foundation’s mission. A comprehensive study of science and technology strategic planning processes was funded in part by the Carnegie Foundation. The study found that there were ten best practices for successful strategic plans. This information can provide insight into understanding the components of an ORU strategic plan that can contribute to sustainability. (Coburn & Berglund, 1995). The Alfred P. Sloan Foundation supports Industry Centers located at universities. The primary intent of these centers is to contribute to a better understanding of these industries and do not require corporate sponsorship. (Alfred P. Sloan Foundation, 1999).
Industrial associations/consortiums.

One function of Industrial Consortiaums and/or Associations is to provide funding support to universities for research activities that will enhance the specific industry that the Consortium/Association serves. The non-profit industry corporation that is closely aligned with this industry addressed in this study was investigated to gain a better understanding of the research focus and environmental issues that impact the ORU sample. (Cavin & Phillips 1998).

Policies and procedures

A review of the literature identified a limited number of studies that provided a comprehensive examination of the procedures and policies utilized by ORUs Directors to assist them in meeting their mission and goals with industry. The manuals describing the NSF Engineering Research Centers and NSF Industry/University Cooperative Research Center programs provide valuable insight into procedures to build relationships between the ORU and industry. (NSF, 1998; Gray & Walters, 1998).

University system.

Traditionally within the university system, tenure and promotion requirements are based on individual contributions. Findings and recommendations suggest that non-tenure faculty exercise considerable discretion when engaging in collaborative research prior to establishing their own professional identify. (Turns, 1991; Baldwin & Austin, 1995). The traditional award structure coupled with the relatively recent emergence of ORUs may provide an explanation for the limited amount of research conducted on the process of university collaborative research relationships. To learn more about the process of faculty
research collaboration, researchers Baldwin and Austin surveyed faculty within the field of higher education to begin to develop a grounded theory of collaboration that would suggest direction and a hypothesis. The survey protocol for this Dissertation study is based, in part, on their contributions and is described in the Methodology Section. A five-campus case study completed for the American Association for Higher Education on Collaborative Departments also provides a wealth of information on this topic. Four issues emerged from this study on Collaborative Department campuses which include: balancing groups and individual interests, developing academic communities as teams; redefining the evaluation of individual faculty members; and evaluating and rewarding group productivity. (Wergin, 1994).

Another issue that emerged from the literature is that the evolution of ORUs has not occurred without substantial controversy, conflicts and problems within institutions. Conflicts between centers and academic departments and central administration management issues have been documented in the literature. Conflicts are not necessarily inevitable, they are most likely to occur when there is competition over such scarce resources as faculty time, internal funding, space, equipment and research infrastructure. Also, external research program needs of funding agencies, as opposed to more academic research goals conducted within departments have been suggested as resulting in a lack of intellectual core at these ORUs. (Friedman & Friedman, 1982; Gieger, 1990; AAUP, 1983; Stahler & Tash, 1994). Another study, that also examined potential conflicts, found that respondents involved in collaborative activities are more positive about financial opportunity and the ability to achieve greater monetary awards then their non-involved counterparts. (Campbell-Daza, 1997). The ORU structure runs counter to the
traditional academic department organized around a single discipline and narrow
disinterested research program. (Pipes, 1987; Younglove-Webb, Gray, Abdalla, Purvis-
Thurow, 1999). One study found that there was a view that ORUs are temporary
structures and should be reviewed periodically for their contribution to the university’s
academic and educational purposes. (Saxberg, Newell & Mar, 1981).

**ORU director/department chairperson.**

A review of the literature identified a limited number of qualitative or quantitative
studies on ORU Directors. One of the factors in achieving successful collaborative
activities between academic and industry is a strong leader. Studies have suggested that
center directors must be established and respected researchers within the academic
community, and also be familiar and have a knowledge base of experience with industry.
(Tornatzky, 1990). Other studies point out that the choice of the leader of an ORU is very
important to the success of the organization (Friedman & Friedman, 1986). Center
directors have greater autonomy then department chairs, therefore, the centers bear the
imprint of the director’s philosophy, interests and goals more directly then is the case with
academic departments. (Friedman & Friedman, 1982). Senior level managers were also
studied in New Zealand because of their level of responsibility regarding research projects
in the ORU. The study found that the impact of their prior related knowledge of the
participants, the initial conditions of the relationships and aspirations for the alliance were
important. (Davenport & Davis, 1998). To augment the information, one approach is to
explore research conducted on department chairpersons since these individuals have
varying responsibilities in cultivating the development of the research program within their
department. Studies have found that successful department chairpersons employed four
strategies to succeed. These strategies include: hiring senior scholars; recruiting junior faculty anticipated for their future achievements; developing a vision and plan to articulate that vision; and providing strong leadership within the university. (Heveron, 1987).

**Industry-university collaborative research activities.**

A review of the literature identified two common views addressing whether universities should enter into university-industry collaborative relationships. One view recommends that universities proceed with caution, to prevent non-academics from dictating the direction of the institution. (Dressel, 1969). Another study found that ORUs were not well integrated into the university’s governance structure (Hays, 1991). A second view is that university administrators are the architects of the university’s future and should aggressively pursue the formation of new partnerships to improve their institutions and to meet society’s changing needs. (Hemsley, 1980).

Studies have indicated particular characteristics of universities that may influence relationships between the two sectors. These include size, available resources, quality, prestige, institutional type, location and organization. (van Rosmalen, 1998). Little empirical research has been reported that tests the validity of these relationships. A study has been completed that examine the similarities and differences of the universities from which the electronic equipment and aircraft industries draw research knowledge. Citation analysis is used as a mode of inquiry in an initial attempt at linking firm activity with the higher education institution from which industry draws knowledge—uses citations to articles written by university-based scientists. A limitation of this approach is that only a selected group of industry scientists publish their results, another issue questions whether the cited material was used in any substantial manner. (Tornquist & Kallsen, 1995).
Other variables that were investigated that may contribute to successful research collaborative relationships between industry and universities are the level of communication and the impact on the long term development of effective university-industry linkages. A review of five centers suggested that even though communication levels may be different successful relationships can develop if the management mandates that industrial scientists formally participate and be active participants in the research projects. Findings were inconclusive and further studies were recommended. (Bell, 1996).

Other descriptive studies discuss the emergence of problem areas that arise due to different cultures working together and question whether significant participation with business firms in joint R&D ventures erodes the academic ideal of “disinterested pursuit of knowledge”. Other studies stress the conflict between the university’s research obligation to disseminate the results of R&D as widely and promptly as possible and industry needs to have the research findings remain confidential. (Baldwin, 1998). A review of industry-university linkages cite other personal experiences where research projects eroded because the company and university researchers were not sufficiently sophisticated in defining, organizing and sustaining research connections. (Dooris & Fairweather, 1994). Leventman conducted a case history of a US Technology Reinvestment Project (TRP) and concluded that people form industry or the university who benefited from the partnership became the ‘change agents’ for establishing other programs that involved high risk research. (Leventman, 1998).

Industry.

Exploring the industry system can help determine whether there are characteristics of successful industry alliances that can be generalized and transferred to ORUs. The
literature noted that two-firm alliances are the predominant structure in the universe of alliances. Multi-firm alliances are emerging especially in high tech industries. Multi-firm alliances bring about new challenges for managers who must focus on the inter-organizational perspective and recognize that the final joint decision of a multi-firm alliance represents multiple, interdependent decisions among group members. One suggested strategy to effectively address these new challenges is to use Game Theory in exploring interdependent decision-making. (Hwang, & Burgers, 1997). Sandia Science Park and similar types of science parks that previously were funded primarily by the Federal government are currently exploring new opportunities with industry to exploit its strengths through alliances with businesses that surround the complex. (Brown, 1999).

Research productivity

Developing research ideas, planning research activities and conducting research activities emulate from the individual. To fully understand the ORU structure, research related to motivation processes and techniques used to achieve desired research outcomes and goals is included because of the direct contribution to the ORU research program. Studies exploring research productivity can be categorized into two separate categories. One focus evolves around the faculty member’s characteristics, the other relates to environmental issues that reflect the university’s policies.

Faculty researcher

Several studies examine the characteristics of the faculty member to determine their level of research productivity. A study was conducted that examined the relationships between Type A personality and faculty researchers productivity and concluded that
Type A behavior directly predicted both quantity and quality of published research. The study failed to account for factors such as academic rank, disciplinary area and institution affiliation. (Taylor, Locke, Lee & Gist, 1984). Another study focused on the "vital" faculty member and cited a number of characteristics that differed from their "representative" colleagues. Findings included differences in length of the workweek, allocation of time on tasks, amount of time dedicated to professional activities, flexibility in revising their work roles, and issues related to multi-faceted and risk perspectives. (Baldwin, 1990). Factors found in other studies state that more productive faculty are less involved in university governance or decision making activities. (McGee & Ford, 1987). Moriarity and Prudy found that motivation toward research productivity is neither purely intrinsic nor purely extrinsic. Rather, both appear to operate depending on the circumstances of the individuals, their values and the social situation of the moment. (Moriarity & Prudy, 1992). Another area of study that is applicable to understanding industry-university collaborative research activities is the relationship of past experiences with a research partner or funder and preference to pursue additional activities. From the perspective of the funding source, past experience was found to play a key role in the professor's choice of research partners. (Bolder, 1994).

Environmental issues.

Environmental factors cited included the type of administrative support that a productive faculty member received which included: public recognition for their work, reduced course loads, funding for equipment and travel, and friendly administrator relations. They also note more environmental obstacles such as inadequate labs and libraries. (Baldwin, 1990). Creswell argues that different approaches may be applicable in
assessing faculty research performance based on level of assessment—individual, department/program/college and institution. (Creswell & Brown, 1994). Rice and Austin argue that organizational culture, including variables such as a clearly articulated mission, leadership, colleagueship, customs and rituals, can contribute to faculty productivity. (Rice & Austin, 1988). Tien and Blackburn explored the relationship that rank has on research productivity and found that full professors published significantly more research publications than do Assistant and Associate Professors. Their results also suggested that there is no significant publication difference between Assistant and Associate Professors. (Tien & Blackburn, 1996). Other arguments state that low productivity does not result from the security of tenure but that conditions for review procedures, peer sanctions and better inter-institutional mobility should be implemented. (Rousseau & Parks, 1992; Robinson 1996).
CHAPTER III

Methodology

Introduction

This study was designed to build upon the earlier survey research conducted on ORUs. The overall approach was developed and implemented to understand in-depth, the development and sustainability of the collaborative research relationship between the ORUs and industry. Data collection was based primarily on the experiential knowledge of the full range of university research leaders who are responsible for the ORU research program. In order to accomplish this, the research focused on the ORU leader’s actions and perspectives in collaborating with industry and the industrial and university environment in which the ORU exists.

Defined as qualitative, the research was also empirical, as it involved the gathering of information about and observation of the topic so as to make generalizations and draw conclusions. (Shulman, 1987). The research is descriptive and exploratory as it explores in detail the ORU environment, processes and procedures.

Design

To obtain a comprehensive understanding of the ORU, the study was based on the multiple case study strategy that included content analysis and interpretations of interview data. The method was selected to identify emergent categories from empirical data. Documented data from historical documents and reports contributed to the richness of the
information gathered. (Yin, 1993). Case studies were conducted at three ORUs located at three different leading research universities. The selected universities are among the top 40 Carnegie I Research Universities as reported by the National Science Board. A purposive sample of ORUs from one grouping of universities helps to control for prestige of the institution. The basis for this approach is drawn from the work of Dooris and Fairweather (1994) from their work in Biotechnology. All three ORUs investigated for this study conduct research that focuses on the same industry, have been in existence for at least 10 years and receive over $1M in funding support from industry. To provide parameters while maintaining confidentiality, the specific field of industry relevant research will only be referred to under the general term “information technologies manufacturing industry”. The strategic approach to limit the study to one specific industry attempts to control the impact of variables that may be unique to certain industries. Research on the relationships between the ORU and a particular industry offers the advantage of allowing the writer/reader to develop a concrete understanding of the nature of the contribution that would tend to elude more aggregate, broad-based studies. Also, as noted in the literature, problems are often encountered when making comparisons across diverse research units. By limiting the study to one specific industry, confounding effects of different disciplinary bents or research fields were minimized.

The primary level of analysis is the ORU, specifically senior level ORU members that included, ORU Directors and Research Thrust Area leaders who are responsible for research projects at the specific ORU. These individuals are responsible for building relationships with industry, conducting collaborative research and insuring that the desired
outcomes and goals are accomplished. This core university team has first hand knowledge of effective processes and procedures in collaborating with industry.

**Character of sample.**

An interview protocol with open-ended questions was developed and piloted tested to provide a structure to the data collection phase. Initially, 14 ORU senior members were interviewed for the study. A majority of the sample participants interviewed have faculty appointments in the National Research Council’s top quartile ranked departments within the respective School of Engineering. Because of the complexity of the research problems addressed by the ORUs and the multi-disciplinary ORU structure, other departments outside engineering were also represented in the study.

The main focus of the study was from the university perspective. As data was collected from the interviews, several faculty members suggested complementing their information with the perspective from industry. In response to this suggestion, an executive from the industrial consortium (N=1) and two industry senior executives (N=2) that represented companies who were sponsoring members of the ORUs were interviewed to gain their insight. Industry representatives were only asked to respond to sections C&D of the interview protocol. An extensive follow-up study addressing the industry perspective is suggested. A majority of the information gathered for this study was collected through face-to-face interviews (N=11). However, due to scheduling challenges five interviews were conducted over the telephone, all three industry representatives one ORU Director, one Research Thrust Area Leader (N=5). One
interview was conducted via electronic mail (N=1). Data was gathered and responses were organized by themes and categories. Data was reviewed and analyzed for commonalities, differences and patterns.

The collection of data using three different approaches may have influenced the scope of data collected for the following reasons. The face-to-face interviews allowed the researcher to probe further and to note the body language of the participant. The interviews conducted through the telephone allowed for the interviewer to probe further their responses, however, body language could not be noted. The interview conducted through electronic mail was requested by one of the Research Thrust Area Leaders. The responses to all of the questions were succinct and completed in a timely fashion. Disadvantages of this method was that the researcher could not probe further nor note body language. Overall, when comparing the amount of relevant information that emerged from each interview, the method of data collection did not fluctuate greatly. Further studies comparing the use of these methods should be conducted to expand the scope of data collection methodologies to reflect the development of new telecommunication technologies.

**Interview instrument.**

The Interview Instrument was constructed based on themes raised in the literature. The emerging Grounded Theory of Collaborative Activities proposed by Baldwin and Austin (1995) helped to shape the topics for the interview. Their emerging theory is based upon the following questions: How do collaborators find each other and initiate their work? What institutional factors affect the success of collaborative relationships? How do
collaborative relationships change over time? What stages do they pass through? What role patterns emerge, and what is the relationship of these patterns to productivity? What problems occur in collaborative relationships? What are strategies that address these problems? How do collaborative partners either terminate or agree to continue their joint work over time?

**Pilot test.**

A Pilot Survey was conducted in order to determine if the interview questions provided the clarity and yielded the expected information in the areas under study. The Interview instrument was pilot tested at three ORUs located at the New Jersey Institute of Technology. NJIT is a Doctoral I Public Research University with a major concentration in the Engineering and Technology Fields. The ORUs selected to pilot test the protocol are comparable to the study sample in respect to the following criteria: Research is nationally recognized, the research focus falls within the field of engineering, and each ORU receives significant external funding support from industry. Three ORU Directors and three Project Leaders/Principal Investigators, one from each ORU, piloted the survey instrument. Individuals that serve in these positions have similar background characteristics and position responsibilities comparable to the sample that was studied.

**Hazardous and toxic substance research center.**

The Center started initially as the Institute of Hazardous and Toxic Waste Management with seed funding support provided by the university. The research program focuses on controlling and reducing hazardous substances. The Center competed and was awarded the NSF Industry/University Cooperative Research Center status in 1984 and in 1989 the Center was selected by the US Environmental Protection Agency (US EPA) to
be the lead university for one of five based national centers devoted to hazardous
substance research. The Center membership peaked in 1992 and currently is supported by
13 member companies in addition to the government funding. Individuals in the following
positions employed by this ORU reviewed the survey instrument with the investigator for
clarity, provided feedback and recommendations: One ORU Director (served in this
position since 1987) and one Project Leader/Principal Investigator.

**Emission reduction research center (ERRC).**

The ERRC was established in 1992 with initial seed funding from the US
Environmental Protection Agency (US EPA) and industry. The research program focuses
on technology development to sustain a “Green Environment”. In 1993, the Center
received $1.5M from the US EPA for implementation of the Integrated Pollution
Prevention Initiative. Currently the Center is supported by six member companies.
Individuals in the following positions employed by this ORU reviewed the survey
instrument with the investigator for clarity, provided feedback and recommendations. (1)
ORU Director, served in this position since it’s inception. (1) Project Leader/Principal
Investigator.

**Multi-lifecycle engineering research center (MERC)**

MERC was established in 1994 with support from the university and industry. The
research program focuses on a complex, next generation engineering system that
integrates environmental responsibility with manufacturing and demanufacturing
technology. In 1996, MERC competed and was awarded $5M in funding from the NJ
Commission on Science and Technology under the R&D Excellence Program. The Center
currently is supported by 30 member companies. Individuals in the following positions
employed by this ORU reviewed the survey instrument with the investigator for clarity, provided feedback and recommendations. (1) ORU Director, served in this position since its inception. (1) Project Leader/Principal Investigator.

Based on the comments provided by the individuals who participated in the pilot test, refinements to the initial interview protocol were made. Specifically, the interview protocol was streamlined into three subject areas and four categories. The initial interview was "overwhelming" and solicited information that did not focus specifically on developing and sustaining university-industry collaborative research activities. Changes were made to the protocol based on the pilot test of the first two ORU Directors. The recommended streamlined interview protocol was then pilot tested on the remaining individuals. This second sequence resulted in minor adjustments to ensure clarity and efficient use of the participants' time. The final interview protocol was condensed into three main subject areas—1) Development of the ORU; 2) Industry collaborative activities; and 3) Future plans. The first two subject areas elicited the majority of the information. The third section was intended to capture a sense of the future plans for the ORUs. The pilot test of the refined protocol provided informed responses to sufficiently address the objectives of the research questions.

Supporting Documents for Triangulation

Analysis of institutional documents, combined with interviews and observations provided an understanding of the ORUs' history and culture in context and also provided valuable insight as to why certain processes, procedures, and collaborative research activities emerged. Existing data can provide a wider perspective of the environment in which the university and ORU must interact. Existing university, ORU, and reports and
documents such as college publications, Web Sites, official records, position papers, publications by the selected ORU were collected and reviewed from each university involved in the study. Similar documents were also collected and reviewed from government agencies that provide funding support. Information describing the associated non-profit industry consortium was also collected.

Organization of the Study

Chapter I, the Introduction, provides information regarding the current environment for the selection of the research topic, background information describing the development of ORUs and the specific research questions upon which the study is based. Chapter II, provides a literature search that includes background information describing related studies from a broad range of perspectives.

Chapter III, describes in-depth the selected methodology, the rationale for the highly specialized characteristics of the study sample and the development of the questionnaire protocol.

Chapter IV, is presented as a thick description format and is divided into two sections. Section One, provides the historical development of the three ORUs investigated to acquaint the reader with the diverse impetus for the establishment of each ORU and the developmental sequence employed by the Directors. Section Two, provides an overview of the industry to develop an understanding of the industrial environment that these ORUs must interact.

Chapter V, provides an analysis and discussion of the data collected from the ORU Directors and Research Thrust Area Leaders concerning sustaining university-industry collaborative research activities.
Chapter VI, provides a discussion of the conclusion, compares the conclusion to two related federal programs and provides recommendations for further studies.

References, cites the full body of information where certain statements and comments included in this study may be found.

Appendices, includes the interview protocol, letters inviting participants to participate in the study, the consent form and a listing of documents reviewed to contribute to a comprehensive understanding of the topic.
CHAPTER IV

Overview of the Organized Research Units and the Related Industry

Introduction

The main focus of this study is to gather a comprehensive body of knowledge from experts in the field to understand the pertinent issues that contribute to the effectiveness of Organized Research Units in sustaining collaborative research activities within the information technologies manufacturing industry for over 10 years. An investigation into the historical development of each ORU revealed alternative origins that are useful to share with the higher education community as they strive towards establishing strategies to engage industry in long-term research relationships. As stated in Chapter III, the four criteria for the ORUs selected for this study are as follows: 1) The three ORUs are located at three different leading research universities. The selected universities are among the top 40 Carnegie I Research Universities as reported by the National Science Board. 2) All three ORUs investigated for this study conduct research that is relevant to the information technologies industry. 3) All three ORUs had to have been in existence for at least 10 years. 4) All three ORUs received over $1M in funding support from industry annually for the last five years. As noted by industry executives interviewed for this study, these three ORUs are the major university “players” in this field of research. Five to seven other
universities conduct research for this industry, however, their activities have been established more recently and are smaller in scope.

The intent of this chapter is to provide a background description of the university, the School of Engineering with which the ORU is associated, and a brief history of the establishment of each ORU. This information is intended to enhance the understanding of the application of the ORU model in sustaining industry collaborative research activities by faculty and university administrators. The historical component of the case study is based upon interviews with the ORU Directors (N=3). Comments from each ORU Director regarding the decision-making process and five-year strategic plan are included to provide a comprehensive “visual” of each ORU.

To inform the reader of the industrial environment in which these ORUs must interact, the second component of this chapter provides an overview of the related industry. To maintain confidentiality the specific field of research will only be referred to under the general term information technology manufacturing. Information technology manufacturing is a generic term used in this study to set parameters for the reviewer.

Section One: Organized Research Units

Organized Research Unit Subject 1

Subject 1 is an unofficial Organized Research Unit of the university system, located within one Engineering specific department. The Director, who was also the Chairman of the specific Engineering Department for the last eight years until June 1999, chose not to pursue official university recognition for the organized research unit. However, the unit is recognized by industry and meets the four criteria for ORU selection in this study.
University background.

The ORU resides in a Carnegie Classification Research I University. The university is organized into 14 colleges and schools. The College of Engineering traces its roots to the passing of the federal Morrill Land Grant Act of 1862. The academic department that houses the ORU is one of seven academic departments. In 1995 the National Research Council (NRC) ranked the department in the top 10 for "scholarly quality" of the faculty. The university has nearly 40 formally recognized Organized Research Units. In addition, there are some 50 departmental research facilities and centers in the College of Engineering. The College of Engineering has two well established frameworks in place for corporations, Foundations, and individuals to provide funds to further their relationships with engineering faculty and their peers in external organizations. The department specific to the ORU also has a program in place for direct contributions to support the department's instructional and student programs. However, according to the ORU Director this research unit does not receive any funding support from these college activities nor from the formalized Department Industry Program.

Genesis of the ORU.

The ORU was formed in 1989 by the Director after several years of close collaborative research activities between the department's faculty members and industry. The Director has been a faculty member at the university since 1967. During his initial academic years he conducted theoretical research funded by the National Science Foundation. During his early years he also worked for industry during the summer months as a visiting industry-faculty Fellow. It was during this period that the faculty member
began to identify problems that industry faced that he believed would be valuable as research projects for his students. He approached one company to provide financial support for students to work on these industry relevant problems as part of their educational program. The company agreed with his proposal and provided the requested funding. Experimental activities were conducted at the company facilities. As research areas broadened, industry support was secured for equipment to have the research conducted at the university. Also, during this period the state government established a funding program to advance research and educational activities within the information technology field. The goal of the program was to have universities work with industry in conducting research and educating students. One program requirement was that industry needed to match the funding proposed by the faculty member. Building on his earlier research initiatives with industry, the faculty member was able to solicit five additional companies to be involved with the state funded program. The Director was successful in securing funds under this government program that contributed to the growth in industrial sponsorship for his research. In 1987, the Director submitted a proposal under the National Science Foundation Engineering Research Center (ERC) Program. To fulfill the NSF ERC program requirements for active industry members the Director needed six months to recruit the additional companies. The submitted proposal was not funded. However, the exercise of promoting the ORU to the additional companies resulted in these companies developing an awareness and commitment to the ORU’s research activities.

Within the same time frame, industry began exploring the establishment of a university-based center that would conduct interdisciplinary research in his field. His Dean
encouraged an interdisciplinary group of faculty to submit a proposal, however, it was not selected. The center that was selected by industry did not have expertise in his area, and as a result the funded center subcontracted research projects to his activity. By 1988, the faculty’s research activity had outgrown the loosely organized structure causing the faculty member to develop a strategic plan to formalize the research activity as an Organized Research Unit. Based on his own philosophical orientation, the Director decided not to pursue the university official Center status. Over the last ten years the ORU program has expanded its research program and has integrated new industrial demands related to software development. Throughout the history of the ORU the research program has remains small and highly specialized. The ORU Director resigned as Chairperson of the Academic Department during the 1999 Summer and is now dedicated full time to teaching and the ORU activity.

The primary objectives continue to focus on providing a quality graduate education program in the industry relevant field, to research topics of direct relevance to industry and to rapidly transfer research results to the supporting companies. The goal of the ORU continues to target research in discipline aspects of the specific industry in close cooperation with and funded primarily by industry through the industry non-profit corporation and corporate gifts.

Organizational structure.

The formal organizational decision making structure is comprised of the Director and an Advisory Council. The Advisory Council includes two to three faculty colleagues and a representative from each member company. The Advisory Council meets once a year during the ORU’s annual meeting. Since the ORU is not officially recognized by the
university there are no reporting lines to the Dean or other university executives. The
current research consists of four research activities, each led by a different faculty member
from the same department. The Director leads one of the research activities. The ORU
provides funding for administrative support and a computer technician. (See Figure 1).
Figure 1: ORU 1 Collaborative Research Organizational Structure
Policies and formal model for industry participation.

All policies were developed by the Director and reflect his philosophy of university-industry collaborative research activities. A multi-tier membership structure with varying levels of benefits was designed and implemented as a mechanism to build and sustain a company’s participation in the ORU. A company becomes a member by sending a check stating that the funds are an unrestricted gift to support the research of the ORU and by signing the appropriate agreement. The industry membership framework is an “informal” relationship with industry where there are no research project contracts nor deliverables. The Director’s philosophy in selecting this format focuses on whether the company values the research conducted by the ORU. Simply stated, if the company is satisfied and places value on the research, the company will renew its membership.

Benefits vary according to one of three membership levels. Each level of membership provides access to technical reports and entitles a number of industry representatives to attend the ORU annual meetings. The number of representatives permitted increases with each membership level. The middle membership level provides access to software developed by the ORU. The highest level receives all the benefits of the other two levels, plus companies may send up to six representatives to the annual meeting and are also permitted to place a visiting industrial fellow at the ORU. Membership is and always has been open to all companies, including foreign companies. Currently there are 23 companies of various sizes that are formal members of the ORU. In addition to yearly membership fees, industry can also provide funding for targeted research projects. It is the
policy of the ORU that all results from research studies (targeted and non-targeted) are shared among all members.

**Formal industry meetings.**

The ORU sponsors an annual two-day industrial meeting that includes presentations of research projects as well as a meeting of the Advisory Council. Additionally, there are lab tours and technical poster presentations. Industry participation is limited to sponsoring member companies of the ORU.

**Web site.**

Research information is posted on the ORU’s Web site. All sponsors have access through this medium to technical reports and students’ master’s theses and doctoral dissertations.

**Intellectual property issues.**

The university has an Intellectual Property policy to facilitate the process of legally protecting research findings. It is up to the discretion of the researcher to determine if the findings are suitable candidates for the patent process. The ORU has implemented the policy requiring that all research findings be submitted for publication. Benefits to the members are that the sponsors receive a copy of the findings when the document is submitted for journal publication. This process allows sponsors to have access to the research findings and apply them to their manufacturing system before the information is published in a journal. The typical lead time for journal publication in this field is 18 to 24 months.
Project selection and research direction.

The formal two-day annual meeting with industry serves as the forum for the presentation of findings from the current year research projects and the presentations of proposals by faculty for consideration for next year funding. The standard format is that faculty members write a one-page proposal and make a brief oral presentation highlighting the key points. Industry ranks or grades the proposals according to importance to company needs not according to scientific merit. At the end of the meeting, each company representative reiterates what is important to their company. The Director equipped with this feedback from industry, makes the final decision for allocation of resources for each project area.

Funding streams.

The majority of funding support for the ORU is provided through industry memberships. Targeted research from industry, government, and the industry non-profit corporation provide less than 25%. It should be noted that gifts to the university are not subject to overhead expenses, however, his department has the policy that a percentage of the gift’s value is “taxed” to support the department’s general research initiatives for the students.

Interactions between ORU director and senior research team.

The Director encourages faculty members to “get in touch” with industry to learn what challenges they face. The Director encourages faculty members to work for a company during the summer so they can develop an educational research plan that is also relevant to industry. In the past the Director has made arrangements for faculty summer positions for interested faculty at sponsoring member companies. The Director advises the
faculty to develop project proposals that are important to industry and that also have scientific merit for doctoral level work. From his perspective, the main reason why faculty are not successful with industry is because they don’t make an effort to learn directly from industry their problems and objectives.

According to the Director, ORUs are essentially created by individuals who have the desire and the talent to “put things together”. From his perspective, at present, there are no other faculty members that are totally dedicated to the ORU. The Director is unsure of what will happen when he retires. Due to the difficulties of meeting the needs of the several constituencies that comprise the university, he expresses doubt that the university will specifically recruit someone to succeed him. He has always felt that the research program may evolve into some other activity for someone else to lead. At the time of the interview the Director was uncertain as to the research and business plan of the ORU in five years. One of the Research Thrust Area Leaders did express interest in continuing the activities of the ORU for at least another five years. The faculty member was not sure of the formal structure, however, did envision possible research areas related to the future of the industry.

Organized Research Unit Subject 2

Introduction

The current Director of ORU2 has been active with the ORU since its inception. As a faculty member he was on the university advisory committee to develop the ORU. Prior to becoming the ORU Director, the faculty member conducted research as one of the researchers. Sponsoring industry companies convinced him that the ORU format could foster opportunities of high quality research for his students while addressing problems
relevant to the industry. He has held a faculty position since 1960, and in 1990 succeeded the prior Director upon his retirement. The current Director comes from a family of small business owners, but has pursued an academic career ladder.

**University background.**

The university was founded in the early 1960s and is ranked in the top 10 among all US universities in the amount of research and development funds it receives from the federal government. The university is comprised of several undergraduate colleges, a School of Engineering and a medical school. The School of Engineering is ranked among the nation's top ten engineering schools according to the 1995 National Academy of Sciences. The school's mission is to provide an educational framework to develop students to become industry and academic leaders and to create technologies that will fuel economic prosperity. The university houses 49 Centers, Institutes, and other Organized Research Units, 14 of which are directly affiliated with the School of Engineering. The School of Engineering has four academic departments. Partnerships with industry are essential to both the education and research missions. The school has a Corporate Affiliates Program that was designed as a framework for industry to sponsor student internships, senior design projects, help identify new curriculum directions, and provide fellowships and scholarships to support students and programs. The ORU does not receive any funding support from this industry program.

**Genesis of ORU 2.**

ORU 2 was established in 1983 and has the distinction of being the only ORU within the university that was started from outside the university—founded by a consortium of related companies. A local visionary business entrepreneur, a supplier of the
industry, envisioned in 1981 that the industry was heading on a trajectory that would need an increased level of scientific technology. He had the wisdom to foresee that the technology would increase while costs would decrease in the future. From his viewpoint, the industry required diverse ideas and input and this new knowledge should come from the universities. The entrepreneur pursued his vision by engaging other companies to form a consortium and as a group they investigated different universities to house the center. After a review process, this university was selected and an agreement was reached between the university and the industry consortium. The ten company industry consortium contributed a total of $12M over a three-year period to the development of the ORU2. The initial funding was used for the construction of the ORU building, for research funding, an Information Center, and the endowment of four chaired professorships. At the outset the university provided the land for the building and additional funds for the construction of the building.

All of the faculty members who hold endowed chairs are recognized nationally as experts in their subspecialty. These faculty members attract qualified students who contribute to a high quality educational core. Several graduate students are now middle managers at these companies making significant contributions to the industry. Since 1983, the Director believes that the internal rate of return to these companies and the university is 35 to 40%. The Director’s proposed evidence for this is the number of graduate students and post-doctoral fellows that have conducted research at the ORU and are now making contributions within the industry.
Organizational structure.

ORU2 is an officially recognized Organized Research Unit at the university. In compliance with university policy, the ORU reports to the Vice President of Graduate Education and not to a Dean because of the multidisciplinary nature of the research. Since it is an official ORU, the Director is responsible for preparing material for the 5-year review by the university and upcoming 15-year sunset review. ORU2 is affiliated with the School of Engineering though not within this college. The organizational structure and leadership reflect the originally developed structure with the endowed chairs sharing the decision-making responsibilities with the Director. Presently there are approximately 65 individuals that are part of the ORU2 team. The team is comprised of a 10 member administrative and professional technical staff and a research component that consists of a core of five faculty in residence (four are endowed Professors from different disciplines, and one is an Associate Director who shares administrative functions with the Director while also conducting research and several senior research associates). In addition there are over 40 graduate, undergraduate, and Post Doctoral Fellows. All endowed professors have a faculty appointment within their academic discipline and carry a full teaching load. The graduate students and undergraduate students are from discipline specific departments and receive degrees from those departments. ORU2 has weekly common seminars for faculty and students. These seminars provide an environment where students gain an interdisciplinary focus to their research field. (See Figure 2).
Vice President for Graduate Education

ORU 2 Director

Assoc Dir  RTAL  RTAL  RTAL  RTAL

Postdoctoral Fellows, Graduate Students

Industry Advisory Council

Note: RTAL, Research Thrust Area Leaders also Industrial Funded Sponsored Chairs

Figure 2: ORU 2 Collaborative Research Organizational Structure
University support.

The university provided the land and the additional costs to supplement industry’s contribution for the construction of the building. The university provides for continuous maintenance and utility expenses of the building and funding of faculty salaries. The university provides modest funding support for the administrative functions of ORU2.

Policies and formal model for industry participation.

The policies and formal model for industry participation were developed through a committee format involving the Director, the endowed professors, and a university committee comprised of faculty and university administrative executives. ORU2 has a formal multi-tiered membership structure consisting of three levels provided as gifts to the center. Benefits vary by level and include access to attendance at ORU2 sponsored technical meetings, appointment on the ORU advisory board, opportunities to sponsor proprietary development projects, and opportunities to send industrial researchers to the center for an extended time. Presently the industry membership consists of 14 large companies.

Formal industry meetings.

ORU2 hosts semi-annual, two-day meetings during which the faculty and students present an overview of their research activities. Industry provides an evaluation of the activities in a “collegial” way which helps to shape the research program.

Information center.

ORU2 has an information center that provides a centralized location for resources on research information relevant to the industry. Information includes books, journals, theses, technical reports, standards and specifications, videotapes, databases, and corporate
information sources. The center also provides specialized services such as translation of journals and tracks current information on the industry.

**Newsletter/web site.**

A newsletter is published several times a year and provides information on ORU2 activities workshops, seminars, grant funding, visits by prominent academicians and industry experts, student and faculty research, and items of interest to the sponsoring industry. ORU2 has a Web Site that provides an overview of the background, programs, and achievements of the ORU.

**Project selection and resource direction.**

The Industry Advisory Council, which is comprised of one representative from each company, formally meets at the semi-annual meeting. During the meeting the industry representatives provide feedback and comments to help shape the research program. The academic group of the Advisory Council makes the final decision on the direction of the research program and allocation of resources. Several companies also provide additional funding for targeted research projects and student support. The research direction for these projects are decided jointly with industry.

**Relations between director and other ORU members.**

The university environment encourages each faculty member to be mini-entrepreneurs where they determine their own research direction and are responsible for the activities. The Director is a full professor who in addition to his administrative responsibilities conducts his own research and directs a research group of 15 people. The Director leads ORU2 by obtaining the resources that the faculty needs and, along with his staff, is responsible for the daily administrative operations of the center. The Director, the
Associate Director, and the endowed professors, through a committee format meet monthly to discuss issues and make decisions that impact the ORU2.

All of the endowed professors have been with the ORU since its inception and are now considered leaders in their subspecialty. As reflected by the Director, ORU2 is experiencing "a graying of the ORU" and needs to prepare for the future. In his mind, there is no doubt that the ORU will continue to train state-of-the-art individuals and no doubt that the industry will continue to grow. Throughout the history of the Center, industry has been active in providing guidance for the research program and in recruiting students as employees. Today, several former students have achieved a senior level status with the Center's corporate sponsors. The research program continues to meet the more demanding requirements presented by their industry sponsors. From the Director's perspective university spin-off companies within this industry are unlikely.

Organized Research Unit Subject 3

Introduction

In the early 1990s, this ORU was awarded funding under the National Science Foundation Engineering Research Center Program. (NSF ERC). Historically, ORU3 originated as another, much smaller ORU that was established in 1983. On a national level, this ORU is the largest of all the university research units that conduct research in this specific area. The founding Director worked for industry at a major corporation for five years before pursuing an academic appointment and was responsible for the establishment and the development of the ORU to it's current level of activity. Recently, the founding Director resigned his position as Director, opting to leave the university for a senior position with industry. The new Director, also serves as Chairperson of one of the
academic departments within the School of Engineering. The new Director has held senior level positions with industry and the federal government.

**University background information.**

The university where ORU 3 is located is a private university that can trace its roots to the beginning of the twentieth century as a technical school. Today, the university consists of seven colleges and schools and has a vision to lead educational institutions by building on its traditions of innovation and transcending disciplinary boundaries to meet the changing needs of society. An important element of the university’s mission is to transfer research results to society. Over 60 research centers and institutes based at the university facilitate this element. Many centers have been established that provide a bridge between the traditional departmental structures and the focus of some of the university’s interdisciplinary research programs. Presidential initiatives characterized during the initial development phase of the NSF ERC sought to build its reputation for innovative ideas and pragmatic solutions to the problems of industry. These ORUs provide the framework needed to build strong relationships with the business world, matching industry’s needs with the university’s areas of research strength. The School of Engineering which houses ORU3 is comprised of seven departments, 11 centers and over 20 research groups, initiatives, and large federal programs.

**Genesis of the ORU3.**

The founding Director of ORU3 worked for over five years with a major corporation as an industrial researcher. Upon securing a faculty position at the university, the Director sought to establish his research agenda by working closely with industry. The Director was aware of what universities were not doing and he knew that industry would
be delighted to have a university work in this interdisciplinary field. In 1982, the Director sponsored a two-day workshop inviting technical first and second line managers from key companies plus university faculty to shape his research program and establish the criteria for the research plan. With this information, he developed a strategic plan and a formal multi-year membership fee schedule to adequately support the research program. The fees were set high and companies were required to commit to participate for a minimum of three years. The founding Director dedicated 12 months to engage industry and was successful in securing the support of two key industry players. In 1983, ORU 3 was established as an industrially-sponsored Center of Excellence to educate students trained in the specific industry research area and to provide its member companies with the research base to compete in the rapidly growing industry. Several faculty at the university had some expertise in the field to further develop the research area. The Director provided seed support for faculty and students from seven departments to focus their efforts in this field. Initial industry support was $3M. By 1990, industry was committing $5M annually for support of the ORU’s program. Against this backdrop, ORU3 sought and achieved the award of the National Science Foundation ERC grant in the early 1990s. The ORU’s charter is to broaden the scientific and engineering knowledge base of the industry and educate engineers and scientists in the field while striving to achieve the technology breakthroughs necessary to reach ambitious long-term, systems-level engineering goals.

University support.

The university directed funding provided from the state government and industry for the construction of the building that houses ORU3 and its associated laboratories. Other ORUs are also based within the same building. Over 18% of the annual budget is
comprised of university support through capital equipment funds, personnel support, and other cost-sharing for the ORU. The university does not charge overhead on industry funding.

**Organizational Structure**

ORU3 is based on a systems program approach that currently focuses on five major Research Thrust areas. Senior level administrative functions are performed by the Director and the Director of Operations. The founding Director recently resigned after 15 years in that position leaving the university for a position with industry. A new Director has been selected who also serves as the Chairperson of one of the School of Engineering academic departments. The ORU has a present staff of over 200 personnel, which includes faculty, graduate students, postdoctoral Fellows and visiting researchers, and undergraduate students involved in ORU sponsored research projects. A majority of ORU3 is housed in one newly constructed building. ORU3 is interdisciplinary and draws from six academic departments to provide a unique integrated approach to technology development not possible through individual investigators. ORU3 reports to the Dean of the School of Engineering and submits annual technical and financial reports. The policies and model for industry participation were developed by the founding ORU Director. The membership structure was based on recovering the full benefit to industry for participating in the ORU's research program. (See Figure 3).
Note: RTAL, Research Thrust Area Leaders

Figure 3: ORU3 Collaborative Research Organizational Structure
Formal industry interactions.

ORU3 has a multi-tiered membership structure framework that ranges from a limited membership level where the company receives research reports and technology from only one research thrust area to the highest level where the company is considered a full partner in the research consortium and has special benefits associated with this status. Full partner membership comprehensive benefits include: facilitated access to graduate students; facilitated access to faculty consultants of the ORU; preprints of research reports published by the ORU; attendance at the semi-annual members meeting and industrial review of the Center's programs; annual reports; research highlights; free use of computer software developed by the center; royalty-free license to patents received by the ORU; right to place a research scientist or engineer at the ORU; invitation to members only workshops on related technologies; membership on the Industrial Advisory Board of the ORU that supervises the ORU's activities and option to direct half of their contribution towards specific research projects where the company is then expected to assign liaison personnel to interact with the university researchers on the projects. Industry can also provide funding for research grants to directly sponsor a specific project.

Formal industry meetings.

ORU3 hosts two reviews each year where all sponsors are invited. The format of each meeting emphasizes the targeted sponsoring group: 1) NSF review and industry is invited, 2) Industry review and NSF is invited. Each meeting consists of two days of presentations and a technical poster session. Three to five representatives from each company typically attend. The meeting agenda includes a closed session by industry where
they caucus among themselves and then present their comments to the ORU. Presently there are 42 companies that are members of the ORU3.

**Newsletter/web site.**

ORU3 has a newsletter published at various times throughout the year, which provides information on the research activities, students, and faculty members. ORU3 also has a comprehensive Web Site that provides information on the ORU’s program, achievements, personnel, and activities. The Web Site provides a private section accessible by sponsoring members only. Student’s thesis, dissertations and research technical reports are available through this section.

**Project selection and resource direction.**

The founding Director sought and received industrial funding support for ORU3 research activities. The Director provided this initial funding as seed money for faculty to explore research activities more closely related to the interdisciplinary needs of this specific industry. Industry provided advice to shape the research program, focusing their recommendations on short-term initiatives. Once the ORU achieved NSF ERC status, funding allocation was based on the ERC strategic plan that emphasized more of a systems and long-term research plan. Advice from industry was considered against the goals of the strategic plan. The final decision for project selection and resource allocation was made by the founding Director in association with the Director of Operations.

The new Director also in line with the goals of the strategic plan is now engaging other Research Thrust Area Leaders in the decision-making process using more of a consensus building-strategic planning approach. The semi-annual meetings with industry provide a very constructive exchange, whereby, the Research Thrust Area Leaders
question industry as to the basis for their comments and suggestions. Currently, the senior team members are looking at the achievements/merits of each area and formulating different paths to succeed, taking into consideration resources needed to achieve these goals and objectives.

**Funding streams.**

Initially, all funding for ORU3 was secured from industry. Achieving the NSF ERC funding expanded the size and scope of the program. Presently, ORU3 support breaks down as follows: industry 37%, NSF 27%, federal/state 16% and university 18%.

**Interactions between director and senior research team.**

The founding Director was responsible for the establishment and successful development of ORU3 into the recognized center that exists today. The founding Director was the primary decision maker for project and resource allocation and was responsible for suggesting and providing seed money for faculty members to explore research projects specifically within this discipline. The founding Director was responsible for engaging industry support for ORU3 and introduced the faculty members to the industry sponsors.

The new Director has shifted the decision-making process to a more consensus building process among Research Thrust Area Leaders. The new Director espouses a decision-making process that requires greater involvement by the Research Thrust Area Leaders. This approach requires an increase in time requirements for non-research activities for all senior members. The new Director cites his primary responsibilities as focusing on strategic issues, managing faculty and guiding the research direction. The new Director’s view is that the Research Thrust Area Leaders are responsible for setting the research direction and long-term planning for their areas.
The Center is in the "downramping Phase" of the NSF funding. The entire research program is now undergoing a restructuring and each area is being assessed. ORU3 senior team members are considering a number of issues which include other research opportunities, identifying other faculty members that may have skills in areas relevant to the strategic plan, and what they should be doing with the appropriate departments to locate or identify those faculty members. New membership fee pricing schedules are under consideration. Subsequently, the new Director will incorporate the results of this exercise in strategic discussions with industry. Potential areas of reassessment are industry membership structure and intellectual property policy. One new initiative focusing on different but related research areas have been submitted to the NSF for new funding under the ERC program.

Section Two: An Overview of the Industry

Introduction

The United States marketplace is an amalgamation of many different industries. This study focuses on three ORUs that conduct research relevant to the problems and needs of one of the sub-component industries under the generic collective term information technologies manufacturing. The information technologies manufacturing industry that these ORUs interact is a mature $30-50 billion industry where companies have internal research and development budgets in the $10 to $20M range. This industry is unique in that competing companies within the same industry coordinated themselves by establishing a non-profit industry consortium while also maintaining a very competitive position with one another. All three of the ORUs participate in the activities of this non-profit organization/consortium and receive funding for research projects.
A brief overview of the organization/consortium along with comments from one of its executives and two executives from sponsoring companies have been included to provide further insight into understanding the environment in which these ORUs interact. The non-profit corporation executive interviewed for this study has been with the organization for over six years. Prior to managing the non-profit organization, he was an executive within the R&D division of a major corporation. One of the executives is the Vice President for Research for a major corporation and interacts with the 3 ORUs and the non-profit consortium. The other industry representative was the corporate liaison for one of the major corporations that is a sponsoring member of one of the ORUs.

**Genesis of the non-profit industry corporation.**

In 1991, the National Institute of Standards and Technology (NIST) launched the Advanced Technology Program (ATP) to increase non-federal investment in research and development. One of the major proposal requirements was that requests for funding had to be submitted through a coordinated effort of different companies. In the early 1990s, several companies engaged in this information technologies manufacturing industry incorporated as a non-profit mutual benefit corporation to compete in the NIST ATP program. Over the years the industry non-profit corporation broadened its range of activities from its original function as a platform for joint proposal submission to an additional role as a non-profit funding agent that pools industrial and governmental funding awards financial support through a competitive process for projects conducted at universities and company labs.

The non-profit corporation's strategy has three main components. One, is to create an information technologies manufacturing industry roadmap and research strategy. Two,
develop strategies to increase government’s support of the industry. Third, foster the establishment of pre-competitive joint research projects, involving collaboration with manufacturers, suppliers, universities and national laboratories. According to the executives, the non-profit consortium attempts to bring a different dimension than the research program managed by the ORUs located at universities. (N=2). The non-profit organization has a formal multi-tiered membership structure with associated benefits supported by a sliding fee schedule based on corporate revenues. Universities and government agencies are also members and pay an amount contingent upon their status as a participating member of a research project sponsored by the organization. Currently, there are over 25 members which include an industrial component comprised of mostly large companies, government agencies and a university composition of the three main industry recognized centers and then individual researchers located at several universities that conduct research relevant to this industry. Membership benefits include participation in joint research projects with companies, universities and government laboratories; leveraging of member investments in long-term research; participation in the development of a national roadmap for the industry; heightened communication with other companies, universities and government agencies; participation in technology workshops; and pre-publication access to information about university research and educational programs.

The non-profit corporation is a facilitating organization that advances a research agenda that focuses on pre-competitive research. The staff of the organization does not conduct the research, the member universities and companies are responsible.

All three of the ORUs in this study are active members of the industry non-profit corporation. Faculty members receive funding support for their research projects,
collaborate with industry members on joint proposal submissions, make presentations at sponsored technology workshops, and are members of the organization’s technical committees.

**Project development and management.**

Funding support for the organization is derived from membership fees and funding received through competing under government programs. Project selection is determined by the members of the organization. Management policies require quarterly meetings of the team for each project. Most projects are very interactive and also require monthly reporting through electronic mail. Each project team develops it’s own Intellectual Property (IP) policy with a common standard that all partners who participate in a project receive ownership of the IP. The industry is moving so quickly that the organization currently favors open publication and dissemination of information which is a change from encouraging the patent application processes of a few years ago.

**Interaction with universities.**

According to the organizational executive, programs at universities are now more closely managed or better managed than in the past. Universities “generally don’t like strings attached” and would like more autonomy in determining the research deliverables. The process for selection of research projects requires world-class faculty to make presentations and compete in an open forum with their colleagues. Several faculty members appear uncomfortable in this position. The executive anticipates that the relationship between the non-profit organization and universities will stay on course and will increase in benefit for all participants. One of the industry executives is considering
whether to channel funding only to the non-profit consortium for distribution instead of funding all three ORUs and the non-profit industry consortium.

Over the years as an executive with the organization he has had the opportunity to interact with faculty members who have the traditional academic career track experience and those faculty members who had worked full-time with industry prior to their faculty position. He feels that the best working relationships are with those ORUs where the university developed a culture to work with industry. The background of the faculty member did not matter as much as the culture adopted by the university. One industry executive concurred with this comment, the other industry executive stressed the importance of the faculty member having some industrial experience.

Interaction with government.

Government through programs such as the NIST ATP program provides a platform for industry to come together and conduct pre-competitive research that has contributed to the United States being a leader in the industry. Two of the executives are concerned that there is a growing movement in congress to eliminate these type of programs. The programs should not be viewed as “corporate welfare” but as a government sponsored initiative that brings companies together to leverage the resources of each other so that the United States maintains a leadership role. The profit margin in the product development is very small, programs such as these are needed to act as catalysts. The government has provided funding for operational expenses for other non-profit industrial organizations allowing all the pooled resources to go towards projects. This non-profit organization is very interested in negotiating a similar relationship with the government.
CHAPTER V

Sustaining University-Industry Collaborative

Research Activities

Introduction

The research activity conducted by the three ORUs utilizes a systems approach to address complex industrial problems from a basic science or theoretical foundation to an application-oriented framework. The Director along with Research Thrust Area Leaders are responsible for the research activity and integration of the findings and corresponding systems methodology into the educational program. The senior research team also interacts with the industrial sponsors and is responsible for maintaining strong relations with these partners. It is the intent of this study to provide a broad and in-depth view of the factors and issues that may contribute to sustaining collaborative research activities with industry. Chapter IV provided an overview of the genesis, strategies and organizational configuration to build collaborative research activities with industry through an ORU structure. This chapter seeks to build upon this foundation by introducing new data and concepts by exploring the perspectives, experience and viewpoint of the entire ORU senior research team.

Section One of this chapter explores further the unique knowledge, experience and expertise of the ORU Director by analyzing and summarizing the processes and strategies these ORU Directors developed, implemented and/or facilitated to achieve a level of
sustainability between the ORU with industry. In order to maintain anonymity of the ORU Director’s responses the data is aggregated and presented by topic area. The data includes the responses from all four ORU Directors. (Two permanent Directors, one new and one former as presented in the ORU description chapter).

Section Two presents a summary of the comments of the Research Thrust Area Leaders beginning with the ORU’s internal organizational structural framework and progressing outward to the ORU external activities. In order to maintain anonymity of the Research Thrust Area Leaders’ responses the data is also aggregated and presented by topic area.

Section One: The ORU Directors Perspective and Experiences

Interview Analysis and Summary

Evolutionary changes in the industry since the genesis of the ORU.

During the 1980s budgetary allocations for funding support for the ORU program came from the corporate division under “goodwill” or community service activities. It was common place during this period to commit funding for several years. Since the early 1990s in response to an increasingly competitive environment for this industry there was a shift in the internal source of funding from companies. Budgetary decisions and allocations for research activities are now made by the operating or several operating divisions. Any investments made by these business units are expected to demonstrate a direct relationship between investing in these activities and the impact on the profitability of the company. As a result of these changes most companies will only make a one-year funding commitment that is based on the evaluation of the previous year’s ORU activities and the perceived
benefit to the company. This industry budgetary allocation scenario for ORU activities is expected to continue. (N=3).

Currently, within the industry there is a high level of employee cross-fertilization. It is perceived within the industry that this continuous exchange “contributes to the vitality of US industry in this area”. This industry characteristic may impact the continuity of the relationship between the sponsoring company and the ORU. (N=1).

**Sponsoring member companies.**

The portfolio of companies that are members of the ORUs have generally remained constant over the last ten years. The Directors’ responses stated two main reasons for companies not renewing their membership. 1) Company mergers within the industry and 2) A change in the corporate strategic plan resulting in a discontinuation of product development in this specific area. (N=3).

Issues related to US or foreign ownership have impacted the portfolio of companies for the ORUs. Two of the ORUs originally restricted corporate sponsorship to US owned companies. The other ORU had no restrictions on corporate ownership. The two ORUs who have restrictions are now revisiting this foreign-owned exclusion policy.

At present all three ORUs are members of the non-profit industry corporation, are active in the various committees and through a competitive process receive funding support for consortium related research activities. When the industry non-profit consortium was first established the ORU that allowed non-US companies to be sponsoring members was restricted from participating. Recently, this US company restriction policy has been abolished and the ORU participates fully with the non-profit industry consortium.
Sustaining ORU-Industry Collaborative Research Activities

An analysis of the data reveals that the ORUs Directors share similar views as to why their ORUs have been successful in sustaining collaborative research activities with industry for over ten years. Their responses are categorized as follows.

University research team.

Each ORU Director participated and/or facilitated the development of a core research team that is comprised of tenured faculty members who are recognized in their subspecialty both by academia and industry. These faculty members along with the Director are responsible for the research program and building/sustaining collaborative research activities with industry.

Having a strong core research team and program attracts highly qualified students to the ORU to conduct their graduate research work. As reported by the ORU Directors, access to the highly trained, industry specific graduate students contribute to these companies continued participation in the program. Some companies have in place a very aggressive internship program. Providing support to the ORU is a relatively inexpensive method for companies to develop and recruit students.

Research program.

To achieve a ten-year level of sustainability with industry the ORUs in this study have been successful in proposing and implementing a research program that meet the requirements of both the university and the industry sponsors. The final decisions for the research program are made by the core university team with advice by the industry sponsors.(N=4). Each ORU sponsors an annual industry meeting to provide the opportunity to critique and render advice to the following year’s program. It is typical for
each company to have one main point of contact with the ORU, however, several other representatives from different sites also attend the annual meetings.

Criteria for the selection of research problems are based on the following. 1) The proposed projects methodology are educationally sound and totally defensible, 2) The problems and research are suited for peer review by the National Science Foundation and 3) The problems targeted by the ORU meet industry needs and requirements for financial support. It should be noted that the ORUs do not want to be a considered a “job shop”; industry’s perspective now also reflect this standard. (N=4). Industry needs to feel that they are receiving tangible and intangible results. Industry wants the ORU to take risks, to conduct research that looks to the future generations of the product. Industry needs to know what they will be shipping in 2 years, the ORU research program should be targeting no further then 5-7 years into the future.

It is recommended that the research program does not have objectives too close to what industry is currently doing. The ORU cannot compete with industry. The ideal situation is where initially all the companies work together through the ORU framework. As the companies begin to understand how the technology could be applied, the partnering slows in that specific area. The technology development then continues at the company’s facilities under proprietary conditions. “The success of the ORU is that they operate by leveraging funding support from government and industry and achieve a level of research results where industry can use it and then go their separate ways.”

**Frequency and Type of Interactions**

All three ORU Directors emphasize the need for frequent interactions with industry representatives (at least monthly). It should be noted that two of the ORUs are
located within close proximity to the sponsoring companies. It is perceived by the two ORU Directors that this close proximity contributes to the sustained relationship with industry. However, the largest of the three ORUs is not located in close proximity to the sponsoring companies. Any disadvantage related to distance appears to be minimized by frequent visits by the Director to the companies and by the use of telecommunication technologies to maintain an adequate level of communication and flow of information.

All faculty members at each ORU interacts with the sponsoring companies. It should be noted that different representatives from each company can have a major influence over the amount of interactions. Industrial representatives can change regularly. In some situations a few have remained the same over the ten-year period. When new industry representatives become involved with the ORU, the ORU needs to provide an orientation as to the expectations of the partnership.

Each ORU provides the opportunity for students affiliated with the ORU to interact with industry. Several students spend time during the summer at the industry sponsor’s facilities where they conduct research applying their newly acquired academic skills to meet industry needs. During the summer industry internship program they also acquire industry specific skills which provides them with a broader perspective which they then integrate into their doctoral research program.

Overall, the recommendation was that working with industry requires “hard work”. One ORU Director stated that people outside the ORU may assume that the ORU has a “golden goose and that they pluck it”. “The most significant indication of potential failure in working with industry is to think that industry is just a sinecure”.
Each ORU Director was asked to state the reason(s) they believe industry participated in the ORU. The responses are as follows. Two of the Directors stated the interest in cutting-edge research as the primary reason, the other expressed this as his second reason. Explanation for this response was due to the shorten time requirements to move from the lab to product. One ORU Director stated the industry's interest in recruiting the graduate students as the primary reason. This ORU Director considered the industry need for the research as secondary to the need for highly qualified future employees. The other ORU Director stated that initially the main focus was access to the highly qualified students, however, as the research program evolved the level of research conducted by the ORU achieved a level of significance to the company sponsors. A third response is that the ORU provides a "neutral turf environment for companies from within the same industry to discuss possible directions for research 5-7 years into the future."

**Intellectual Property Issues**

Questions specific to the ORU Director's views concerning Intellectual Property issues were not included in the formal interview protocol. However, under the question, "are there any other issues that your would like to discuss", all of the ORU Directors expressed their views regarding Intellectual Property issues. The following section summarizes their comments.

Intellectual property issues have been a problem since Day-1. They do not believe that they will be able to completely resolve the issues, "they have learned to live with it". It should be noted that patents are for defense within this industry and that cross-licensing among companies is common. They believe that industry would like to have access to all Intellectual Property developed at universities as part of public domain. One ORU
Director expressed his view that the evaluation metrics for young faculty are changing. In the past the Director would not have recommended to a young faculty member to feature their patents to demonstrate technology transfer. There is a concern that in light of the Government Performance and Results Act of 1993 (GPRA), faculty might be forced to pursue patents as a performance metric and he now is beginning to advise young faculty members to pursue patentable research activities.

One ORU Director shared his experience which shaped his policy regarding patents. On three different occasions the ORU Director reached an agreement with the technical and financial divisions at a sponsoring company. The ORU Director spent a significant amount of time in developing these relationships and in negotiating the agreement to conduct the research activity. The legal departments located at the company and the university could not reach an agreement, as a result the research activity was not funded.

Section Two: The Research Thrust Area Leaders Perspective and Experiences

This section presents a summary of the comments of the other senior level members beginning with the ORU’s internal organizational structural framework and progressing outward to the ORU external activities. Two of the ORUs employ senior level administrative research Directors to facilitate the activities with industry. One administrative Research Director also conducts research as a Senior Researcher, non-tenure track. The other is also responsible for the financial operations of the ORU and does not conduct research. They are considered part of the senior team and for these reasons their comments are included in this study.
Interview Analysis

Structural configurations and internal coordinating methods.

Each ORU has an official organizational structure that is an outline of the desired pattern of activities, expectations, and exchanges among the research team. The shape of the formal structure may enhance or constrain what an organization is able to accomplish. (Bolman & Deal, 1991). The formal organizational chart of the three ORUs has common characteristics. Each is comprised of a research core—Director and Research Thrust Area Leaders. The two larger ORUs also have a senior level administrative position that is responsible for the increase in administrative requirements associated with larger organizations for managing the more complex financial, reporting, and information dissemination issues. In order to fully understand how these ORUs grew and sustained collaborative activities within the same industry, the selected methodology explores the common traits and differences of the internal organizational relationships between the senior level members and the Director.

The responses, though limited, addressed the methods that linked individual and group efforts to shared goals while also providing incentives for participation by the tenured faculty members. Comments pertained to the coordination and control of resources and selection of research direction by project area. Responses suggested that formal coordination was achieved in two primary ways: 1) vertically, and 2) laterally. According to Bolman and Deal, vertical coordination is implemented by creating a chain of commands; establishing policies, rules and control systems. Vertical coordination tends to dominate in an environment that is relatively stable. The task is well understood and
uniformity is a critical need. Those in position of authority are formally charged with integrating the activities of an organization and maintaining a goal-oriented focus.

Characteristics of lateral coordination include formal and informal meetings for developing plans, solving problems, and making decisions. Teamwork that brings together representatives from different areas and specialties to work together on a certain project or problem, is likely to dominate in organizations that perform complex tasks in an environment of high uncertainty and rapid change. Authority systems and rules are typically less formalized and more flexible.

Responses for this topic were aggregated by ORU. It should be noted that the senior team members at each individual ORU all expressed similar responses. One ORU primarily reflected a lateral and collegial coordination of the research, education program and allocation of resources to achieve the goals. Another ORU espouses vertical coordination and allocation of resources with open communication and a loosely organized structure. For both of these ORUs their styles have not changed since they were established.

The third ORU was based on a blend of vertical and lateral coordination structure since its inception. However, as the research activity grew in size, the structure evolved into primarily a vertical coordination with a closed communication exchange that was somewhat politicized. All members of the senior core commented that the Director would make the final decision on resource allocation. One Research Thrust Area Leader believed that if the Director had a different philosophy, the ORU would be stronger. Another Research Thrust Area Leader suggested that the set of rules for funding allocation should be made known. Personality issues came into play and Research Thrust Area leaders
needed to craft a response to obtain funding. Under the new Director, the management style has shifted to a lateral coordinating structure emphasizing management by consensus. One faculty member suggested that this style would require a greater time commitment by Research Thrust Area Leaders.

From this limited study, either type of internal coordinating organizational structure does not appear to impact or impede the success rate for the ORU in building and sustaining collaborative research activities with industry.

Why faculty participate in the ORU.

Faculty typically conduct research and advise students as part of their academic responsibilities. To fully understand why these ORUs sustained activities with industry, it is important to understand why these faculty members chose to participate within the ORU framework—what did they perceive were the incentives. Their comments may contribute to the success of the ORU with industry.

According to the faculty members, the ORU provides an environment for broad interaction. The technology requires an interdisciplinary approach to development. Interaction with other faculty contributes to their effectiveness and enhances the program. The interaction provided by the ORU environment affords the opportunity to build upon the work of their ORU colleagues.

The university administration through allocation of resources, meetings and written material strives to promote an interdisciplinary research environment. By providing a research environment under “one roof” the ORU is able to successfully operationalize this interdisciplinary goal. The university system encourages faculty to work with industry without providing guidelines or recommendations on how to do so effectively. The
process is often more complicated than anticipated and faculty need to pursue effective methods of dealing with industry. The ORU provides a stable and continuous framework for these relationships to succeed. The ORU structure also furnishes the opportunity for faculty to work on parallel projects at the same time with many students, allowing the faculty member to simultaneously pursue different paths. This multiple project pursuit is not common in industry. (N=10).

**Industry impact on ORU research program.**

Industry provides financial support for the research program with expectations that there will be a return on their investment. The following comments were in response to the topic of the industrial role as a sponsoring member in determining the research direction of the ORU.

All respondents stated that the research direction is based on industry views regarding “demanding” topics and problems. Industry assists in shaping the program by providing advice and feedback on research proposals and current projects. However, the final decision is made by the faculty member. There have been conflicts over the intended industrial application of the long-term research. The industry representative is generally most concerned with the immediate problems and situations that he or she will confront at the office that day. Through a tutorial process the faculty members have succeeded in educating the industry representatives of the value of the long-term research. Industry has slowly acknowledged the value of the more theoretical type of research. The project selection process incorporates a strategy where the program is relevant to industry while also meeting the requirements for a doctoral level of research. The industry support funds the educational and research experience of students. A major focus is in conducting world-
class research to continuously generate new knowledge. One faculty member commented that he has never accepted funding for a targeted research project with industry. All of the respondents stated that the ORU system is not meant to be “a job shop” (N=10). It should be noted that the membership structure at the highest level at one of the ORUs entitles the company to target a portion of the membership fee to a specific project. In this case industry functions as a full partner with the ORU.

**Why does industry participate.**

Industry conducts research, has been very successful in achieving results, and has millions of dollars allocated each year for labor and facilities to conduct research. Why then would this sector be interested in the comparatively small research operations at these ORUs? Each individual was asked to respond to this question and to share their insights as to why industry participates with the ORU. Their comments were stated according to the most important to next level of importance. The responses are aggregated into three categories. All respondents stated access to the students and the research component as being a reason. The ranking varied. The most important reason for the collaboration was access to the students. (N=9). Access to the students was of secondary importance. (N=1). The research component was stated as most important. (N=1). Research component was of secondary importance (N=9). An additional response ranked after the research and students was access to professors and the information center. (N=2)

Detailed explanations for access to graduate students include access to future employees who have specific training within a specific industry. These students also develop an interdisciplinary team approach to problem-solving within a theoretical and practical framework and have the opportunity to work with quality faculty who are
responsible for planning the research program for the students. The interactive research program allows for students to become familiar with the companies and the companies to become familiar with the students. The ORU framework provides the medium to educate the student by exposing them to important problems in this field. Their doctoral research is quite often immediately applicable to the needs of industry.

Detailed explanations for responses for the research component include an opportunity to utilize expertise not available in industrial labs and to seek solutions to basic problems that due to time restraints cannot be addressed in the industrial environment. This is research that industry is not currently doing and cannot be adequately funded by one company. Problems are interdisciplinary and complex and require a massive research effort larger than each company can address by themselves. The ORU provides the opportunity to leverage each company’s resources. The research is perceived as immediately valuable and worth their investment. The ORUs tend to have a weather vane effect and look long range, whereas the industry as a whole is more concerned with the immediate or “Development” side of Research & Development. The industry is very competitive and the profit margin is low so the critical step to take is to establish a relationship where the ORU is an extension of their research. Industry is also now concerned that the ORUs may make a critical development and they want access to the emerging technology. Detailed explanations for responses to support the faculty’s claim that the industry is interested in having access to professors and the information center include “these resources provide a flow of information that keeps industry informed so that they are not left behind. Industry spends a lot of time acting defensively, they need to access changing trends or new developments in the industry.”
Types of Informal Industrial Interactions

As described in Chapter IV all three of the ORUs developed a formalized membership structure to engage industry. This section explores the personal or informal interactions of the researchers to provide a more comprehensive understanding of the common and ORU specific types of interactions with industry. A review of the comments centered around project interactions and dissemination of research findings as a basis for continued funding. It should be noted that all Research Thrust Area Leaders commented that they interacted primarily with upper level senior engineers or group leaders. This level of interaction may be useful as one strives to sustain collaborative research activities with industry. (N=9).

Project Interactions

Frequency and type of interactions.

In response to frequency and type of interactions with industry all of the respondents commented that a majority of the interactions occurred without leaving the office through telephone conferences and electronic mail. The communication concentrated primarily on the research projects. (N=9).

Visits by industry.

All ORUs invite industry to an on-site visit for an overview of the activities, an opportunity to meet the faculty and students, and to tour the facilities. Faculty and students also visit the sponsoring companies for meetings or to introduce potential members to the program. Having industry visit the ORU is the preferred method because it allows industry to actually view the active research program. (N=9).
Joint research projects with industry.

The ORU by being a member of the non-profit industry corporation also provides the opportunity for faculty members to develop relationships with industry. All ORUs are involved in joint projects as Co-Principal Investigators with industry under the various programs sponsored by the non-profit industry corporation. These projects may or may not pursue the strategic plan initiatives of the ORU. However, these projects provide a platform for the industry representatives to become familiar with the faculty's work and talent, thus strengthening the relationship between industry and the ORU.

On another project, industry approached the faculty member at one of the ORUs to prepare and submit a proposal as a Co-Principal Investigator in response to a federal program. The industry representative learned of the work of the faculty member at meetings sponsored by the ORU. (N=1). All of the ORUs provide opportunities for industry fellows to collaborate with faculty members for a period of time on-site at the university. US companies typically send a senior industrial researcher on a sabbatical to the university to educate them on the new technologies. Foreign companies often send junior engineers to pursue the doctoral degree while working closely with faculty at the ORU. Students also play a role in joint projects with industry. At one ORU, students visit the industry sites to learn about the problems that they are having from the industry representative. (N=1). In another ORU, the students go to the industry site to train the industry group on the application and use of the information. (N=1).
Dissemination of Research Findings

Presentations.

Presentations by faculty members on their research findings relevant to projects supported by the ORU provides the opportunity for industry to learn about their research, become familiar with their work, and allows for opportunities to talk directly with industry in neutral territory. Quite often faculty members introduce the work of their ORU colleagues during their presentations. (N=4). All faculty members make presentations at the formal industry meetings sponsored by the ORU, several of the students also make presentations at these meetings. All faculty members submit papers for publication and make presentations at professional society conferences. Two ORUs sponsor weekly or monthly seminars for the ORU faculty and student research team to learn about the most current research in their field. Industry are invited to these meetings. (N=2). Faculty members also make presentations at the facilities of industry sponsors. This forum provides the opportunity for the faculty member to interact with the entire research group of which the industry representative is a member. Quite often the faculty member initiates the meeting and is very willing to visit industry and make a presentation. (N=10).

One faculty member developed a series of courses for industry and adjusts the content according to the level of the industry group. (N=1).

Information center, web sites.

Two ORUs provide access to an information center housed at the ORU that pools resources and material relevant to industry. All ORUs have theses and technical reports available on-line via the respective Web Site.
Factors That Contribute to Sustainability

This section reflects the Research Thrust Area Leaders' experiential view categorized by topic area as to why their ORU has sustained collaborative research activities with industry.

ORU research team.

The team members conduct research, furnish an educational environment for students, and interact with industry. Comments suggest that sustainability can be attributed to the fact that the research team are all leaders in their field. The faculty produce high quality research, are very talented, and are recognized as top in their class. The faculty also conduct high-quality research that no other entity is addressing.

Every university member needs to be comfortable and effective as they interact with one another and with industry. These one-to-one interactions promote a collegial atmosphere when having discussions. Collegial discussions encourage a high level of candor where all participants can talk freely about their problems or issues. This type of atmosphere promotes the exchange of ideas and information and contributes to identifying solutions. (N=10). Four Research Thrust Area Leaders located at one ORU emphasized the Director's personality as he interacts with the ORU team and industry, coupled with his talent as a researcher, as positively impacting on the sustainability. The entire team needs to interact on a one-to-one liaison relationship with each company.

ORU students.

Industry is interested in students trained in the field that have a high level of knowledge and insight so that when they become full-time employees they will exhibit a high level of productivity within their first year. By providing an interdisciplinary
educational experience that integrates industry relevant problems into the educational program, the ORU develops students that are sought after by industry.\(N=10\). Currently, the biggest challenge for industry is that there are not enough trained individuals. Two of the ORUs have a formal internship program to enhance the industrial experience for the students.

**Research program direction.**

The ORU’s mission and the strategic plan to implement the mission are critical for attracting industry to the ORU activity. There are many problems that faculty can address in their research activities. The ORU’s research effort targets future challenges relevant to the performance of next-generation products. The faculty needs to continuously demonstrate that they recognize industry’s business environment and that the faculty member understands that the companies thrive in a very competitive environment.\(N=10\). The faculty member needs to be very clever to initiate relationships with industry, needs to figure out what will attract their interest, and what will be of value to them without using a lot of resources.

The selected project needs to be specific to their industry and something that industry cannot accomplish themselves. Faculty members are not interested in solving current problems, this would not fit into the goal of providing a quality experience for students in the doctoral program. The faculty member needs to learn how to work with industry and the reverse is also true. Two Research Thrust Area Leaders state that they have lead the industry by producing real accomplishments that industry has applied, while other ORUs and universities follow the industry. These faculty members’ philosophy is to lead industry and industry recognizes that fact. Faculty members quiz industry and take
their comments into consideration to shape the research program. Industry needs to have a compelling reason to suggest a specific direction. The problem selection process coupled with demonstrated achievements in addressing these problems contributes to the sustainability of industry’s support. Real sustainability is achieved by maintaining flexibility in how you manage your strategic plan in face of rapidly changing technology developments. (N=10).

**Flow of information.**

Faculty members expressed their view that sustainability can be attributed to a continuous flow of information from the ORU to industry and to a lesser extent from industry to the ORU. Marketing plays an important role in sustaining relationships with industry. All of the ORU team members including the students are involved in transferring the information to industry. (N=10).

**Value of continuous interactions with industry**

Faculty at the ORUs understand that they need to develop a strong professional relationship with the company representative and that the representative needs to know their work. Company representatives assigned to the ORU are very busy people and require information from the ORU in a succinct, problem-oriented report or presentation. All ORUs have a policy where the faculty member quite often brings students along with them to visit industry. (N=10). One Research Area Thrust Leader sends the student by themselves to present or to train the company representative on the research.

**Profile of industry representatives.**

One Research Area Thrust Leader commented that the ORU can push all that they want, however, if a company cannot find an individual internally within the company who
feels strongly about the research topic and expresses why he or she supports the activity, the interaction will be “killed”. ORU members interact primarily with senior level engineers. (N=10).

Evolutionary changes in ORU-industry relationships since founding of ORU

Each of these ORUs was established over 10 years ago and has succeeded in sustaining collaborative research activities with industry. To fully understand how these ORUs matured and advanced from the building phase to the sustaining phase, it is important to gain some insight into any perceived changes between the ORU and industry from the initial development of the ORU to the current period.

Research program.

The overall theme of the ORUs has not changed, although the individual Research Thrust Areas have been expanded. (N=10). The research program has become more fundamentally oriented and “since industry is not doing this or does not know how to do the research, they are becoming more valuable.” (N=10). Consolidation and downsizing within the industry has created a greater need for this research. In the beginning, sponsors did not appreciate some of the basic research approaches that the ORUs were taking. Companies did not understand the significance for product development. Now industry understands that to keep up with technological advances and increasing competition they need to look at engineering issues and to take into account other properties that require a research effort from other disciplines. The research effort emphasizes a long-term strategy and industry is now realizing the value continues to financially support it. (N=9).
Interactions and pace of activities with industry.

Relationships with industry have become more intense. The area is very “hot” and there is more pressure from industry to provide information. (N=1). The pace of the activities with industry has increased. One faculty member commented that he hustles more and spends more time looking for money.

Changing attitudes within the industry.

There was a consensus that during the ORU development period, corporate funding was more altruistic. Since the early 1980s, companies have downsized, most no longer have a large R&D operation, have reduced research budgets and rely more on the ORU for results. Initially, companies were looking for students, now they also want profitability from their investment.

Where do you see the ORU in five years.

All respondents are confident that their ORU will continue to be a leading university ORU in five years. They all feel that they have the right elements and vision to continue playing a principle role in this field. All respondents believe that their ORU will diversify into other related areas, branching out within the current standard. All are now looking at other product issues that are different but related to their current focus. (N=10). Only one respondent stated that they may form a spin-off business. (N=1). One respondent stated that he will begin to do video conferencing of workshops. However, he added it is still better to talk to live people one-to-one. (N=1). All respondents hope to be growing and increasing the number of professors. (N=10). One of the respondents expressed concern for the “graying” of the research team and the need to train younger individuals to take over. The three ORUs came together at the right time with an industry that is
growing rapidly and will continue to grow. It was expressed by one Research Thrust Area Leader that if the industry stagnates, this would be detrimental to the ORU. (N=1).

**Funding streams.**

Two Research Thrust Area Leaders from the same ORU expressed a need to assess the current membership fee structure and explore an increase in the amount paid by industry to reflect the benefit received by participation. (N=2). These two individuals also commented that they are looking to expand company membership to new areas. (N=2). One leader is considering increasing activity level with the industry consortium directly and in developing a joint proposal submission with industry to the federal government. Other Research Thrust Area Leaders commented that they will be looking for more support from the National Science Foundation for individual Principal Investigator funding. (N=5). Another leader added that you cannot rely on revenues from royalties on patents as a consistent source to provide funding support for research activities. (N=1).

**Problem area working with industry.**

Overall, all respondents enjoyed the intellectual and dynamic environment provided by the interactions with industry. One expressed concern that some students do not complete their doctoral requirements due to the distraction of strong financial incentives from industry. Another expressed concern that the dynamics of the graduate students and industry representatives are different. Students have their educational requirements to fulfill in addition to meeting industry demands. This situation at times requires that the faculty member must act as a buffer between the industry and the students. (N=1).
CHAPTER VI
Study Conclusion and Recommendations

Introduction

Chapter V provided an analysis and discussion of data collected from interviews with the ORU Directors and Research Thrust Area Leaders. Thematic categories and patterns were identified and expounded. The intent of the first part of this section is to discuss the relevance of the themes expressed in this study by comparing the patterns and trends that emerged from the data to the manuals authored by ORU Directors of two major federally funded programs. The comparative format conclusion of this study is also intended to raise issues for follow-up studies.

Background of Comparative Publications

In 1998 two manuals were published that explored several issues related to developing federally funded industry-university collaborative research programs. These publications describe how university-based centers funded under the National Science Foundation’s Industry-University Collaborative Research Centers (I/UCRC) and Engineering Research Center (ERC) programs promoted and developed collaborative research activities between industry and the academic community. The research program of each center targets a different research area that is relevant to a certain industry. The manuals represent an aggregate of information based primarily on the center Director’s perspective complemented in certain sections by other senior members. The manuals do
not distinguish characteristics by industry or research area, however, case studies
highlighting different centers are presented to exemplify certain concepts.

**Industry-university cooperative research centers.**

Industry-University Cooperative Research Centers Program began as a pilot
program of the Experimental R&D Incentives Program (ERDIP) initiated by the National
Science Foundation during the early 1970s. In 1980 the program received full NSF
support and by 1997, the I/UCRC program included 55 cooperative research centers, over
80 universities and 700 member firms. The broad scope of research technologies
addressed ranged from advanced telecommunications to steel processing. (Gray &
Walters, 1998).

**Engineering Research Centers.**

The NSF Engineering Research Center Program began in 1985 when the Nation
was facing a strong emergence of highly competitive foreign firms fueled by government
investment. Engineering Research Centers provide an integrated environment for academe
and industry to focus on next-generation advances in complex engineered systems
important for the Nation’s future. Over 25 ERCs have been funded since the program’s
inception. The broad scope of research systems investigated range from civil infrastructure
systems to material processing for manufacturing. (ERC, 1999).

**Current Study**

The focus of this study differs from the comparative studies in that a nucleus of
ORUs that concentrate their program on the research requirements of one specific
industry, the information technologies manufacturing industry, was investigated. Data was
collected from all the senior ORU members who participate in activities with industry. All
three ORUs investigated in the study initially received a significant portion of their funding from industry and continue to receive at least $1M per year from this sector. One ORU research program after receiving industry support for several years competed under and was awarded funding under the NSF Engineering Research Center Program. The common patterns and trends for sustaining industry collaborative research activities by this ORU were established prior to receiving the federal program support.

**Similarities and Differences**

**Industry boards.**

The I/UCRC, ERC and the three ORUs investigated in this study all have active industry boards that meet at least annually to review the entire program, provide feedback and advice. These annual or semi-annual meetings are critical in that they provide an opportunity for corporate representatives to assess the value that the company receives from participating in these programs. Several of the ERCs have a two-tier industry member board. One board is comprised of technical representatives that assess the and provide recommendations concerning the technical component of the research program. Another board is comprised of senior representatives whose primary responsibility is to provide advice and recommendations concerning the strategic plan and future directions of the research program.

**Research program.**

The research program implemented by the I/UCRCs is developed through a collaborative process between the center and industry. Industry in conjunction with the center approves the research projects. The ERC model also promotes a collaborative decision making process between the center and industry. Industry plays an advisory role
and makes recommendations regarding projects and the research direction. The final decision for the allocation of funding resources and project selection is made by the ERC. The ORUs resource allocation and project selection process mirrors the ERC program.

One can conclude that the ORU model has been successful in sustaining collaborative research activities with industry regardless how the final research program agenda was reached. A common pattern among all three studies is that industry representatives were included in the research program decision-making process.

**Industry sponsor recruitment.**

Recruiting companies for participation in the I/UCRC center research activities as presented in the manual is primarily the responsibility of the Director. However, because the task of recruiting new companies to the center is a continuous process, all I/UCRC researchers are encouraged to exploit every opportunity and every network available to serve as center ambassadors to potential new members. The comprehensive role of the senior members as presented in the manual on the I/UCRCs is not reported in detail thus preventing a complete understanding of their responsibilities in the industry recruitment process. In the ERC model all senior members are expected to participate in all recruiting activities with industry. The trends identified in this study are similar to the ERC model in that all senior members are active in the recruiting process of new companies. This direct responsibility may be related to the research role of the Director and Research Thrust Area Leaders. In the present study Research Thrust Area Leaders have a similar role to the ERC Research Thrust Area Leaders in that these individuals are responsible for their specific research area which includes insuring that the projects pursued meet the requirements of company sponsors. The differences among the programs may be related to
the level of responsibility in the resource allocation decision process. Much larger follow-up studies are recommended to determine the effectiveness of the recruitment process for sponsoring companies.

**Major issues concerning corporate sponsorship renewal.**

The I/UCRC stated that the best predictor of whether a company would remain in a cooperative R&D relationship is whether they perceive the benefits of knowledge and technology transfer to justify the financial investment and time commitment. In this study and the ERC study, the knowledge and technological information were important for sustainability. However, access to students (future company employees) educated by leading scholars within a multi-disciplinary, industry specific program ranked as high and in some cases higher then access to the research results. One may conclude that a research program that provides research results and a future workforce relevant to the specific needs of industry are strong indicators necessary to sustain collaborative research activities with industry. Also, another point to consider is that ORU research results that are commercially applicable do not develop on a continuous, predictable basis. The number of graduate students who are being educated at the ORU within this specific industry is predictable and does occur on a somewhat continuous timeline. The sustained level of students may contribute to maintaining industry’s participation in the research and program.

**Industry-university interactions.**

Another significant trend found in all programs is the emphasis on continually interacting with the industry representative throughout the life of the project. As mentioned previously all programs have annual meetings, however, the industry
representative that is familiar with the project and academic research team may also act as a champion for the university within the corporation. Quite often, these individuals are asked by senior industry members to summarize the benefits to the company by participating in these programs. The summary provided may impact the renewal decision.

Strategies for future growth.

The I/UCRCs expressed three main categories of strategies for future growth and program development. 1) Expanding the current company sponsors by volume by increasing membership fees or by developing research enhancements. 2) Broadening the geographic dispersion and potential impact of this research program. 3) Broadening the vertical integration by providing additional educational and research related services.

These categories reflect the proposed strategies for future growth and development by the senior team in the ERC program and this study.

Summary of Research Study Findings

An investigation of ORUs that have been successful in sustaining industry-university collaborative research activities provided a wealth of information regarding strategies, trends and patterns based on the experiences of the entire senior research team. Data was also collected from a limited number of industry representatives upon the recommendation of several members of the ORU research team as a litmus test to provide a level of validation to their perspectives. The categories and patterns that appear to play a significant role in sustaining ORU-industry collaborative research activities have been categorized into three main areas: 1) Characteristics or profile of faculty and students, 2) Formal ORU structure for participation and interaction, and 3) Interactions with industry. The following section summarizes these key issues that emerged from the data.
Characteristics/profile of faculty and students.

The characteristics or profile of the faculty emerged as significant in sustaining collaborative activities with industry. In this study the faculty oversee the development and implementation of the research program and are recognized by their peers as being among the leaders in their subspecialty. This highly recognized core of faculty members attracts highly qualified students to the university and ORU.

The faculty and student's profile also appears to play a significant role in meeting the industry’s workforce requirements. The faculty and industry representatives stressed that industry depends on the ORU to provide an educational program that prepares the student with skills for their specific industry and are willing to provide additional resources (funding, technical expertise) to insure that the program reflects the needs of that industry. Further studies should be conducted that compares the skill set of the student who participates in the ORU activities as part of their educational program to those students who do not participate for skill-set assessment.

Expanding the collection of data to include the perspectives of the entire ORU research team, not only the Director, was based on the researcher's experience and assumption that sustained activities with industry requires the effort and "hard work" of the entire research team members—the Director, Research Thrust Area Leaders, students and non-research senior ORU members. The data pooled from this comprehensive sample begins to provide documentation, though limited, that sustainability is related to a team effort. Further studies are recommended to understand the significance of each position in sustaining collaborative research activities. Additional studies are also recommended to collect data from a large sample of industry sponsors for their perspective.
ORU formal structure for participation and interaction.

The formal ORU structure appeared to be significant in sustaining research relationships that engage both the faculty and industry. From the Research Thrust Area Leader's perspective, the ORU framework provides a stable and continuous environment for faculty members to expand their research interests, pursue multiple projects at the same time with more students while also providing a level of continuous funding support for their ORU related research activities. The ORU structure appears to be significant in contributing to the sustained effort with industry by providing a stable framework for continuous participation by the faculty and students. It should be noted that two of the ORUs are located within close proximity to a majority of the sponsoring companies. However, the largest of the three ORUs is not located in close proximity. Any disadvantage related to distance appears to be minimized by frequent visits by the ORU Director to the company site and through the use of telecommunication technologies to maintain an adequate level of communication and flow of information.

To achieve a ten-year level of sustainability with industry the ORUs in this study have been successful in proposing and implementing a research program that meets the educational doctoral research requirements of the academic community while also addressing the problems and needs of the industry sponsors. To achieve this level of success, each ORU holds annual or semi-annual structured meetings where the research program is presented by the faculty and students and reviewed by industry. Industry through different procedures implement by each ORU provides feedback and guidance to the ORU team. It should be noted that the ORU faculty reviews the advice provided by industry and then determines the final research program.
Each ORU also has a formal multi-level membership structure associated with different fees and benefits to engage industry. It appears that the multi-level membership approach meets the diverse needs of the sponsoring member companies and plays an important role in sustaining collaborative research activities with industry. It should also be noted that industry funding categorized as a membership fee or as a gift that is dedicated to the ORU that has no contractual agreements regarding specific projects or time restrictions, provides the opportunity for the ORU to “build-up a cash reserve” that can be rolled over to the following year. This reserve operates as a savings account and can be accessed when there is a decreased in level of funding or to support new projects that have emerged during the fiscal year. This cash reserve appears to be significant in maintaining a continuous high level of research activity.

Interactions with industry.

The university team all expressed the importance of interacting with the industry representatives on a continuous basis. Companies are very concerned with their return on investment and on a yearly basis assess the benefits that accrue to the company by participating in the ORU. Quite often the senior management relies on feedback from the company’s representative to the ORU and the flow of information from the ORU to the company as part of the basis for the funding renewal process. Each researcher engages in continuous interactions with industry via telephone calls or electronic mail throughout the year. These continuous interactions also appear to be significant. Passive interactions through the dissemination of a newsletter and continuously up-dating information on the ORU Web Site for access by industry appears to be significant in sustaining collaborative research activities by providing a continuous flow of information from the ORU to
industry. Further studies to quantify and analyze the number and scope of the interactions are suggested to develop a better understanding of the nature of the discussions.

Conclusions

Conducting a case study analysis at elite universities that have a strong research infrastructure in place and by also focusing the study on ORUs whose mission is to work closely with one industry has strengths and limitations. One strength of this methodology is that several strategies, trends, patterns, and anecdotal information emerged thus providing greater insight for understanding issues related to sustaining collaborative research activities with industry. The data confirmed findings from other studies that suggested that the ORU Model is a successful structure to engage industry. The data also confirmed the need for formal and informal structures to engage industry over a period of time. Distance issues related to the proximity of the ORU to the sponsoring companies did not appear to play a significant role as long as the ORU team maintained continuous interaction with the industry sponsors and there was a continuous flow of information from the ORU to the companies. Findings also suggested that it is the responsibility of the entire ORU research team to work diligently with industry to sustain collaborative research activities. Issues related to the research program concerning the impact on the faculty’s research agenda and the student’s educational program appear to be positive. All faculty stated that they weighed the advice from industry but that they were ultimately responsible for making the final decisions for the ORU’s research program. By being in the position to make the final decisions regarding the research program one can assume that the faculty members did not perceive that their autonomy was being compromised as a result of collaborating with industry. The faculty members also commented that the
doctoral level research (relevant to the ORU mission) conducted by students is of high quality and is defensible in accordance with the National Science Foundation’s standards of research. The findings also suggested that the ORU structure enhanced the faculty member’s research program by providing a stable and continuous level of funding support, provided opportunities for them to build upon the work of their ORU colleagues and facilitated their interactions with industry. The responses also suggested that industry was interested in maintaining collaborative activities with the ORU not only to have timely access to the research results but also to have access to the students (their future employees) who are receiving an education that is closely aligned with their industry. A limitation of this study, as suggested in the literature, was the transferability of the results to other universities that do not have a strong research infrastructure in place. However, one may conclude that the ORU Model may act as a catalyst in developing the research infrastructure at a university by facilitating collaborative activities among faculty from various departments under a common research mission and by providing a formal structure to engage external sponsors in collaborative research activities with the faculty.

**Suggested Further Studies as Expressed by the Interview Participants**

During the interview process the last question of the protocol asked, “if the participant would like to provide any additional comments that were not covered by the previous sections.” The following issues were raised and have been included due to the perceived significance as expressed by the industry and faculty.
Intellectual property.

Issues related to Intellectual Property (IP) and the future role of government emerged under the additional comments section of the interview protocol. Several university members and two industry representatives raised these issues and their concern. Intellectual Property is perceived as a continuous issue that requires a significant amount of time on part of the ORU and industry to resolve. Specific issues were related to the potential revenue realized or not realized from the IP, whether IP information should be released as public information, the specific IP relationships between companies involved in this industry, and the significance of the ORU research. Further studies related to IP issues are suggested.


Another concern emerged regarding the National Science Foundation’s response to the Government Performance and Results Act of 1993 (GPRA). Two university researchers expressed their concern that the performance assessment metrics that are eventually implemented may have a negative impact on the “signature” long-term or basic research of universities. Further studies exploring the impact of different assessment metrics on university research programs are suggested.

Other Recommendations for Further Studies

This study focused on ORUs that conduct research relevant to the $30-$50 Billion information technologies manufacturing industry. One of the characteristics of this industry is that a significant amount of the research and development activity is conducted in the United States. However, the actual manufacturing of the products is done overseas. Recommendations for further studies would be to 1) investigate ORUs that conduct
research relevant to other large industries such as the pharmaceutical industry for trends and patterns, and 2) explore issues related to the current trend of transferring manufacturing activities to overseas locations on the research infrastructure in the United States and the possible impact these trends may have on the roles of ORUs.

From another perspective as many industries begin to place a greater emphasis on the development role in research and development and less of an emphasis on their role in research, it may be meaningful to explore emerging industrial models that may facilitate the ORU’s role in industrial research.
REFERENCES


Appendix A

Interview Protocol ORU Directors
ORU Director Interview Protocol

How long have you been employed as an ORU Director?

Have you worked for a company (not as an university employee) that engages in relevant research or relevant product development/manufacturing?

Section 1: Understanding the Growth and Development Phases that Led to ORU Maturity.

A. Development

Discuss the genesis of the ORU. Describe organizational structure and reporting within university.

As the ORU matured, has the research direction changed, if so, what prompted it? How are research priorities selected within the ORU?

B. Support

B. 1 Interpersonal

Describe the different types of interactions and support provided by the ORU Director to the Research Team? Frequency? Have the types of interactions changed over the years?

Would you like to see other types of interactions implemented?

B. 2 Resources/Financial

How are resources allocated to support ORU project activities?

What type of support does the university provide? Has this support changed over the years?

C. Evaluation

How is progress on research projects and outcomes communicated by the ORU Director to the ORU Project Leaders?

How do departmental & institutional committees evaluate the research that is conducted with support from the ORU?

D. Additional comments
Describe any relevant lessons learned or pitfalls to be avoided regarding the development of an ORU.

Section 2: Research Collaborative Activities with Industry

A. Development

Describe the ORU structure to engage industry in collaborative research activities.

As the ORU matured did the types of interactions with industry change?

Did the ORU change in response to engaging in collaborative research activities with industry?

What do you do to sustain collaborative research interactions with industry? How would you define sustainability?

B. Support

Describe industry’s involvement in the ORU research activities? Is industry engaged in all ORU research projects?

Does the collaborative research activities vary by company? Has this changed over the years?

What percentage of your total budget is supported by industry? Has this changed over the years?

C. Evaluation

How does industry assess the research activities of the ORU?

D. Additional Comments

Describe any lessons learned or pitfalls to be avoided when engaging in collaborative research activities with industry?

Section 3: Looking Ahead

Where do you see the center in 5 years?

Looking ahead do you see the ORU being maintained as it is, perhaps spinning off as a company? Evolve into the mainstream of industry?
Section 4: Additional Comments

Based on what I told you what I wanted to do, are there any other issues that I should include?
Appendix B

Interview Protocol ORU Research Thrust Area Leaders
ORU Research Thrust Area Interview Protocol

How long have you been an employed as a Project Leader at this ORU?

Have you worked for a company (not as an university employee) that engages in relevant research or relevant product development/manufacturing?

Section 1: Understanding the Growth and Development Phases that Led to ORU Maturity.

A. Development

Describe the organizational structure and reporting within the ORU.

As the ORU matured, has the research direction changed, if so, what prompted it? How are research priorities selected within the ORU?

B. Support

B. 1 Interpersonal

Describe the different types of interactions and support provided by the ORU Director to the Research Team? Frequency? Have the types of interactions changed over the years?

Would you like to see other types of interactions implemented?

B. 2 Resources/Financial

How are resources allocated to support ORU project activities?

What type of support does the university provide? Has this support changed over the years?

C. Evaluation

How is progress on research projects and outcomes communicated by the ORU Director to the university Project Leaders?

How do departmental & institutional committees evaluate the research that is conducted with support from the ORU?

D. Additional comments
Describe any lessons learned or pitfalls to be avoided regarding the development of the ORU?

Section 2: Research Collaborative Relations with Industry

A. Development
Describe the ORU structure to engage industry in collaborative research activities.

As the ORU matured did the types of interactions with industry change?

Did the ORU change in response to engaging in collaborative research activities with industry?

What do you do to sustain collaborative research interactions with industry? How would you define sustainability?

B. Support
Describe industry's involvement in the ORU research activities? Is industry engaged in all ORU research projects?

Does the collaborative research activities vary by company? Has this changed over the years?

What percentage of your total budget is supported by industry? Has this changed over the years?

C. Evaluation
How does industry assess the research activities of the ORU?

D. Additional Comments
Describe any lessons learned or pitfalls to be avoided when engaging in research collaborative activities with industry.

Section 3: Looking Ahead
Where do you see the center in 5 years?

Looking ahead do you see the ORU being maintained as it is, perhaps spinning off as a company? Evolve into the mainstream of industry?

Section 4: Additional Comments
Based on what I told you what I wanted to do, are there any other issues that I should include?
Appendix C

Letter Inviting Faculty to Participate in Study
Sample Letter

Dear ORU Director or Research Thrust Area Leader:

I am currently collecting data from Directors and Project Leaders of Organized Research Units that conduct research in the field ofxxxxxx located at Carnegie Classification Research 1 Universities. I am specifically interested in interviewing individuals that lead nationally recognized research activities in this area to gain a more comprehensive understanding of how they sustain collaborative research activities with industry. The data that I collect will assist me in completing my dissertation requirements for my Ph.D. in Higher Education Administration from Seton Hall University and perhaps more importantly contribute to the literature that will assist other universities as they seek to build and sustain collaborative research activities with industry.

The field of Data storage was selected because of its promising future and interdisciplinary research approach. Frank Mayadas, (former IBM Vice President for Research), currently Program Officer of the Alfred P. Sloan Foundation and also a member of my dissertation committee upheld the achievements of your ORU in this research area.

My methodology employs a Case Study Design requiring that I conduct a personal interview with you that addresses the following topic areas: Understanding the growth and development phases that led to ORU maturity; Research collaborative activities with industry; Looking ahead—where do you see the ORU in five years. Based on my pilot study I believe that the interview will last approximately 60-75 minutes. After the interview, I may also need to contact you via telephone to clarify any questions regarding the data that I have collected.

Please note that your participation is on a voluntary basis and all information that I collect will be maintained as confidential information. All information that I collected from these interviews will be coded using random numbers and will be destroyed once the study report has been completed. My final dissertation document will not state the name of the university nor the ORU or the specific field of research. As a courtesy to participants I will provide a copy of the dissertation document for your review prior to submitting the document to the Dissertation committee. For a two week period you will be provided the opportunity to review the document and provide any comments that you feel will compromise your anonymity.

I look forward to your participation and will be calling you to answer any questions that you may have. For your information I can be contacted at 973-642-4352 or at mcdonnell@admin.njit.edu

Sincerely,

Elizabeth T. McDonnell
Doctoral Candidate
Appendix D

Informed Consent Form
Informed Consent Form

Title of Study  An Analysis of Sustained Collaborative Research Activities Between University Organized Research Units (ORU) and Industry: A Case Study of Three Institutions.

Researcher  The proposed study is being conducted by Elizabeth Taraski McDonnell, a doctoral candidate at Seton Hall University in partial requirements for her Ph.D. in Higher Education Administration.

Purpose of Study  The proposed study, using a Case Study Design seeks to collect a comprehensive body of information from the experienced Organized Research Unit (ORU) Director and Project Leaders regarding best practices, processes, procedures and lessons learned as they developed and sustained collaborative research activities with industry. The study is intended to enhance the quality and depth of information available to the higher education community.

Time required for Participation  Based on the Pilot Study, the face-to-face interview will require approximately 60-75 minutes. Additional follow-up questions via the telephone may be required to clarify responses.

Confidentiality  Written documentation of the interview will be coded by position (Director or Project Leader) using a random numbering system. All collected information will secured in a locked file cabinet. The final dissertation document will not state the name of the university nor the ORU or the specific field of research. As a courtesy to the participants, a copy of the dissertation will be provided to each participant to review prior to submitting the document to the Dissertation Committee. For a two week period the participant will be provided the opportunity to review the document and provide any comments that they feel will compromise their anonymity. All information will be destroyed once the final report has been completed and submitted to the Dissertation Committee.

Voluntary Participation  It is the intention of this study that all participation is voluntary. The subject may discontinue participation at any time. This project has been reviewed and approved by the Seton Hall University Institutional Review Board of Human Subjects (IRB). The IRB believes that the research procedures adequately safeguard the subject’s privacy, welfare, civil liberties, and rights. The Chairperson of the IRB may be reached through the Office of Grants and Research Services. The telephone number of the Office is (973) 275-2974.

Subject (Participant’s) signature ____________________________ Date ________________________